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Introduction

The Agricultural Mechanization Forum was established on June 10, 2017 with the objective of promoting evidence-based dialogue on the most appropriate mechanization for the various scales of farming practiced in Ethiopia. The Forum uses instruments such as conferences, panel discussions, and technical briefs to promote dialogue and feed into the policy process. This technical brief is the first and draws largely but not exclusively on the proceedings of the South-South Knowledge Sharing Conference held on October 31–November 2 and organized in collaboration with the International Food Policy Research Institute.[i] The major deliberations are summarized, and key lessons are drawn to inform policy makers and practitioners. [ii]

Historical context

Agricultural mechanization issues were neglected in the 1980s and 1990s, partly because of the general decline in investment in agriculture over that period and partly because a number of influential studies concluded that many developing countries were not ready for mechanization.[iii] Asia was the exception, as it witnessed rapid growth in small engine mechanization.

In Ethiopia, during the Emperor Haile Selassie period (pre-1974), more emphasis was given to mechanizing large and commercial private farms. During the later stage (i.e., in the 1960s), through different Agricultural Development Units,[iv] attempts were made to develop and promote different agricultural technologies (including farm implements) fit for smallholder farmers. The *Dergue* (1974–1991) government gave more attention to mechanizing state-owned large farms and to mechanization support to the emerging smallholder producers' cooperatives in cereal-based systems. Tractors and combine-harvesters were introduced in the southeastern part of Ethiopia due to the presence of larger-scale farmers and commercial farmers, flat terrain, and two cropping seasons. These technologies have resulted in significant reduction in harvest losses.

The first tractor assembly plant, which was a breakthrough in agricultural mechanization in the country, was established during this period. Presently, the government is supporting both imports of machineries and the development of domestic machinery manufacturing plants producing/assembling tractors, implements, and water pumps.[v]

Mechanization in Ethiopia is mainly used for land preparation, threshing, and harvesting. It has the potential to increase labor productivity and reduce harvest losses but is constrained by factors such as land fragmentation, agroecological diversity, and topography. In recent years, agricultural mechanization has been afforded greater focus to address both the small- and large-scale farmers. Accordingly, a mechanization strategy has been developed with a vision to raise the agricultural mechanization index from 0.13 kw/ha to 1 kw/ha by 2025. The strategy has four major components: research and development, manufacturing and import, distribution and promotion, and purchase and usage.[vi]

Conceptual context

A clear definition of mechanization is critical to strategy design and implementation. Lack of clarity and consensus on definitions could lead to lack of consensus on pathways for mechanization. Mechanization can be defined as the application of tools, implements, and powered machinery, where the power source can be human, animal, or mechanical.[vii] A similar definition states that agricultural mechanization is the economic application of engineering technology to enhance the effectiveness of human labor, including land preparation, planting, harvesting, on-farm processing, storage, and marketing of products.[viii, ix] These two definitions show the wide range of technologies and purposes for which mechanization is used.

Photo by Tatek Woldu (field visit to Arsi, Oromia Region, Nov. 2, 2017)

International experience

1. Drivers and constraints to mechanization

In **Asia**, the major drivers of mechanization are efficiency gains, addressing farm labor scarcity, and faster land preparation. Small-scale mechanization was suitable for Bangladesh's highly fragmented land. Its success is attributed to the vibrant private sector, academic engagement in policy processes, building of agricultural and rural development institutions, localized technology interventions, and setting up of physical infrastructure. China's experience shows that land fragmentation is not necessarily a constraint for mechanization. Harvesting is the most commonly mechanized operation, followed by plowing. Mobile mechanization teams provide the services and as teams have a better bargaining position and can overcome harassment in unfamiliar places. More importantly, working in teams reduces the cost of spare parts and other services that are costly for individuals. Thailand has larger average farm sizes than Bangladesh or China, and the farming system is dominated by medium-scale farmers. On the demand side, mechanization is driven by farmers' technologies that (i) are labor-saving; (ii) increase productivity; (iii) reduce post-harvest loss; and (iv) increase quality of products. On the supply side, Thailand's experience shows that small-scale domestic manufacturers are the key players.

