SMART Technologies for Improved Livelihoods and Environmental Management

Flood-Based Livelihoods Network Foundation

The SMART Centre Group

META

PREFACE

This document is made for MetaMeta group and contains the inventory of technologies that have been developed and implemented by their partners all over the world. It also includes other innovative technologies which are implemented by farmers, NGOs etc worldwide. This is to create awareness on Smart Water Agriculture technologies, Smart WASH techniques, Smart processing and storage methods and finally the setup of support systems known as the 'Distributors Network".

The examples of local action presented here have been drawn from a variety of organizations and many different countries. They should provide a useful resource for:

- professionals in agricultural extension services at both centralized and a decentralized level;
- local government groups interested in what is going on elsewhere;
- civil society groups trying to find ways to improve the livelihoods of farmers and their community
- policy-makers who want to strengthen the local dimension of agricultural sector and
- anyone interested in what local action can do and what support organizations are available.

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1.0 Introduction

The agriculture sector has been an important sector for many developing countries. The sector serves an income generating one to the economy down to local farmers. In recent years, production of food crops by smallholders has increased, but is still characterized by low productivity (FAO, 2015). Even though the sector is still improving over the years, agriculture continues to be subsistence-based and largely rain-fed, with less or no technology. Therefore, to increase food productivity, environmentally and user-friendly technologies are been promoted by MetaMeta and their partners. The technologies promoted are meant to improve the livelihoods of small and medium sized farmers by gaining more income and above all these technologies are environmentally and ergonomically friendly.

Most of these technologies can be locally produced when materials and labour are readily available. The document is structured into four sections namely:

- Smart AgWater techniques
- Smart Processing and Storage techniques
- Smart WASH techniques (Available with Jasmina and Henk)
- Setting up the support system - Finance/ Marketing/ Promotion/ Training Local Entrepreneurs (based on experience in SWA and of the current Smart Centres)

2.0 Smart water for Agriculture (Technologies)

Smart Water Solutions (SWS) in agriculture range from improved water resource management such as in-field soil moisture conservation, mulching and water harvesting to hi-tech precision irrigation (drip and sprinkler) systems used for example in green houses.

> *Box 1: The Smart Water for Agriculture (SWA)*
>
> The project aims to promote market-based solutions which are appropriately adapted to meet the needs and opportunities of small and medium-sized entrepreneurial (SME) farmers. These products and services should be combined with innovative water resource management practices to realize the best possible agricultural water productivity and the maximum achievable income.

2.1 Types of SWA Technologies

The technologies promoted and tested under the SWA are in four categories namely:

- Technologies for Extracting Water- This includes solar pumps
- Technologies for Storage of Water- This comprises of the ponds and pond liners
- Technology for Water Application-This includes drip irrigation, shower irrigation
- Technologies on soil moisture and concentration- This includes waterpads, panoramix

2. 2 Sunlight Pump

What is the Sunlight Pump?

The "sunlight" pump as name suggests is a solar water pump that converts sun rays to energy for irrigation and domestic water supply in developing countries. This pump is an innovative technology which is an environmentally friendly pump because there are no CO_2 emissions. The pump is very portable, has a simple installation manual and has very low maintenance cost.

Benefits of Sunlight pump

This pump is made to suit small and medium scale farmers and rural household in developing countries where rainfall pattern has not been stable. This solar pump is targeted to reduce high costs associated with obtaining fuel for diesel pump or the traditional way of carrying water from long distances to farms. On average, a farmer spends 1000 KES on fuel to pump water and an annual cost of 52000 KES which reduces farmers profits. This pump will specifically improve household's income because there is no cost for diesel.

How is the Sunlight Pump used?

The solar pumps are currently been installed by Greenserve, a Kenyan company focusing on farm solutions especially to Small and medium farmers by providing high quality plus comprehensive support service. The sunlight pump has several components such as the solar panel and or solar battery, suction and delivery hoses and cables with connectors. It is capable of pumping 18,000 litres of water per day assuming there is sunlight throughout and up to 50,000 litres of water when powered with solar batteries. It can pump to horizontal distance of 2km and a vertical distance of 40m with a depth of 7m.

Feedback on Sunlight Pump

The solar pump has been tested in Kenya amongst small-scale farmers which has provided positive and successful reviews. According to one farmer using the pump he said:

"*Since I own a sunlight pump, I don't have to use an expensive gasoline pump anymore. Also, I am independent from rainfall which has become unpredictable in recent years. This allows me to increase the production and generate more income for my family" (Farmer : Mr. Evanson Murimi, Kutus, Kirinyaga ; Kenya)*

"I like the sunlight pump because it is a completely automated system. This allows me to save a lot of time and irrigation is not hard physical work anymore" (Farmer Mr. Titus Githinji, Kerugoya, Kenya.)

Cost Indication

The cost of a solar pump is **95000KES** and its equivalent in dollars ranges between **$900-$1000.**

Distributors network

The Distributor network is to set-up a supply chain for the solar pump technology. The solar pumps are manufactured in Switzerland and imported and distributed only by **Greenserve** in Kenya. Greenserve wanting to improve the income of rural farmers has engaged with several financial and development institutions to enable farmers to get the solar pump and pay slowly or pay at once if they can afford it. The financial institutions are included to provide loans for farmers to adopt the technology.

Fig 1: Sunlight Pump
Source: Greenserve Kenya

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2.3 Barsha Water Pump

What is Barsha water pump?

Barsha Pump is water pump used to irrigate fields without using any fuel or electricity. The pump works on an optimized spiral principle and is designed as a sustainable, low maintenance, low-cost irrigation pump to enable rural communities to increase crop yield.

Benefits of Barsha water pump

The Barsha pump is made for rural communities or farmers to provide water for farming and domestic services. Most importantly the Barsha pump can save over 70% of watering costs for farmers, compared to fuel pumps. This is an environmentally friend pump because there are no emissions. Moreover, it has no maintenance costs and can be locally manufactured when materials are available.

How is Barsha water pump used?

The pump itself is essentially a water wheel on a floating platform, that's moored in a nearby flowing river. The moving water rotates the wheel that in turn utilizes a spiral mechanism to compress air; the air drives water through an attached hose and up to the fields.
This hydro-powered pump can easily be implemented anywhere where there is flowing water nearby and can be used as a stand-alone unit to pump or can be combined with other complementary technologies like drip or sprinkler irrigation systems.

The pump allows water to be scooped up and pumped towards a location up to 2 km inland, making it an ideal solution for small-and mid-sized farms situated near rivers and canals that require continuous access to water for irrigation. The current version with 1.5m in diameter which can lift up to 20 meters vertical head and 2 km inland in flat lands, while reaching up to 40,000 litres of water per day, depending on the flow velocity of the water.

Feedback

More than 40 pumps are currently in use in Nepal, Turkey, Indonesia, Spain and Zambia.
After the installation of the first Barsha Pump in Spain, the Innovagri initiative, which is a Community of Innovative Farmers, values the ecological characteristics of this hydro-powered pump.

Distribution Network

The Barsha pump has been designed and built by the aQysta Company based in Netherlands. The Company's goals are to develop technologies that provide economic benefits without hampering the environment and empowering the society.

