# A critical review of selected appropriate traditional evaporative cooling as postharvest technologies in Eastern Africa

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**Abstract:** The issue of postharvest losses (PHL) is of high importance in the efforts to combat hunger, raise income and improve food security in the world's poorest countries. PHL of horticultural products in developing countries sometimes may reach up to 45%. PHL have an impact on food security for poor people, food quality and safety, economic development and the environment. The exact causes of PHL vary throughout the world and are very much dependent on the specific conditions and local situation in a given country. Irrespective of the level of economic development and maturity of systems in a country, PHL should be kept to a minimum. The failure to harness the physical and chemical characteristics of horticultural products using technologies has been very costly to farmers, processors and marketers in many parts of the world. A number of researchers and undocumented indigenous African Knowledge custodians in rural areas have innovated and constructed different technologies using locally available materials for the purpose of extending the shelf life of horticultural produce like vegetables. This review article seeks to critically examine some of the selected agricultural technologies and equipment used in African rural settings with view of assessing why they fail.

**Keywords:** perishables; technologies; technology use; shelf life; storage, food processing

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## 1 Introduction

Hunger, malnutrition, and poor health are widespread and stubborn development challenges especially in the developing world. Agriculture has made remarkable advances in the past decades, but progress in improving the nutrition and health of poor farmers and consumers in developing countries is lagging behind. According to UN projections, Sub-Saharan Africa's population is expected to grow from the current level of over 818 million to between 1.5 and 2 billion in 2050 (United Nations, 2013). Some 218 million people in Africa, around 30% of the total population, are suffering from chronic hunger and malnutrition (FAO, 2009). It suffices to note that Sub-Saharan Africa is home to about 3,000 species of indigenous vegetables and fruits (AIFVs) and only about 1,000 of these are used traditionally. Efforts to explore the potential of such fruits could lead to enhanced agricultural productivity, more-stable food supplies, and higher incomes in rural areas across the continent can contribute to nutrition, food security, rural prosperity, and general land care (Anyanwu, 2004). Indigenous food crops are plants that are native to a particular region or introduced to the region from another geographical area over a long period of time. They are grown locally in a small scale, often resistant to diseases and tolerant to environmental stresses.

The African continent is home to hundreds of AIFVs with high nutritive value, a potential that is hardly being used to contribute to the nutrition and food security of the region (Jain, 2007). Consequently, the potential of AIFVs emanating from their superior adaptation to local environmental conditions and thus high production without too much investment is hardly

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exploited in the fight against malnutrition, hunger, and poverty. It is estimated that up to 50% of the population in Sub-Saharan Africa is affected by deficiency in vitamins and minerals (Mogaji and Fapetu, 2011). In Eastern Africa, the average consumption of vegetables and fruits is approximated at 200g/person/day, which is far below the WHO recommended minimum intake of 490g/person/day (FAO, 2010). This is despite Sub-Saharan Africa being home to hundreds of AIFVs, which can supply the required vitamins and minerals at relatively very low cost. Many indigenous vegetables have the potential for more widespread use as food and adoption in agricultural food production systems. Therefore proper preservation, processing and storage of such indigenous vegetables are pivotal to ensuring food security and income enhancement.