In most parts of **Africa**, farmers face similar land constraints as their Asian counterparts due to the dominance of small-scale farming. In Kenya, for example, the continued fragmentation and decline in farm sizes led to a decline in the ownership of tractors between 1992 and 2012. In Ghana, mechanization demand has grown but with substantial variation across the country. The determinants of the rise in mechanization demand include urbanization, rising farm sizes among medium-size farmers, and rising rural wages. In Nigeria, the mechanization process depends on labor, animal traction, farm size, and farming system. Despite policy support, mechanization levels in Nigeria are very low. It is unclear if this is due to insufficient demand.

Experiences elsewhere suggest that demand is not the only issue for mechanization. Most countries intervene in mechanization with or without demand. For example, in Germany there is the case of machinery rings,[x] whereby networks of farmers are linked to industries. In China, the machinery industry is led by the Chinese Academy of Agricultural Mechanization Sciences (CAAMS), with subsidy from the government. In Japan, the Japanese Farmers Association, the rice processing industries, and the government collaborate in land reclamation for irrigated and mechanized rice production—a good model of public-private partnership (PPP).

The incentives for agricultural mechanization in Ethiopia are mainly rising real wages and the rising cost of keeping livestock. Further incentives, as stipulated in the government strategy document, are reducing drudgery, modernizing agriculture for market-oriented production, and post-harvest loss reduction.

2. Pathway for mechanization: 4-wheel vs. 2-wheel tractors

For small farmers, the pathways for mechanization technology, especially tractor adoption, are between two-wheel tractors (2WTs) and four-wheel tractors (4WTs). 2WTs are dominant in Bangladesh, while 4WTs are dominant in India and Nepal. In Thailand, 2WTs have been increasingly adopted, substituting for the use of draft animals. Farmers own 75% of 2WTs, while 85% of 4WTs are owned by service providers who may also be farmers. In terms of energy use, electric pumps are commonly used in India, while diesel pumps are common in Thailand. In India, between 1971/2 and 2012/3, the share of farmers using draft animals for crop production decreased from 45% to 5%, while the share of those using tractors increased from 7% to 46%.

The Kenyan experience indicated that tractors are mainly employed in the highlands, while lowland production is characterized by oxen plows. Only 2% of the surveyed farmers own tractors. Growth in agricultural mechanization is dominated by animal traction, not tractors. The share of farmers owning trained oxen increased from 17% to 33% over the period studied. In Ethiopia, animal traction plays a dominant role in crop production. In areas where tractors are used, they are used for the first plowing before the rain when soils are harder. Animal traction is used for the second and third plowing. Despite a recent push to move towards 2WTs, 4WTs continue to be dominant.

In Ghana, promoting affordable smaller tractors suitable for local soil and farming conditions is a key part of the agricultural development strategy, together with supporting research and development focusing on smaller agricultural machinery.

3. Enabling environment: Finance, policy, and infrastructure

Governments in Asia rarely promoted mechanization directly but rather facilitated private sector-led mechanization through reform, liberalization, and market coordination. In Thailand, locally adapted and manufactured machineries widely substituted for expensive imported machines. There was minimal direct policy support other than creating an enabling environment for the private sector. The sustainability of mechanization in Thailand relies on private maintenance and repair providers. In India, individual entrepreneurs are the most common providers of mechanization services.

In China, cooperatives are promoted and encouraged to own machinery. However, in most cases, while the machinery owners form cooperatives, machines are still owned individually. The Ghanaian experience suggests that the professional services model is not profitable without huge subsidies. Instead, farmer-to-farmer hiring services provided by medium-scale farmers, after they have plowed their own land, helped them achieve profitable utilization rates. They provide hiring-out services to 100–120 other farmers on average, of which almost half are small-scale farmers with landholdings of less than 2 ha. In Nigeria, as in Ghana, the private sector is the most effective service provider of mechanization services.

According to Gesellschaft für Internationale Zusammenarbeit (GIZ) experience in Ethiopia, although substantial yield increase is recorded by using the highest mechanization technology (H-2/AT), from the service-provider side, an intermediate technology level is found to be more profitable. Some of the challenges to agricultural mechanization are lack of skill, lack of credit, lack of policy support (e.g., tax exemptions), land fragmentation, and lack of customized tools.