Fig 2: Barsha Water Pump

Source: aQysta Company

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2.4 Waterpad

What is waterpad?

A waterpad can be described as a sandwich of hessian, polymers and paper that when placed at the root zone of plants ensures an efficient use of water and nutrients. This concentration of polymers placed at the root zone of plants allows the roots to grow into the gel creating an optimal environment for water and nutrient exchange between plant and polymers. The waterpad is fully biodegradable and can be reused after applied on a plant.

Benefits of waterpad

Waterpads are made to reduce the water and nutrient application between 20-40% when compared to conventional drip irrigation. It has the tendency to increase plant yields between 10 to 20%. Waterpads can also significantly increase the survival rate when transplanting saplings for reforestation or plantations. The waterpad reduces water and plant nutrient losses in drainage, deep percolation and leaching.

How is waterpad used?

Once you have a open furrow (30 cm depth and 20 cm width) you can place waterpads on furrow and cover by soil. The waterpads have been tested in the Netherlands, Turkey, Spain, Pakistan and Ethiopia. It has been used on plants such as tomatoes, cucumber, pepper, roses, eggplant, citrus saplings and other plants are been included. Some of plants have shallow root system which it is important not to dig too deep, otherwise plant roots may not reach to waterpads Only seven (7) grams of polymers can absorb (or buffer) 1 litre of water turning it into gel. The biodegradable waterpad acts as a water and nutrient buffer for 2-3 weeks at the rootzone, which slowly releases water and nutrients to the plant when it needs them.

Feedback

The Antep Pistachio Research Institute, Gap Agricultural Research Institute, Sindh Agriculture University and Harran University have tested waterpads on plants and in their laboratories.

- The research and tests concluded that can reliably be used to save water and to reduce fertilizer applications.
- All tested plants also had increased yield as compared to the control experiment. The waterpads improved yields by producing more leaves which are darker and bigger, roots became thicker when compared with control experiment.

Cost Indication

The cost of waterpads depends on the price specifications given by Plantpads and MetaMeta.

Distribution Network

The waterpads are produced by Plantpads in the Netherlands. They distributed by MetaMeta in Turkey and sold to some Agro shops across Turkey. In promoting the waterpads in other countries, MetaMeta is setting up demonstration trials to both the private and public sector. The public sector includes governmental bodies and research institutes whilst farmers, horticultural, arboriculture companies are targeted for the private sector.

Fig 3: Waterpads
Source: Waterpads/MetaMeta

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2.5 Shower Irrigation

What is shower irrigation?

The mobile shower irrigator is a climate-friendly and conservation agriculture technology. It is a water management technology and therefore is the solution to persistent water scarcity problems in crop production. As a result, the shower irrigator has a tendency to increase food production in the water scarce arid and semi-arid lands.

Benefits of shower irrigation?

The mobile shower irrigator is about **Water Use Efficiency-WUE** in agriculture, efficiency in usage of fossil fuels/petrol or diesel under pump-fed irrigation and the subsequent reduction in carbon emissions and climate change. This will address agricultural mechanization issues in most developing countries. Through agribusiness, the shower irrigator will increase food production, create employment to reduce poverty. This irrigator saves the cost of fuel over Ksh 2.70 over the other 2 technologies of the **Furrow** and **Sprinklers,** which makes cost of food production cheaper where **Shower** irrigation is applied. The technology is labour saving with less clogging problems. While it costs Ksh **750,000 (74,000 USD)** to grow **10,000** cabbages in manual labour under the **Bucket/Spot** Irrigation method, it costs only Ksh **15,000 (150 USD)** in labour and fuel costs to grow the '*same'* **10,000** cabbages under the mechanized **Shower** Irrigation. This is a huge saving in crop production costs for the farmers and also reduces inflation on consumer food prices. The mobile shower irrigator is an asset for hunger and drought management for arid and semi-arid regions.

How is shower irrigation?

The shower irrigation uses less fuel in generating power. It can be connected to both water and power supply to irrigate the farm.

Feedback

The mobile shower irrigator can use 3.2 million litres of water to irrigate 3.2 acres of cabbages against 1 acre of cabbages irrigated with the same 3.2 million litres using the conventional Furrow technology. With 2 shower irrigators for one season (three months) can quickly irrigate 10,000 pieces of cabbage in an hour as compared 25 peasant farmers required to grow 10,000 cabbages per season.

Fig 5: Shower irrigation
Source: E5 technology

Fig 6 Shower Irrigation
Source: E5 Technology

3.0 Smart Agricultural Tools

3.1 Scythe

What is Scythe?

The Scythe is an agricultural tool which is used to harvests dry-stem crops and grasses. The scythe has been tested in India which has also provided successful reviews from users such as it is a simple tool with less weight and ergonomically friendly (as it does not require continuous bending of the back and knee).

Benefits of Scythe

This tool is made for farmers to reduce the long working hours associated with working with a sickle. This because the scythe weeds four (4) times faster than the sickle, this saves a lot of time and energy. The scythe has a sharp high-quality blade attached to a bent iron bar. The Scythe can be locally produced when materials are readily available. However, the sharp blades are currently imported from Turkey.

How is the Scythe used?

The scythe can be used by twisting the upper body and then cut up to 30 cm of plants that stand to the right (an approximate 120^{o}angle) in one sway.

Cost Indication

The cost of the scythe depends on the type of local materials used for production.

Fig 7: Scythe
Source: water channel

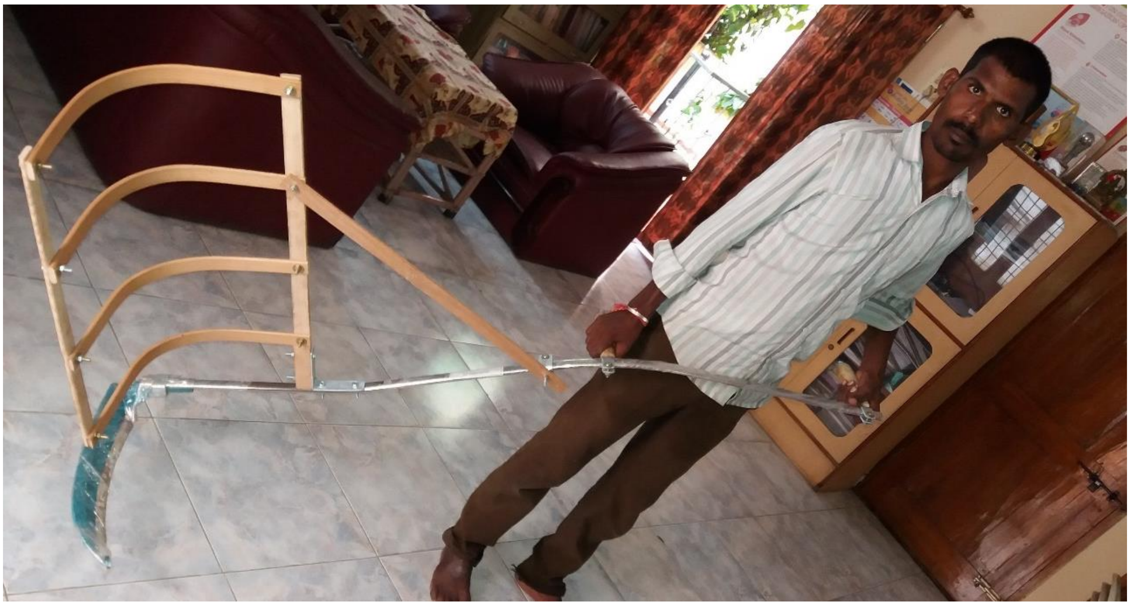

Fig 7: Scythe

Contact: (Links)

- http://scytheconnected.blogspot.nl/2016/06/sowing-seeds-for-scythe-revolution.html
- http://www.thewaterchannel.tv/media-gallery/6370-scythe-project-in-india-2016

3.2 Tree puller

What is Tree puller?