For any technology to be successive at grassroots level in Africa, it must: have no power grid sources, be easily duplicated by farmers with readily available materials, be on an appropriate scale in operation and economics for individual farmer/family or village Saving and Credit Co-operative (SACCO), have more than one use (year-round utility), be inexpensive and efficient and preserve organoleptic properties of the food. Technologies centered on evaporative cooling as method for preserving vegetables in developing countries are discussed. This is because such technologies do not require any special skill to operate and are simple to construct in rural areas. According to Liberty et al. (2013a) the biggest challenges that occurs during storage of vegetables are the change in quality parameters such as the color, texture, and freshness which determine price and consumers perceptions. During storage, vegetables undergoes chemical and physical changes due to evaporation of water from the tubers, respiration, sprouting, and spread of diseases due fungal invasion resulting in storage losses. However, to prevent storage losses favorable storage conditions within the store should be maintained. According to Liberty et al. (2013b), deteriorative reactions in vegetables can be minimized to increase their shelf lives, ensuring that the produce will be available during off season to reduce changes in market supply and prices. Basically, evaporative cooling storage facility can extend the shelf life of vegetables for quite period of time if it is well designed and constructed. Evaporative cooling is the cheapest and simplest method as well as more efficient way for preserving vegetables (Kamaldeen et al., 2013). Consequently, there is need for simple and cheap means of preservation, such as evaporative cooling which is simple and does not require any external power supply (Liberty et al., 2014; Tabrez and Chaurasia, 2014). According to Vala et al. (2014) good storage condition can be provided to vegetable produce through the use or adoption of evaporative cooling system, which will decrease the temperature and increase the relative humidity of the air surrounding the produce. Evaporative cooling happens when dry hot air passes over a wet surface and the cooling efficiency depends on temperature, relative humidity and evaporation rate of the air around the facility (EL-dessouky et al., 2004). According to FAO (2013), there is probably no other economic activity where sub-Saharan Africa has been by-passed by technological development, than in farm field operations - particularly the growing of crops and storage of crops at household level Just as it has been a matter of human sweat and drudgery for centuries, so it remains today for the majority. Many people in the rural sub-Saharan Africa use mobile telephone, travel by bus, own at least a radio, and most own television including satellite television, and yet most do not own, have access to, or use even oxen or mules for farm field and postharvest handling operations. For example, over 90% of the transportation of agricultural produce from field to home and/or local markets is done on the heads of women and children. This article review seeks to critically examine some of the selected agricultural technologies and equipment used in African rural settings with view of assessing why they fail.

## 2 Overview of selected traditional evaporative cooling technologies and their application in rural Africa

Evaporative cooling techniques have been reported in the literature (e.g., Chinenye, 2011; Amrat et al., 2013; Ndukwu and Manuwa, 2014) with different designs and construction, for the purpose of extending the shelf life of fruits and vegetables. The designs vary from the simplest to the most complicated. According to Workneh (2010), the padding houses of typical evaporative cooling facility in African rural settings are made from local materials that can be wetted with water. Saturating the walls and roofs first thing in the morning is tedious though it generates a condition for evaporative cooling of the padding house. The biggest challenge of these structures is the construction materials which weaken quickly and is vulnerable to rodent attack. Chinenye (2011) reported an improved design and construction of evaporative cooling facilities. He introduced external energy in some of his design in terms of powered fans to maintain continuous air supply to the wetted pad. A water tank raised up to saturate the fabric material continuously causing cooling effect. However, the rural populace never embraced these design because of the cost implications and level of sophistication. Consequently, Odesola and Onyebuchi (2009) constructed an evaporative cooling structure for storage of fruits and vegetables with a double wall made of baked bricks. The top of the storage space is covered with cane, cloth or any other plant material like a bamboo framed structure as shown in Figure 1. This design has been implemented in parts of western Uganda with very little success.

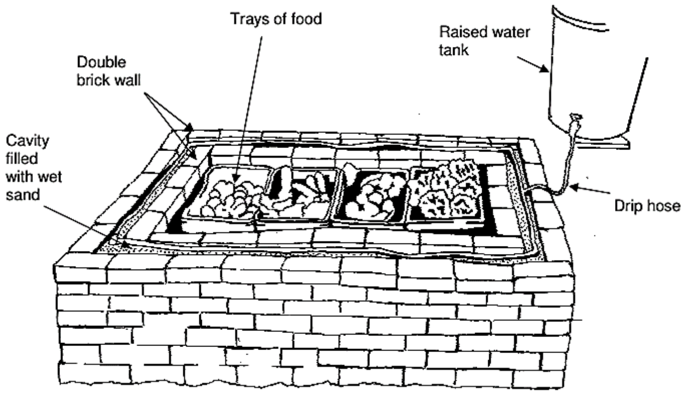


Figure 1 Static chamber cooler. (Source: Odesola and Onyebuchi, 2009)

Sharma and Rathi (1991) constructed evaporative cooling chamber made of an open wood frame of approximately 2 inch x 1 inch in section. The door was made by hanging one side of the frame which was covered in mesh, in and out, leaving a cavity of 1 inch which is filled with small pieces of charcoal as depicted in Figure 2. The cooling happens due to spraying the charcoal with water and the incoming air.