With respect to tax exemptions in Ethiopia, there is a two-tier system, which the private sector finds problematic. On the one hand, licensed importers whose application for importing agricultural machinery is approved are exempt from duty. On the other hand, farmers without investment approval need to pay duties. If agricultural mechanization is to effectively take off, this discriminatory levy system needs to be avoided.

With respect to land fragmentation, experience elsewhere suggests that it is not a binding constraint—instead unavailability of appropriate mechanization technology is. In Japan, for example, there are "standard plots" (100 meters by 30 meters) where small, appropriate machines are used. Most Asian countries achieved a green revolution with an average landholding of less than 0.5 ha.

Photo by Tatek Woldu (field visit to Arsi, Oromia Region, Nov. 2, 2017))

4. Public-private role in agricultural mechanization: Dos and don'ts

It was instructive to note that the majority of contributors to the South-South Knowledge Sharing Conference were from the private sector. An important lesson is the need for clear division of roles between the public and private sectors (including cooperatives and farmer organizations) and areas where they can collaborate (such as public-private partnership). The public sector (i.e., government) is best suited to providing subsides, reducing transaction costs, providing regulations that promote agricultural mechanization, availing alternative and cheap energy, and establishing clear roles for tiers of government. It can also help fill knowledge and capacity gaps, for example, on the type and the mix of mechanization; provide demonstration/education on the use of new technology; and promote service provision business models.

In China, for example, the government provides a uniform subsidy to any would-be buyer. Local governments also provide technical training on operation and maintenance, but their most important facilitative role is to help migratory service providers overcome coordination failures by setting up communications platforms and providing harvest calendars for different locations. The Chinese government also established the Chinese Academy of Agricultural Mechanization Sciences to lead all the mechanization technology research and development. The academy not only conducts research but also leads big machinery industries (the YTO tractor factory; other combine and heavy-duty earth-moving machineries).

The South Korean government developed a Mechanization Act that promoted mechanization in rice farming. The Act facilitated, among other things, importation of small engines; planning and distribution of agricultural machinery; tax exempt status for fuels; application of a zero value-added tax for agricultural machinery; and price adjustments for agricultural machinery. Experience from Ghana indicates that where subsidies exist, they should avoid arbitrary selection of recipients and increase transparency to eliminate rent-seeking behavior. Government can play facilitating roles in market coordination to help the private sector overcome the information asymmetry in the hiring-out market.

The private sector plays a central role in agricultural mechanization development in general and provision of services in particular. It could grow organically from this process and respond to emerging needs such as import and distribution of appropriate equipment; provide equipment hire services; and provide maintenance services. It should be encouraged to manufacture appropriate technology for the diverse scale of farming.

Overall, the experience from the African and Asian countries shows that public sector-supported private sector mechanization is the best model. They should also develop partnerships based on efficiency, effectiveness of service delivery, and good value for the clients—the farmers.

The research–higher learning institutions–policy–industry nexus

Researchers and higher learning institutions have a critical role to play in agricultural mechanization. Broadly speaking, they diagnose the problems that hinder agricultural and livestock productivity and generate knowledge and technologies to overcome the constraints. Ethiopian researchers have experience in investigating mechanization options. They have exposure to developments that have taken place in many of the countries that are featured in this technical brief. Three further steps are needed. First, encourage a systematic linkage between researchers, higher learning institutions, and industry and service providers; second, build consensus on options for mechanization given Ethiopia's diverse agroecology and scale of farming; and third, strengthen systematic linkage to policy. Policy makers need clear options backed by evidence.

Lessons for Ethiopia

The South-South Knowledge Sharing Conference was the first of its kind and yet covered a wide range of issues from which Ethiopia can draw lessons. This section highlights some key lessons.

There are two mechanization pathways in terms of tractorization for small scale farmers: the two-wheel tractor-led pathway seen in Bangladesh and four-wheel tractor-led one seen in India and Nepal. Ethiopia can resort to both types of tractors. But researchers should

investigate these options within the local context and map out agroecologies and socioeconomic settings where each type of machine can effectively and economically work. Regarding farm size, it is important to recognize that mechanization started to grow in Asia in the 1980s and 1990s with fairly small farm size, and it is still the case today in some Asian countries. In countries like Bangladesh, agricultural productivity has kept rising even though farm size has become smaller.