Tree puller is a simple tool that is used to uproot small trees or old trees in and around urban and rural gardens and roadsides. The tool has a claw, fulcrum and an arm as lever with which trees with a stem diameter of up to 5cm (2 inch) and with relatively shallow rooting systems can be uprooted.

Benefits of Tree puller

The tool can be used for clearing grazing lands and invasive species. This tool has been successful in India as it helped pastoralists in uprooting trees and shrubs in an easy manner.

How is Tree puller used?

The tree puller works on the principle of a claw, fulcrum and an arm as lever. The claw is placed around the stem (tree may need to be topped) and by pulling the long arm the tree is uprooted. This tool can also be produced locally when materials are readily available

Cost Indication

The cost of a tree puller depends on the type of local materials used for its production.

Fig 8: Tree Puller
Source: water channel

3.3 Dual-purpose carrier

What is dual-purpose carrier?

The dual-purpose carrier/trolleys can be used to carry liquids such as water or soluble nutrients or materials such as soils, seeds, fertilizers and agricultural produce. The dual-purpose trolley is made up of firmly welded strong iron pipes with strong tyres.

Benefits of dual-purpose carrier

The carrier has good ground balance which is suitable for diverse rural terrain and is easy to manoeuvre in fields. Additionally, it saves time and energy carrying products to and from the farm and it can also be locally manufactured. The Dual-purpose carrier is can be locally manufactured when materials are available.

How is dual-purpose carrier used?

The dual-purpose carrier is used by pushing the carrier with the (two) handles accompanied by the strong tyres underneath.

Cost Indication

The cost depends on the local materials used in producing the dual-purpose carrier.

Fig 8: Dual-Purpose carrier

3.4 Fodder chopper

What is fodder chopper?

The fodder chopper is a hand or electricity driven machine, that can be used in households or at farms to chop fodder.

Benefits of Fodder chopper

The fodder chopper is saves time and energy as compared to manual cutting of fodder. Furthermore, the chopper is easy to maintain and operate and can be easily adjusted to chop dry and fresh fodder. The chopper can be produced locally if the materials are readily available.

How is fodder chopper used?

The fresh/dry fodder can be placed in the designated section and the machine can be connected to a power source or can be hand powered.

Cost Indication

The cost of a feeder chopper ranges from **$250 to $350.**

Fig 9: Fodder chopper
Source: waterchannel

Contact:

http://www.thewaterchannel.tv/media-gallery/3836-rural-technologies-fodder-chopping-machine

3.5 Milk churner

What is Milk churner?

The milk churner is an electrical churner used to extract butter directly from milk. There are different models in use such as the Pakistani model which has horizontal blades.

Benefits of Milk churner

This churner saves time and energy as compared to the manual way for extracting butter by hand. The churner can be produced locally if materials are readily available.

How is milk churner used?

The milk churner is plugged to an electric source and left to churn the milk continuously for 15 minutes.

Feedback

From Ethiopia…still experimenting

Cost indication

The cost depends on the type of local materials used for its production.

Fig 10: Milk Churner
Source: Waterchannel

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3.6 Oil Press

What is the oil press?

The oil press is an electrical machine that extracts oil from different kind of seeds such as rapeseed, mustard, sesame amongst others. The oil press processes the seeds to produce a high-value oil. Currently, the oil press is used in rural areas in Pakistan.

Benefits of the oil press

The oil press has improved households' income by reducing potential losses from rodents, birds and moulds attacking seeds.

How is oil press used?

The raw materials (seeds) are squeezed under high pressure when the oil pressed is plugged in a electric source. As the seeds are been pressed, friction causes it to heat up; The oil seeps through small openings that do not allow seed fibre solids to pass through. Afterward, the pressed seeds are formed into a hardened cake, which is removed from the machine.

Cost Indication

The cost of the oil press ranges from **$250-$350**

Fig 11: Oil press machine
Source: Waterchannel

3.7 Flour mill

What is Flour mill?

This flour mill is a mechanical grinding machine which is used to make flour. The machine is currently in use in Pakistan by rural households. However, a traditional flour mill is handy for small-sized families.

Benefits of Flour mill

The machine has a bigger capacity and conserves more time and energy for operating as compared to hand flour mill. Moreover, it is easier to operate and maintain and has shown to be economical and useful to many people in Pakistan. The flour mill can be locally produced if materials and labour is readily available. The producers will train people who are interested to manufacture the flour mill locally and sell them as well. This allows home-scale businesses to expand and become micro- or small-scale enterprises.

Cost Indication

The cost of an electric flour mill ranges from **$300-$450** whiles the traditional flour mill can be locally produced if materials are readily available.

A traditional flour mill

Fig 12: Traditional flour mill
Source: water channel

Contact

http://www.thewaterchannel.tv/media-gallery/3837-rural-technologies-flour-mill

3.8 Single Axle Tractor

What is a single axle tractor?

The GT18 is a single axle tractor, powered by a fuel-efficient water-cooled diesel engine. It is ergonomically designed, the unit is compact, robust and easily maintained. The tractor can be fitted with metal paddle wheels for working in wet conditions, as they will prevent slipping.

Benefits of single axle tractor

The equipment is suitable for both traction and stationary drive. This means the machine is able to undertake multitask agricultural operations when the appropriate tools and attachment are used. The tractor requires proper maintenance and care to expand its shell life beyond 10 years.

In traction mode it can be used for:

- Ploughing
- Rototilling
- Towing trailer

In stationary mode, as a power source it can be used for:

- Water pumping
- Grain threshing
- Flour milling
- Fodder cutting
- Food oil pressing

Fig 13: Tractor in operation
Source: Greentree

Fig 14: Single Axle Tractor
Source: Greentree

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4.0 Smart Processing and Storage techniques

Globally, postharvest loss is a major problem affecting the agricultural industry. According to the FAO estimations, about 30% to 40% of food crops is lost or wasted before it gets to the market: These losses can be as high as 40%-50% for root crops, fruits and vegetables, 30% for cereals and fish, and 20% for oilseeds. This is due to lack of appropriate post-harvest storage, processing and transportation systems (FAO,2011; Mahajan, et al 2014). In developing countries, food losses occur in the production chain and small farmers suffers the most.