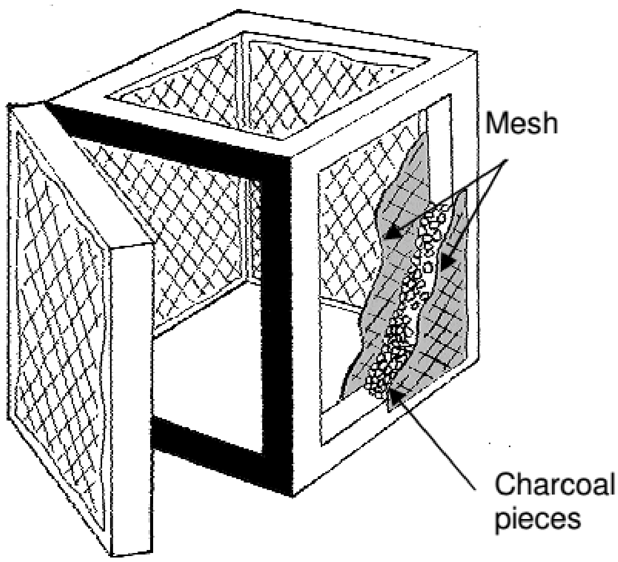


Figure 2 Charcoal cooler. (Source: Sharma and Rathu, 1991)

Odesola and Onyebuchi (2009) proposed two simple evaporative cooling chambers by using a rice shell and jute bag as the cooling pad for cooling and storage of vegetables. They prevented deterioration by washing the product first with chlorinated water. This design was not popular in the rural areas of Africa because of the requirement of chlorinated water. Odesola and Onyebuchi (2009) introduced a new development of an evaporative cooling system for the storage of vegetable crops by using water flow rate, controlled fan speed and wetted thickness. This was made possible as a result of changing relative humidity and temperature within the facility. As its predecessors, it was not successively adapted in the rural areas of Africa because of its requirement for grid power to run fans. Odesola and Onyebuchi (2009) constructed a very simple design that can be used at home for food preservation (Pot in Pot Design) as illustrated in Figure . The design consists of two pots with different sizes, the small one used as storage is inserted inside the bigger one that holds water. This design has been adapted in rural areas of Uganda, Tanzania, Kenya, Rwanda and South Sudan for the preservation of vegetables like tomatoes, okra, carrots and fruits like mangoes, guavas and citrus.

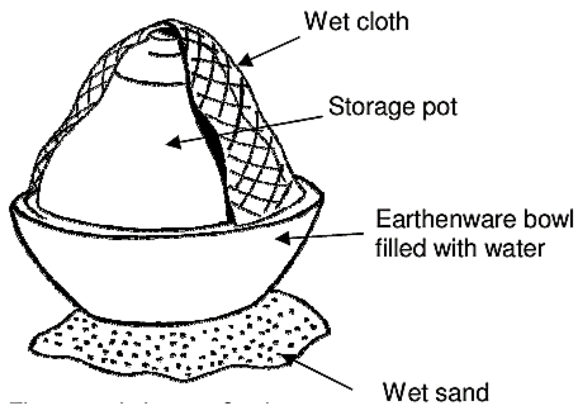


Figure 3 Pot in pot cooler. (Source: Odesola and Onyebuchi, 2009)

Dzivama (2000) tested different local materials as absorbents and reported sponge was the best among the materials tested. He achieved this with the help of mathematical models for the evaporative cooling process at the end of the porous material and the storage chamber. Mordi and Olorunda (2003) reported a drop in temperature by 8.2℃ while the relative humidity increased by 36.6 percent during storage of tomatoes in evaporative cooling environment. Furthermore, they reported that the shelf life of unpacked tomatoes in the facility increased from 4 days to 11 days. Abba (2003) developed a clay pot evaporative cooler with the same working principle as the Pot in Pot design. He used river bed sand and water to fill the space between the two pots to achieve better cooling as illustrated in Figure 4. This storage design was introduced in Sudan, Kenya, Uganda, Tanzania and also in Burkina Faso for food preservation (Rinker, 2014).

Figure 4 Clay pot cooler (Source: Rinker, 2014)

Jain (2007) developed an indirect evaporative cooling chamber for vegetable and fruits preservation which had a heat exchanger. Although the design was costly, it extended the storage life of the tomatoes by 14 days. Its success in rural areas of Eastern Africa was curtailed by the inclusion of a heat exchanger. Chinenye (2011) reported that the daily maximum ambient temperature reduced by 10 $^{o}$C inside the evaporative cooling chamber while the relative humidity of the incoming air rises with 50.3%. The chamber has an efficiency ranging from 20 - 92 percent with peak cooling capacity of 1207 W. The facility was able to keep the tomato fresh for 19 days.