Animal traction is still important in African as well as Asian countries. It is used side-by-side with mechanized plowing. Therefore, depending on agroecology and socioeconomic conditions, Ethiopia could continue to use animal traction alone or in combination with engine power by making significant innovations in the implements and by improving oxen body condition so they can provide the required draft pull. This means that a suitable combination of engine-powered machines, like 2WTs and4WTs, and oxen power needs to be used.

Tax or duty exemption is the most commonly cited government support to the private sector. This is in recognition of the fact that the tax revenue lost from the machinery can be more than compensated by the revenue generated from increased productivity, production, and youth employment created.

Other countries' experiences show that the scope of mechanization is wide and includes, among others, crop protection tools and irrigation tools. But in Ethiopia, the concept of mechanization seems restricted to tractors and combine harvesters. There is a need for a broader understanding of mechanization to include, for example, solar energy as a source of power for irrigation.

Finally, there is unlikely to be a single "right" formula for government involvement in mechanization. The conference has underlined that the Ethiopian government has a lot to learn from Asian and African experiences, as well as needing to learn-by-doing from its own experience. Accordingly, monitoring and evaluation of the ongoing interventions will be important for making necessary adjustments. It is equally important for researchers, academia, and practitioners to come to a consensus on the most appropriate combination of technologies for Ethiopia given its diverse ecology and scale of farming. Policy makers need clear options backed by evidence.

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Endnotes

[i] This Technical Brief is written by Dr. Fentahun Mengistu and Dr. Amdissa Teshome (both from the Agriculture Knowledge, Learning, Documentation and Policy project) on behalf of the Forum Management Group. The authors thank the group members for their comments on the draft document. The Conference Proceedings that form the basis for the brief are prepared by Helina Tilahun, Yetmwork Habte, and Hiroyuki Takeshima, IFPRI. The logos represent organizations that sponsored the conference and are used with their permission for this technical brief only.

[ii] Presentation of keynote address and all sessions are available at IFPRI's ESSP website https://www.slideshare.net/essp2.

[iii] The best example in this regard is Hans Binswanger, 1986, Agricultural Mechanization: A Comparative Historical Perspective, *World Bank Research Observer* 1 (1): 27–56.

[iv] These are: CADU (Chilalo Agricultural Development Unit), implemented in two phases, Phase I (1967/68–1970/7) and Phase II (1970/71–1974/75), and financed by the Swedish International Development Agency (SIDA); WADU (Wolaita Agricultural Development Unit), started in 1969/70 and in operation until the early 1980s and financed by the World Bank; and ARDU (Arsi Rural Agricultural Development Unit), a follow-up to CADU and later expanded to Arsi-Bale Rural Development Project. It was financed by the Italian government under the Ethio-Italian Cooperation.

[v] Farm Mechanization and Conservation Agriculture for Sustainable Intensification (FACASI) Project, Activity 3.1.2; FAO and UNIDO, 2008, Agricultural Mechanization in Africa: Time for Action, Report of an Expert Group Meeting Held in January 2008, Vienna, Austria, FAO, Rome and UNIDO, Vienna.

[vi] MoANR, 2016, Agricultural Mechanization Strategy, Addis Ababa.

[vii] L. Clarke, 1997, Strategies for Agricultural Mechanization Development, The Role of The Private Sector and the Government, AGST, FAO, Rome.

[viii] A. G. Rijk, 1999. Agricultural Mechanization Strategy. In *Plant Production Engineering: CIGR Handbook of Agricultural Engineering*, Vol. III, ed. B. A. Stout, and B. Cheze, 536–553, CIGR/ASAE.

[ix] FAO and UNIDO, 2008, Agricultural Mechanization in Africa: Time for Action, Planning Investment for Enhanced Agricultural Productivity, Report of an Expert Group Meeting, January 2008, Vienna, Austria.

[x] One of the basic conditions of empowering farmers is to get them organized. Machinery rings are a promising organizational concept to link up the farms and raise their profitability and power by promoting mechanization in rural areas (see http://www.rural21.com/english/news/detail/article/machinery-rings-a-mechanisation-concept-for-african-farmers-00001150/).