Horticultural crops such as fruits and vegetables are highly perishable in nature therefore good post-harvest techniques are needed to reduce physiological processes of senescence and maturation and minimize the risk of microbial growth and contamination (Mahajan et al 2014). Most staple foods are highly seasonal and must be preserved from one growing season to another since the demand for these foods is perennial.

Most farmers in Africa have problems with storing their horticultural crops for longer times due to lack of storage systems and this leads to post harvest losses. However, the World bank (2011) reports that with 1% decrease in postharvest loss results in $40 million of profits and the key beneficiaries of these profits are farmers. There are many postharvest technologies such as chemical treatments, gaseous treatments, emerging technologies such as plasma treatments that have allowed horticultural industries to meet the global demands of local and large-scale production of fresh produce that have high nutritional quality (Mahajan, et al 2014).

The storage life of fruits and vegetables can be extended greatly by removing the field heat and cooling as soon as possible after harvesting. The optimum storage temperature of most fruits and vegetables is about 0.5○C to 1○C above their freezing point (FAO, 1995). Moreover, while refrigerated cool stores are the best method of preserving fruits and vegetables they are expensive to operate in developing countries.
Therefore, there is an interest for simple low-cost storage units for small-scale and probably medium-sized farmers. This review will hence focus on low cost post-harvest storage systems for horticultural produce.

4.1 Charcoal Cooler

This charcoal cooler is an evaporative cooler is designed to provide an environment which is both lower than ambient temperature and at a higher level of relative humidity. This cooler can be used for all types of produce, but subtropical fruits respond best because their optimum storage temperatures are closer to those achieved by Evaporative Coolers. They are mainly used in some parts of Malawi and Rwanda to store fresh produce (Nenguwo,2000).
This is a storage unit made with charcoal walls. The charcoal is used because it has a very porous structure that can hold water and is a material which is readily available. The structure has a wooden frame which supports the walls and roof. The charcoal walls are constructed from a wooden frame covered with wire mesh separated by about 10 cm with the interior being filled with charcoal. The charcoal walls are on all four sides, filled up to the top 15 to 20 cm below the roof, with this space being left open so as to allow air circulation. The cooler has a door for security purposes and the roof is made preferably with thatch or any material that

provides a cool shade. The floor can simply be bare ground that is compacted, however a more durable floor such as cement, or bricks is more durable. The use of wooden pallets on the floor is advisable as this will keep produce off the ground, reducing the likelihood of infection of produce with soil borne diseases, and moulds in general. An example of the charcoal cooler can be seen below:

A fully constructed Charcoal cooler

Fig 15: Charcoal Cooler
Source: *Nenguwo,* 2000

The coolers therefore have the potential to be useful for reducing deterioration of fresh produce, which is especially important for that destined for export markets.

4.2 Pot Cooler (Janata Cooler)

Another simple technology is the pot cooler developed by the Food and Nutrition Board of India. This pot has a storage pot that is placed in an earthenware bowl containing water. The pot is then covered with a damp cloth that is dipped into the reservoir of water. Water drawn up the cloth evaporates keeping the storage pot cool. The bowl is also placed on wet sand, to isolate the pot from the hot ground. This can be seen in the picture below:

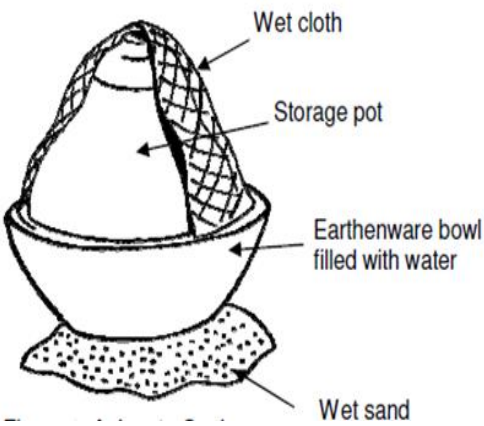

Fig 16:Pot in Pot *Source: Practical Action, India*

Fig 17: Pot in Pot used in Nigeria
Source: Provident living today

These pots have been experimented in Nigeria and Sudan and has proven to be effective and economical. Accordingly, it has been demonstrated by Mogaji and Fapetu (2011) that these cooling devices can be used for preservation of fresh vegetables with their quality still maintained for at least fourteen (14) days in developing countries like Nigeria relative to ambient storage. Others have also proved that the storage life of potato, tomato, mango, banana and spinach can be extended by 3 to 15 days compared to ambient conditions. (Rayaguru, Khan and Sahoo (2010).

In Sudan, Practical Action and Women Association for Earthenware Manufacturing have experimented with the storage design (Longmone, 2003) and the result of shelf life increase obtained is as shown in table 1. (Lal Basediya, Samuel and Beera 2013).

Table 1: Vegetable Shelf-life Change

Produce	Self-life of produce without using the storage pots	Self-life of produce using the storage pots
Tomatoes	2 days	20 days
Guavas	2 days	20 days
Rocket	1 day	5 days
Okra	4 days	17 days
Carrots	4 days	20 days

Source: Longmone (2003)

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4.3 Static Cooling chambers

The basic structure of the cooling chamber can be built from bricks and river sand, with a cover made from cane or other plant material and sacks or cloth. There must also be a nearby source of water. This cooling chamber was developed by the Indian Agricultural Research Institute. The construction is simple because it can be constructed by using locally available materials. In the same vein, Choudhury (2005) has also indicated that the shelf life of fruits and vegetables stored in the cool chambers could increase from 3 days at room temperatures to as much as 90 days. The picture can be seen below:

A static cooling chamber

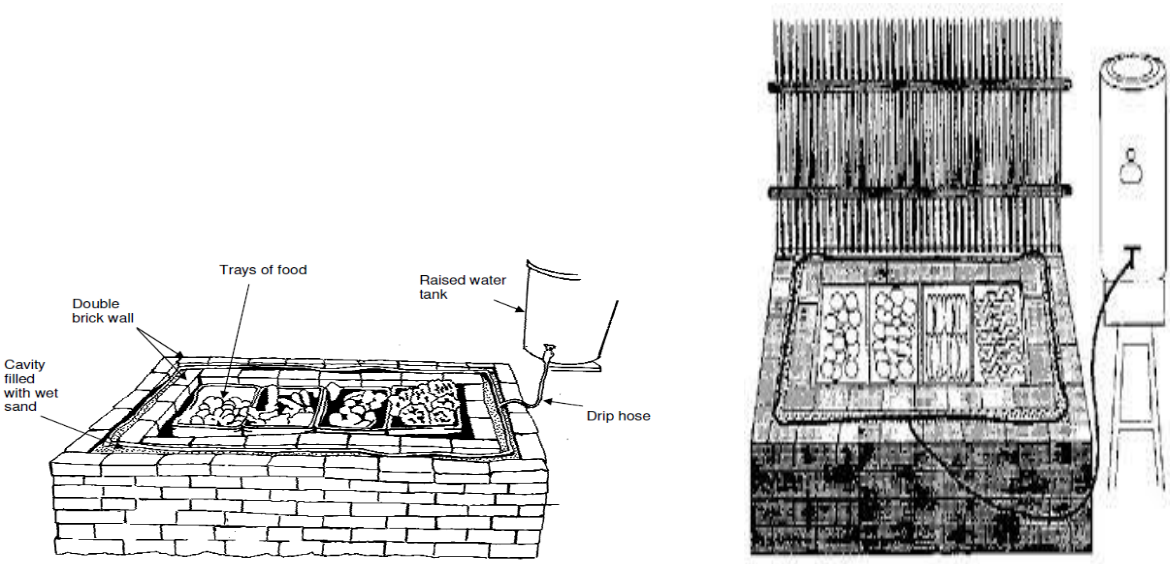

Fig 18: Static cooling chamber
source: Practical Action

4.4 Zero Energy Cooler Chamber (ZECC)

A zero-energy cool chamber (ZECC) consists of a brick wall cooler and a storage container made of locally available materials, such as brick, sand, bamboo, straw, and gunny bags. The ZECC requires no electric energy (Roy and Khurdiya,1985). The brick wall cooler can be made of bricks with a mixture of moistened sand and zeolite which allows low temperature and high relative humidity to be maintained based on the principles of a natural evaporative cooling mechanism. (ZECC stays 10-15° C cooler than the outside temperature and maintain about 90 percent relative humidity) (Islam and Morimoto, 2015; Kale et al, 2016).

Fig 19:Zero energy cooling chamber (ZECC)
Source: Practical Action

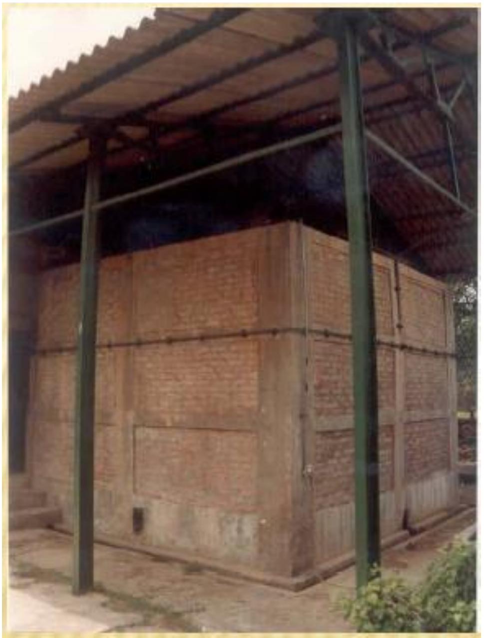

Fig 20: ZECC
Source: Kale et al,2016

Box 2: Construction

- Select an upland having a nearby source of water supply.
- Make floor with brick 165 cm x 115 cm.
- Erect the double wall to a height of 67.5 cm leaving a cavity of 7.5 cm.
- Drench the chamber with water.
- Soak the fine river bed sand with water.
- Fill the 7.5 cm cavity between the double wall with this wet sand.
- Make a frame of top cover with bamboo (165 cm x 115 cm) frame and straw or dry grass etc.
- Make attach/ shed over the chamber in order to protect it from direct sun or rain.

Operation

Keep the sand, bricks and top cover of the chamber wet with water.
Water twice daily in order to achieve desired temperature and relative humidity or fix a drip system with plastic pipes and micro tubes connected to an overhead water source.
Store the fruits and vegetables in this chamber by keeping in perforated plastic crates.
Cover these crates with a thin polyethylene sheet.
The cool chamber should be reinstalled once in 3 years with new bricks utilizing the old bricks for other purposes.

(Prof. Susanta)

A research has been conducted on this technology by Kale et al (2016) to study the effect of ZECC environment on storage life of different fruits and vegetables. The results have been presented in the table below.

Table 2: Storage life of fresh fruits and vegetables in zero energy cool chamber and ambient conditions

Crop	Duration	ZECC		Ambient condition/Room temperature	
		Days	Weight loss (%)	Days	Weight loss (%)
Mango	June-July	9	5.0	6	14.9
Banana	Oct-Nov	20	2.5	14	4.6
Grapefruit	Dec-March	70	10.2	27	11.9
Sapota	Nov-Dec	14	9.5	10	20.9
Lime	Jan-Feb	25	6.0	11	25.0
Kinnow	Dec-Feb	60	15.3	14	16.0
Potato	March-May	90	7.7	46	19.1
Tomato	April-May	15	4.4	7	18.6
Amaranth	May-June	3	11.0	<1	49.6
Okra	May-July	6	5.0	1	14.0
Carrot	Feb-March	12	9.0	5	29.0

Source: Kale et al,2016

The study was done to understand the effect of storage conditions provided by evaporative cooling chamber (ECC), cold store (CS) and ambient conditions (room temperature) on these stored horticultural products. During study, room temperature varied from 30 to 45°C whereas, cooling chamber provided the temperature 5 to 10°C lower than room temperature. Ambient relative humidity varied from 15 to 56% whereas relative humidity inside cooling chamber was found to be 74-80%. Temperature and relative humidity inside cold store was set as 5°C and 90%, respectively. For example, tomato samples were stored for a period of 15 days and were analysed for selected physio-chemical parameters like physiological loss in weight (%), colour, texture, pH and total soluble solids. It was observed that the lower the storage temperature the lesser, the changes in physio-chemical properties and vice versa. At the end of storage period, physiological loss in weight was more in tomatoes stored at room temperature (16%) followed by cooling chamber (7%) and cold store (2%). Remaining parameters showed similar results. Thus, tomatoes stored at room temperature showed more quantitative as well as qualitative losses compared to that stored in cooling chamber. At room conditions, temperature was higher, and relative humidity was lower compared to cooling chamber which resulted in severe deterioration in quality (Kale et al,2016).

4.5 Naya Cellar Storage

This is a type of evaporative cooling system developed by the 'Practical Action Nepal' for food preservation in the rural areas of the country. It was designed by Dr. Gyan Shresthra (from the Green Energy Mission) and Mr. Joshi of Nepal. It is made from locally available materials; and it is easy to adapt the design to user requirements (Practical Action,2000)

The ground of the site where the chamber is to be built should slope a little so that ground water drains away and does not seep back into the chamber. A layer of sand (about 25mm thick) is spread on the ground over the area where the chamber is to be built and a layer of bricks or stones is laid onto the sand. A double walled chamber with a cavity gap of about 125mm is then made with bricks. The cavity is then filled with clean sand. The sand should be free of soil to prevent contamination from organic impurities. A high-density polythene hose with pinholes is made along its length and laid on the sand within the cavity. The hose is blocked at the end so that water released from a tank spreads through these holes and keeps the sand moist. A thatched roof supported by four bamboo poles is placed above the cool chamber. To keep the chamber cool, there must be an un-interrupted circulation of air around the chamber. The air around the chamber is cooled by the effect of the water evaporating from the porous bricks and sand thus prolonging the shelf-life of the food stored within it. Sacks and bamboo sticks are used to cover the chamber which is kept moist by sprinkling water.

To prevent damage to the fruits and vegetables, they should be carefully stored in bamboo or plastic mesh trays or baskets on a framed-platform (4 legs) raised above the floor of the chamber. The flow of water through the hose needs to be regulated in response to changes in the outside temperature to allow conditions within the chamber to remain constant (Odesola and Onyebuchi, 2009; Practical Action,2000-Technology Challenging Poverty).