## 3 Why traditional evaporative cooling technologies fail in preservation of fruits and vegetables

Spoilage of fruits and vegetables is attributed to microbial growth, chemical or enzymatic reaction. At lower storage temperatures, microbial growth is greatly retarded and any chemical or enzymatic reactions occur at a slower rate. However, preservation of fruits and vegetables often fails in the traditional evaporative technologies because none can achieve temperatures close to refrigeration temperatures of 4 $^{o}$C -7$^{o}$C. In addition, effective evaporative cooling occurs when air, that is not already saturated with water vapour, is blown across any wet surface (Odesola & Onyebuchi, 2009). However, due to poor air circulation, heat and mass transfer systems are compromised in the traditional evaporative cooling technologies. It is pertinent that the technologies for preservation must be aligned to the biological nature of fruits and vegetables. Vegetables differ from fruits in chemical composition. Most vegetables contain more starch than sugar, as contrasted to the fruits, which are high in sugar and low in starch. As a result, fruits get spoiled faster than the vegetables due to the high microbial growth and enzymatic action. Evaporative technologies could be thus, suitable for preservation vegetables for a short time waiting further processing in modern food facilities.

## 4 Why agricultural technologies and equipment fail in rural Africa

The failure of traditional processing systems to provide acceptable quality products is not an isolated case. Many more technologies and equipment have failed to a scale that is grand. In what follows, a discussion of why technologies and equipment fail in Africa ensues.

### 4.1 Lack of local content in agricultural technology development

Machinery and equipment supply system in Africa has historically depended on importation, first from Europe, then from North America, and recently from China, India and Vietnam. Generally speaking, Africa is largely a continent that is technologically excluded. The importation of agricultural tractors is generally a good indicator of the rate at which mechanization is taking place. Records captured by FAOSTAT show that all the countries have been importing very few numbers of tractors per year since the 1960s. Only Kenya has imported tractors in numbers above a thousand per year and this is only for the period 1971-1990, with a peak of about 2,500 tractors imported in 1981. Importation to Tanzania was for some time boosted by a local assembly plant by the Valmet (now Valtra) Tractors of Finland.

For centuries, African technologies and innovations have remained artisanal and not attracted funding from respective governments. In most cases, artisans struggle on their own based on their indigenous knowledge and skills to make any improvements. For example, the abaheesi of Bukoola Kigezi (Uganda) have been black smiths for over a century. There is not any commercial technology on the Ugandan market that is attributed to the century of works of abaheesi of Bukoola Kigezi (Uganda). This unfortunate reality is possibly a fate for many tribes and/or clans that have labored for centuries in technology development. As a result, technologies have not been improved to meet changing demands thus are uncompetitive in quality and pricing. Due to this, the vast majority of technologies are therefore foreign to the African continent. It is very common to find technologies e.g., maize mills, rice mills, dryers, irrigation equipment that has been customized by artisans to meet to expectations of the local population. However, these technologies often do not meet the quality standards..

**4.2 Disregard of gender considerations and scale of operation**

In Africa, women and the girl child provide the bulk of the labor for agricultural activities at farm level in many African settings. Therefore agricultural technologies that do not take into account women considerations for example threshers with raised hopper height are most likely to fail. Semi-automated systems that are simple to operate and maintain would relieve women of the physical labor burden. Furthermore, the vast majority of farmers are small-scale. Therefore, large scale production technologies are not appropriate for the vast majority of farmers that own 2 hectares or less.

**4.3 Disregard of Indigenous Knowledge and cultural considerations**

African culture and knowledge is largely passed on by word of mouth. There is a lot indigenous knowledge that sounds conventional but because it is not documented, integrating it in agricultural technology development is no mean feat. As part of the efforts to create youth employment, governments in the region are also supporting the development of this smallholder manufacturing sector, known as "jua kali" (literally translated as the scorching sun) in Kenya, Uganda and Tanzania.

**4.4 Lack of electricity/ erratic power supply**

The vast majority of farmers in rural Africa has no access to power or is connected to erratic power supplies that render powered systems inappropriate and redundant. Even where electricity is available, it is too expensive for ordinary small scale farmers to afford it. The current prices of power for industrial establishments is Uganda Shillings (UGX) 376.03 /KW/h during off peak time (8:00 pm to 6:00 am) and UGX 458.90/KW/h during shoulder time (6:01 am to 7:59 pm)[2]. Therefore powered systems in agriculture must take into account this reality. It is only a few middle and large scale farmers that can afford fossil fuel driven systems. Any development of agricultural technology that ignores this simple fact will most likely fail and will remain unused and/or underutilized. Of recent, solar driven systems have been on the African scene but these technologies are in their nascent stages to power considerable farm land.

**4.5 Lack of agricultural value chain technical institutions**

The role well trained technicians play in technology use, service and maintenance is known world over. In most African countries, very few technicians willingly choose this career path and/or find well equipped facilities during training. As a result, seasoned technicians are either private sector trained or gained experience from exposure abroad or better working with technicians from abroad. In the past western companies invested in training technicians in technical and ethical aspects in sectors where they had interest e.g., cotton, coffee, tea to mention but a few. That was 50 years ago, this breed of technicians is old and retired. This very important role was taken over by governments and the private sector who are financially stricken. It is therefore no surprise that technical training institutions are overwhelmed by financial burden due to many years of underfunding thus tend to focus on traditional courses/ programmes of brick laying, carpentry, joinery, metal works, basic welding but not the manufacturing of the building blocks in foundry works. The authors are not aware any technical institution on the African continent that has agricultural value chain approach programmes to coherently support the development of any agricultural sector in a holistic manner. If you take the dairy value chain as an example, there is no African institution that focuses on impacting technical skills in animal breeding, animal feed formulation, milking, milk collection, optimization and trouble shooting of thermal processes like pasteurization, sterilization, powder milk spray drying, mixing to produce technicians with transferable skills to fruits and vegetables. The

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[2] 1 USD is equivalent to UGX 2950.

experiences from critical farm and primary processing operations like train driving, mechanized weeding, mechanized harvesting, threshing, winnowing, drying, sorting, grading, irrigation to mention but a few. A lot of agricultural technologies fail to operate because there are no technicians to operate them.

It suffices to mention that a number of technical institutions have been converted into public universities for example the Uganda Kyambogo Polytechnic formed in 1928 was converted into Kyambogo university in 2003, Busitema University established in 2007 is a collection of formerly technical colleges, namely, Busitema Agricultural College founded in 1968 that was the only institution that trained Agricultural mechanization technicians and Arapai Agricultural College of Animal and Plant Production established in 1952. A similar trend has happened in Tanzania. The Dar-es-Salaam Technical Institute established in 1957 and charged with providing vocational training has metamorphosized over the years. It quickly expanded to offer technical secondary school courses. In 1962 it became the Dar es Salaam Technical College, and in 1964 began offering courses in engineering and other related professional areas, leading to Full Technician Certificates. It gradually added more advanced courses and degrees and in 1997 it became the Dar-es-Salaam Institute of Technology Bachelor of Engineering (BEng) respectively and Master of Engineering (MEng) among other courses. In 1998, the former *Institute of TANESCO* in Morogoro (Tanzania) was converted into a Muslim University.

### 4.6 Maintenance and service skills

There are a lot sophisticated and simple agricultural technologies gathering dust even in research institutions just because of lack of a pin, missing an appropriate sieve screen, a filter, a bolt and/or the equipment is not serviced on time thus breaks down. Maintenance and service skills are rare and those companies that have them keep offering incentives to retain them. Normally equipment that is not serviced and maintained in a timely manner will eventually break down. A lot of agricultural technologies fail to operate because there are not maintained or serviced. This is linked to the lack of technicians to service and maintain equipment.

### 4.7 Weak linkages between educational/research institutions, private sector and community

Research in many African universities has no direct relevance to challenges faced by local communities. Although a few successes e.g., in plant breeding have been registered, the general overview is that the linkages between educational/research institutions, private sector and community are weak. There are very few local formal manufacturers of agricultural equipment in East Africa. The few agricultural technologies procured are largely foreign for example, tractors that cannot tilt the heavy soils and not designed for local conditions. As a result, a number of local challenges are not solved by providing appropriate solutions. Simple farm equipment that can ease work at farms is yet to be delivered.

### 4.8 Break down of agricultural extension services

The provision of agricultural extension services is key to the success of agricultural production and productivity. Agricultural extension services help in advising farmers on proper use and maintaining of agricultural technologies. There is evidence that where this advice is missing, Agricultural technologies usage, upkeep, maintenance and service is low. Agricultural extension services workers also help to link farmers to technicians that service equipment and machinery. The government of Uganda had 489 tractors in the government tractor hire scheme by 1965. However, in subsequent years, the service was abandoned partly due to the heavy financial burden on the government as a result of subsidizing the service and the cost of hiring extension workers. In addition, the timeliness of agricultural operations was difficult to perform because of timing conflicts among users of the service.