4.6 Clamps

Tropical roots and tuber crops must be stored at temperatures that will provide protection against chilling, which causes internal browning, surface pitting and increased susceptibility to decay (El-ramady et al,2015). To conquer these conditions in potatoes, a field storage clamp is a simple and low-cost technology that can be designed using local available materials for ventilation and insulation. For example, potato for processing, should have less sugars as they turn dark during heating. Whereas for house hold consumption they should be stored in dark to avoid development of solanine (toxic alkaloid) (CIP 1981). A storage clamp is used in agricultural fields for temporary storage of root crops. Clamps are usually used in temperate regions but are also effective at higher elevations and in warmer climates. In tropical climates of India, extra straw casing is made to give extra ventilation instead of soil. In cold climates, a second layer of straw and soil can be added whereas in hot regions, chimney type air outlets at the top of the clamp can be made. However, during rainy weathers clamp can be constructed under the tree or roof for protection from rainfall.

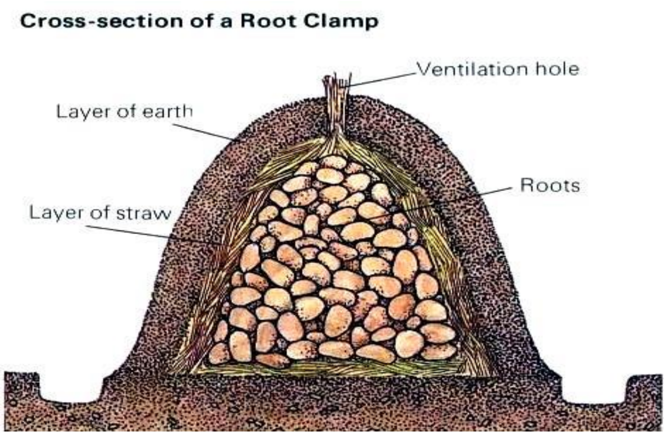

Fig 20: Clamps
Source: Kale et al,2016

4.7 Cellars

Cellar refers to the underground or partially underground structures that are used to store vegetables, fruits, nuts etc. Cellars keep fruits and vegetables at lower temperature and steady humidity conditions. The structure helps in keeping the produce safe from freezing during winters and keep cool during summers (El-ramady et al, 2015; Kale et al,2016)

Common construction methods for storage cellars are:

- Digging down into the ground and erecting a shed or house over the cellar (access is via a trap door in the shed).
- Digging into the side of a hill (easier to excavate and facilitates water drainage).
- Building a structure at ground level and piling rocks, earth, and/or sod around and over it. This may be easier to build on rocky terrain where excavation is difficult.

These structures can be built in cold (Himalayan region) as well as hot climatic regions (North western and western India). A root cellar can be constructed by digging out a pit to a depth of about 2 meters (7 to 8 feet) and framing the sides with wooden planks.

Fig 21: Cellars ventilated storage structures
Source: Kale et al, 2016

Naturally ventilated structures can be used for the storage of fruits and vegetables such as roots and tubers, pumpkins, onions and hard white cabbage. Such structures are designed and built specifically for each intended location. Any type of building can be used that allows free circulation of air through the structure and its contents.

The following points must be kept in mind during their construction:

- Site should have low night temperatures occur over the required storage period
- It should maximize the use of the prevailing wind for ventilation
- Roofs and walls should provide insulation against sun
- Shade of tree should be used: if they do not interfere with the prevailing air flow
- Provide ventilation spaces below the floor and between walls and roofs to give appropriate air flow

This type of storage structure is commonly used in India for the bulk storage of onion and garlic. Onions are stored in these sheds by spreading them on dry and damp roof floor or racks. Some of the improved storage structures for onions include concentric structures, low volume low cost structures (5-10 tons capacity) made of bamboo, high volume bottom and side ventilated storage structure (25-50 tons capacity), Nasik type storage structure etc. (Kale et al,2016).

Fig 22:Bamboo storage unit
Source: Kale et al, 2016

These storage structure for fruits and vegetables hold huge importance considering in mind the amount of postharvest losses taking place in most developing countries. In this aspect information regarding low cost storage structures for holding fruits, vegetables and other horticultural produce is even more important. In developing countries, where major population of farmers are poor, stay in the remote locations they can only afford construction of low cost storage structures to overcome gluts, limiting price falls and overcome shortage of a commodity when prices are high.

4.7.1 Underground storage

This treatment may prolong the storage life for approximately 2 weeks (Ankrah,1986). In underground storage, the cassava roots are buried in moist soil. The soil moisture content is maintained at a level that is not high enough to accelerate rotting and not low enough to cause dehydration. With proper care, this traditional technique can also keep the cassava fresh for about 2 weeks (Pace et al, 1989).

4.8 Hermetic storage Technology

Hermetic storage technology is usually pesticide-free storage bags that eliminates both insects and mould by reducing oxygen/water levels and producing carbon dioxide in the storage units (Walsh et al,2014). The technology has been tried in Kenya and other countries which provided successful recommendation. These storage bags have the capacity to store cereals for a maximum of up-to two years while retaining their distinct quality. Moreover, hermetic bags greatly address the human health and safety challenges posed by the earlier conventional method of treating stored cereals and grain with pesticides. With these bags, no pesticides are required to treat such stored grains and cereals.

The hermetic storage bags have the potential to increase household consumption and cash sales of surplus of cereals for millions of rural households by offering cost effective and efficient. Access to safe, affordable on farm storage technologies allows small scale farming farmers to keep grain year-round for household consumption while providing the household with a marketable asset in case of emergency. Improved grain retention also generates smart income for farmers by giving them the opportunity to sell when market prices are more favourable. Hermetic storage has the same weight as traditional bags and requires no additional labour. These bags can be easily stored within home and protected from theft and animals. Empty bags can be reused for up to five times with no loss in performance. Hermetic storage is sustainable; it is environmentally and user friendly. The technology can be adapted to the protection of commodities in sizes ranging from that of conventional grain bag size to many thousands of tonnes.

Currently a hermetic bag is retailing at Kes 250/= (2.45USD) and there are only five authorized manufacturers of certified hermetic technology bags namely: Purdue Improved Crop Storage (PICS), ZeroFly Storage Bags, Elite Storage Bags, Grain Pro Storage Bags and AgroZ Storage Bags. Each of these bags have the same hermetic principles but differs in design.

A hermetic storage system can be made from specially designed PVC containers such as:

- Cocoon™- commercially available
- the GrainSafe™
- the smaller 50kg IRRI Super bags - available to farmers and processors at low cost
- locally available containers - useful in rural settings, where local containers can be easily converted into hermetic storage systems

The size of hermetic storages can range from 3 litres to 2,000 tons. They can be used for paddy, brown rice, and other cereal crops such as maize and also coffee. Larger hermetic storage systems have also been used with milled rice.

Currently, the hermetic storage bags are used by small scale farmers in Kenya. The growing demand are stimulated by USAID, Kenya Agricultural Values Chain Enterprises (KAVES), private companies and other development partners.