### 4.9 Lack of technology business parks

Experiences from elsewhere show that technology business parks catalyze the transformation of prototypes into commercial units. Technology business parks are a rare entity in many African economies. This is a missed opportunity to develop Agricultural technologies that are field tested in Africa for African farmers. Countries like Uganda, Kenya and Tanzania has developed business incubation parks but not technology business parks.

### 4.10 Lack of agricultural technologies standards

There are no documented agricultural technologies standards that are enforceable in many African countries. The private sector including farmers is left on its own. The technicalities of setting up irrigation systems for example are a matter of negotiation between consultants and farmers. There are no government agencies or departments to ensure that farmers get value for money. Given the cost involved and the associated risks, the best option for the farmers is to withdraw from such undertakings. Interestingly, government departments that used to ensure quality and test technologies for farmers were underfunded and eventually run down. In Uganda, the underfunded Agricultural Engineering and Appropriate Technology Research Centre (AEATREC), Namalere was mandated development and dissemination of improved agricultural technologies. A similar scenario was replicated with Centre for Agricultural Mechanization and Rural Technology (CAMARTEC) in Tanzania charged with development and dissemination of improved technologies for agricultural and rural development and testing agricultural machinery.

## 5 Conclusions and Recommendations

### 5.1 Conclusions

Some technologies such as evaporative cooling have demonstrated capabilities in preserving fruits and vegetables in rural settings in Africa. However, preservation of fruits and vegetables often fails in the traditional evaporative technologies because none can achieve temperatures close to refrigeration temperatures of 4 $^{o}$C -7$^{o}$C. In addition, due to poor air circulation, heat and mass transfer systems are compromised in the traditional evaporative cooling technologies. It is important that the traditional evaporative technologies for preservation be aligned to the biological nature of fruits and vegetables. Since fruits get spoiled faster than vegetables, evaporative technologies could be thus, suitable for preservation vegetables for a short time awaiting further processing in modern food facilities.

An overhaul and a new paradigm shift are needed in technical education in Africa. A holistic approach in setting up or equipping technical institutions is needed. Governments should desist from converting technical institutions into universities because to-date the success rates of Agricultural technologies adoption, service and maintenance is very low in Africa and this state leads to the following consequences with respect to agriculture for development:

1) The very low Agricultural technologies use makes small and medium size farming unattractive to the youth who make the bulk of the most enterprising labor force in Africa. This is because the very low levels of technology use coupled with equally very low utilization of other productivity enhancing inputs such as improved seed, fertilizers and improved water management for agriculture make farming unprofitable.

2）For those who remain behind in the rural areas, the extremely low productivity makes farming a poverty trap in which the majority can hardly produce enough food to meet their minimum calorie needs.

3）The greatest consequence of low input low output farming, of which low technology use is one factor, is the serious logjam it creates in that farmers require outlets for any surplus they produce, as an incentive to undertake the necessary investment to adopt high inputs strategies including mechanization. At the same time, because of the persistent low outputs, agro-industries and agribusinesses are not willing to invest to provide the necessary outlets because the volumes produced are too small to support optimum facilities. Then the limited trade operations in the rural areas reduce the justification for public investment in rural infrastructure.

**5.2 Recommendations**

1) Integrate agricultural technologies into agricultural value chains to improve adoption and adaptation. The current focus on development of agricultural value chains offers real opportunities for accelerating agricultural technology use. As the experiences with grain milling, and recently shelling have shown, the best entry point for mechanization in a particular value chain would be in postharvest handling and value addition processing. Once these processes are fully mechanized, a profit-driven pull is created for mechanizing field operations.

2) Make (agricultural development and food security) policies, strategies and programs "Technology Smart". Efforts are required to convince public and private sectors of the value proposition of agricultural mechanization so that they can make their current and planned agricultural programs and business plans "Technology Smart". The opportunities that technology use could open for the private sector including primary producers and their associations, supplies, financial services providers, and post-harvest handling and marketing agribusinesses are not currently apparent. Furthermore, private mechanization services providers using small tractors, hand tractors and equipment should be emphasized since outright ownership of large equipment is out of reach for most smallholders in Africa.

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