Fig 23: Hermetic bags
Source: USAid

Fig 24: Farmers using the storage bags
Source: Usaid

5.0 Food Preservation techniques

Food preservation is a method of maintain food at a desired level of properties or nature for the maximum benefits (Rahman,2007). Researchers are looking for different methods of preservation techniques to satisfy current demands of economic preservation and customer satisfaction in nutritional and sensory aspects, convenience, absence of preservation, low demand of energy and environmental safety (Rahman,1999). There are traditional food preservation methods carried by chemical, biological or physical means. Chemical preservatives used in traditional food preservation are mainly salt, sugar, and smoke. Alcoholic and acidic fermentations are the biological methods of preservation, while drying, concentration, and heating constitute the physical means of preserving most foods. Preservation is done to delay the growth of micro-organisms, self-decomposition and damage from insects. (Pace et al, 1989). The choice of technique depends on the type of material to be preserved, available facilities and the desired characteristics of the final product. The required raw material for traditional techniques are easily available locally and the equipment used are easy to maintain and affordable by the inhabitants. Many studies have been done globally to explore new and modern food preservation methods, however this section will mainly focus on traditional and low-cost preservation methods.

5.1 Drying

This the process of dehydrating foods until there is not enough moisture to support microbial activity. Drying is one of the oldest method of food preservation and do not require no sophisticated equipment. Most foods such as herbs, fruits, vegetables can be dried in sunlight where outdoor temperature reaches 30°C or higher. Most small and medium sized farmers use this type of method where they cannot afford solar dehydrators or electric dehydrating machine (Pace et al 1989; Krishnan et al,2014). The food produce is spread on clean surface and kept in the sun for few weeks.

5.2 Canning

Canning is a method of preserving food in which the food contents are processed (boiling etc) and sealed in an airtight container. It requires organized and intensive kitchen production during processing. Canned foods need to be stored in a cool and dry place where it will not freeze. For example, equipment for canning tomatoes is minimal, but more costly for preserving other vegetables, fruits and meat. Canning is not a difficult technique, but instructions must be followed accordingly to avoid spoilage and possible food poisoning. Cans and glass jars are suitable for canning. Sterilising your equipment in simmering water for a few minutes (this includes lids) is very vital. Instructions on how to preserve foods by canning has been documented by the United States department for Agriculture.
(https://nchfp.uga.edu/publications/usda/GUIDE01_HomeCan_rev0715.pdf)

5.3 Fermenting

Fermentation has been a commonly used food preservation method for a very long time. It is used to enhance food quality and storage life of some of the food materials. The fermentation technique continued to be used in rural areas due to inaccessibility of industry made products in remote areas. Fermented foods provide vital sources of nutrients and helps in maintaining health and preventing diseases (Bulent and Dobson 2011). Finally, fermentation may also result in the detoxification and destruction of undesirable substances present in raw foods such as phytates, tannins, and polyphenols (Gadaga et al., 1999). Fermented foods and beverages are produced through the action of microorganisms (bacteria, yeast, and mycelia fungi) and their enzymes (Nout, 2003). It is estimated that today, more than 3,500 different fermented foods and drink products, either milk based, vegetable, or fruit based are being produced all over the world. Most of these products are manufactured in Asia, Africa, and in the Middle Eastern countries either in homes, villages, and/or small-scale industries; and produced without any special equipment (Bulent and Dobson 2011). Traditional fermentations have low cost of production, need less labour input; and raw materials needed for preparation are locally or easily available (Krishan et al,2014).

5.4 Pickling

Pickling is the process of preserving food by anaerobic fermentation in brine (a solution of salt in water) to produce lactic acid, or marinating and storing it in an acid solution, usually vinegar (acetic acid) (FAO 2014). The resulting food is called a pickle. This procedure gives the food a salty or sour taste. In South Asia, edible oils are used as the pickling medium with vinegar. Typical pickling agents include brine (high in salt), vinegar, alcohol, and vegetable oil, especially olive oil but also many other oils. Pickling can preserve perishable foods for months and it is normally combined with different preservation method such as canning and fermentation (FAO,2014). Antimicrobial herbs and spices, such as mustard seed, garlic, cinnamon or cloves, are often added.

(Different kinds of Preparation methods can be located here.United States Department of Agriculture.) https://nchfp.uga.edu/publications/usda/GUIDE06_HomeCan_rev0715.pdf

Example

Box 4: Recipe

1/2 Cup white Vinegar, ¼ Water, ¼ sugar, 2 teaspoons of salt, 1 pound of vegetable (steamed, boiled or roast until just tender

Preparation

Combine the vinegar, water, sugar, salt and flavouring variety of your choice in a medium non-reactive pan and allow to boil. Stir to dissolve the sugar and salt; then remove from the heat. Divide the vegetables evenly between jars. Pour the brine solution over mixture, leaving ½ inch of space between the top of the liquid and the lid. Cool, cover and store in refrigerator for three weeks. (*Source: Health.com)*

5.5 Curing/Salting

Curing also known as salting preserves by rendering the food medium an unsuitable environment for microbial propagation (Honer,1997). It can be combined with fermenting, smoking, drying or freezing. Salting is done by placing salt in the gut cavity and outside the fish. The fish are arranged in wooden barrels or concrete tubs with more salt sprinkled on each layer of the fish. The ratio of salt to fish has been estimated to be in the range of 1:3 to 1:6 (Nerquaye-Tetteh, 1979). The salted fish are covered and left for 1-3 days. After salting the fish are removed and spread out to dry in the sun. The salt/brine mixture formed after salting is usually reused 1-3 times with more salt addition. Drying lasts for 3-5 days (Nerquaye-Tetteh, 1979).

5.5.1 Smoking

Smoking is sometimes an additional process to salting that improves flavour and appearance and can also act as a drying agent. Smoked meats are less likely to grow mould than un-smoked meats. For example, in Uganda, smoked meats are preserved with Banana leaves.

Box 3: Preserving meat and using bananas leaves in Uganda

In the Teso sub-region people use to preserve meat in a mound made of soda ash.
The smoked meat is placed inside the ash and covered. The meat can then stay in the soda ash for as long as six months without spoiling. When a visitor comes and/or when there is scarcity or need to eat meat it will be soaked and then cooked in groundnuts paste.
In Buganda, the leaves of banana plants are used to wrap food to be cooked. Meat is wrapped in banana leaves as are all the other ingredients of the dish, such as the bananas themselves. This package will then be steamed until it cooks well and is served on special occasions like marriages and feasts. *(FAO Discussion,2013)*

6.0 Setting up the support system

Agriculture – especially small and medium scale farming – is a vital part of the African economies. The agriculture sector employs most of the continent's labour force and contributes to an estimated 25% of GDP, with smallholder farmers producing up to 80% of the food in sub-Saharan Africa. But regardless of the sector's importance, its potential largely remains untapped. This can be mainly attributed to farmers' lack of access to adequate financing and government support on technologies.

Government funding on environmentally friendly technologies in many developing countries have been hindered by equally important economic challenges. Additionally, most funds do not reach small and medium holder farmers because most of them remain unbanked and do not possess the resources needed for financing collateral. Therefore, much is expected from private actors to invest in these technologies to provide essential services. The technologies described earlier in the other sections can help improve the livelihoods of farmers and other individuals who learn to how to produce them locally.

Moreover, there has been an increasing consensus that most developing countries require innovative strategies to meet its agriculture investment needs and this section seeks to set up a "distributors network" for the technologies to be promoted. The large-scale adoption of these environmentally friendly technologies by small and medium scale farmers needs to be partnered with the private sector. The private sector will include were agricultural inputs suppliers, agricultural Insurance providers, technical support providers (such as technical assistance, quality assessment) among others.

Since most of these technologies can be locally produced when the materials are readily available, a partnership with youth development agencies can be made to teach interested youth on how to manufacture them. The Irrigation Acceleration Platforms (IAP) introduced into SWA project in Kenya can be established in other countries to help promote these technologies. The IAP is a multi-stakeholder collaboration where financial institutions, technology providers interact with farmers' union to bring innovation. These innovations are meant to deliver small and medium rural farmers from poverty.

The promotion of these technologies will be much better through private sector. This because of past experiences from other countries where technology promotion has been made effectively through the private sector. The hope is that this promotion would ultimately take on a life of its own, driven by profit motives, once a network of producers and dealers are in place and the 'product' will definitely become familiar. The promotion will definitely begin with a consumer survey to assess whether there is demand for these technologies and if so which type is preferred by the local communities.

Another important avenue to create a market for these technologies is to allow farmers who have already used them to recommend them to other farmers in other communities to increase demand and also have a chain of suppliers. The smart centres can help create market for these technologies by involving other local NGOs to make demonstrations, promotional events and training interested individuals.

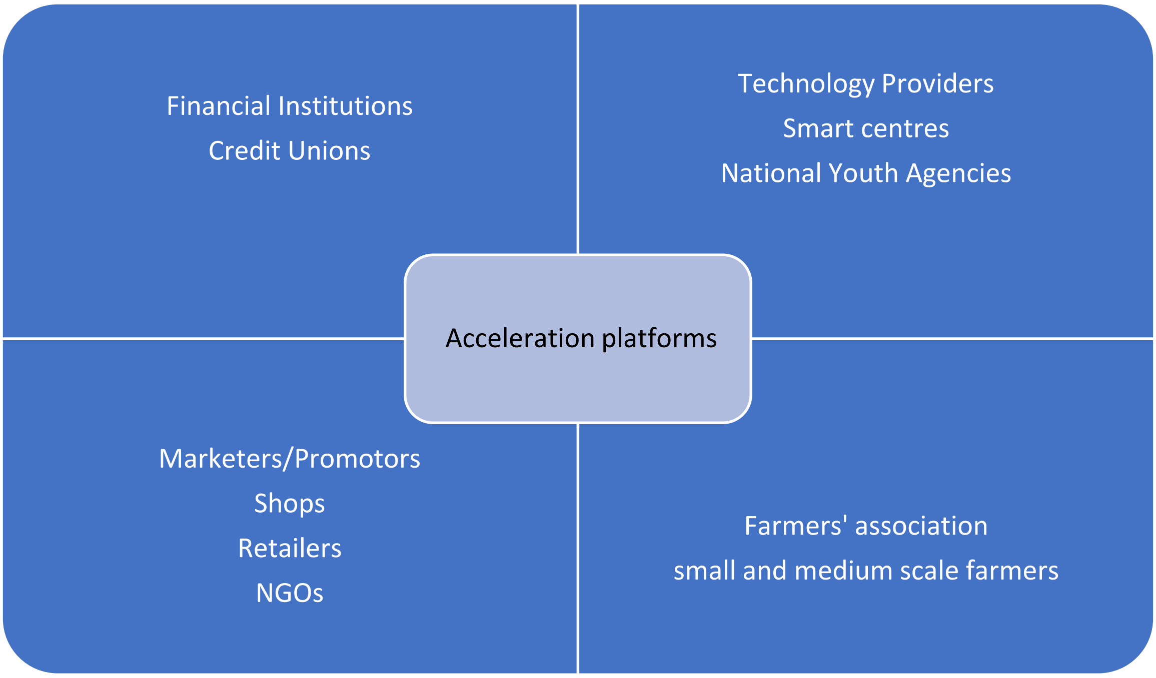

Fig 25: Support system

There have been many research studies documenting effects of climate change on agricultural yields due variations in temperature and rainfall and indirectly through changes in soil quality. The causes of climate change have been attributed to increase use of fossil fuels which releases carbon dioxide. Therefore, to reduce the use of fossil fuels, these environmentally friendly technologies are introduced thus policies are recommended to support the usage and promotion amongst farmers. For example, subsidies can be introduced to help upscale the adoption of these technologies.

According to Fischer (2007,) strong public support for innovation in abatement technologies is only justified if at least a policy is in place and spill over effects are significant. This means that policies and environmental education are very important in promoting and sustaining environmentally friendly technologies. Policies are needed to sustain these proposed support system, the agricultural sector alone cannot make this happen but needs the help of other sectors such as the environmental sector. Most of these support systems will be sustainable if there is adequate funding and assistance from all stakeholders. Most countries have signed onto the Paris climate agreement to do their best to mitigate climate change impacts. There are innovative strategies that most countries are embarking on to achieve their targets on Intended Nationally Determined Contributions (INDCs). Renewable energy, sustainable agriculture, circular economy strategies, sustainable forest management, introduction of eco-friendly technologies and products, just to mention a few are been developed and used by other countries to mitigate climate change issues. This will go a long way to support the agenda of sustainable development. These technologies have the potential to convert small-sized farmers to convert into agribusiness through labour mechanisation.

6.1 Financing Small-scale Farmers

A case study in Rwanda

In Rwanda, more than 80% of the population are involved in agriculture. The agriculture sector meets 90% of the national food needs and export more than 50% of the produce. Most people involved are small-scale farmers or owners. The Government of Rwanda has quite a number of initiatives to boost the agriculture sector especially for small-scale farmers. These initiatives were:

- Introduction of Agricultural Guarantee Funds
- Establishment of Post-Harvest Infrastructure
- Irrigation and Mechanization Initiatives
- Policies on agriculture finances

A business model on agriculture value chain financing was made. This was done to ensure that there is partnership with different actors within the value chain. These actors were agricultural inputs suppliers, agricultural Insurance providers, technical support providers (such as technical assistance, quality assessment), processors and buyers among others.

Opportunity for storage unit receipt systems

Financial institutions can partner with farmers' union to establish post-harvest infrastructures/storage units can provide a solution to the lack of assets that limits small and rural farmers from accessing traditional capital. These storage systems will allow farmers to store their produce in return for a receipt. This means that they can sell their produce at a later time, when prices are low due to high supply. In addition to providing a secure place to store produce, farmers can also collateralise their stored commodities to cover credit from financial institutions. "As an innovative and strategic credit tool, warehouse receipt systems, among other benefits, reduce the pressure on the farmer to sell their produce immediately after harvest, when prices are normally low and reduce post-harvest losses."

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