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Kenyan Pastoralists Improved Way of Life through Innovation and Technology

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Abstract: **The purpose of this paper is to review literature and put together the available innovation and technologies within three (livestock, dryland farming and alternative livelihoods) areas of possible way of improving life by the pastoralists in Kenya. The document is divided into three chapters capturing livestock, dryland farming and alternative livelihoods.**

Innovation and technologies in livestock captured include; improved livestock breeds, dorper sheep, boer goats, feed resource improvements, integration of forage legumes into cereal production systems, integration of forage legumes into cereal cropping systems, silage making, hay making, use of bunched herding to restore degraded rangelands, community-based animal health workers, movable house for kids and lambs, modified chumvikuria for camels, hemp cooling technology for camel milk marketing, donkey carrier for hygienic transporting camel milk in pastoral areas, evaporative charcoal milk cooler, participatory market chain approach technology, ultrasound pregnancy diagnosis as low-tech tool to enhance small ruminant production, and improved reproductive techniques.

Dryland farming innovation and technology captured here include; drip irrigation, fog harvesting, rain water harvesting, slow-forming terraces, m-fodder technology, use of animal impact to restore degraded rangelands, mango grafting technology, conservation agriculture-ca, crop diversification and new varieties, biotechnology for climate change adaptation of crops , agro-forestry, evergreen agriculture, community-based agricultural extension agents, farmer field school, FFSS, kitchen gardens, hydroponic fodder, mango harvesting tools, ethiorirab bee hive, biogas, microdams/waterpans, and improved dryland crop varieties

Alternative livelihoods for pastoralists included in this review are; honey production, ethioribrab' hive, biogas, gum arabic, poultry farming, green charcoal making, and tanning.

Keywords: **Alternative, Dryland, Farming, Innovations, Livestock, Livelihoods, Pastoralists, Technologies.**

DEFINITION OF TERMS:

1. Innovations:

Innovation is simply the process of creating and implementing a new idea or ideas (Richard L. Daft, 2011). In this consultancy task, the aspect of new ideas will be looked into along the livestock/livestock products and other alternative livelihoods (– including gums, resins, spices, honey and artisanal minerals) value chains in ASAL areas. Process, technical and administrative Innovation types will be explored.

2. Technology:

Technology is a body of knowledge devoted to creating tools, processing actions and extracting of materials. The purposeful application of information in the design, production, and utilization of goods and services, and in organizing human activities for the sustainable utilization of complementary livelihood resources – including gums, resins, spices, honey and artisanal minerals. In this regard, all the technological aspects will be considered from the supply side (the tertiary and research institutions) and the demand side (the livestock farmers and the market for the livestock and livestock products).

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3. Dryland farming:

A mode of farming, practiced in regions of slight or insufficient rainfall that relies mainly on tillage methods rendering the soil more receptive of moisture and on the selection of suitable crops.

4. Alternative Livelihoods:

An alternative livelihood refers to economic activities that are different or not directly related to a communities capabilities, assets (including both material and social resources) and activities required for a means of living in the case of IGAD this refers to – gums, resins, spices, honey and artisanal minerals.

1. LIVESTOCK INNOVATIONS AND TECHNOLOGIES

1.1 Improved livestock breeds:

The Ministry of Agriculture and rural development in Ethiopian in collaboration with USAID, introduced drought resistant and highly productive small ruminants (sheep and goat) for the dryland area. The introduced sheep and goat breeds in Ethiopia through the Southern Agricultural Research Institute (SARI) include Dorper sheep and Boer goat. The introduction of small ruminant breeds such as the Dorper and the Boer is contributing to adaptation to climate change and food security and improving the livelihood of the communities of the drylands.

1.2 Dorper sheep:

The Dorper is a South African mutton breed, from the initial crosses between Dorset Horn and Blackhead Ogaden also called Blackhead Somali and Blackhead Persian. The Dorper improved exotic sheep breed well perform and thrive in all agro ecological climates and have high fertility, short generation interval, adaptation in harsh environment and their ability to produce in limited feed resource (Belete et al., 2014). The characteristics of the breed include the ability to walk long distances and to forage well in permanently dry areas and in times of drought. Dorper sheep have a natural tolerance to high temperatures and heavy insect populations, most probably due to their Blackhead Persian origin. They are productive in areas where other breeds barely survive. The other good characteristics include high fertility rate with an unrestricted breeding season. The Dorper has a thick skin, which is highly prized and also protects the sheep under harsh climatic conditions.

1.3 Boer Goats:

The Boer goat is a large; double muscled animal, developed specifically for meat and hardiness. Boer goats have a high resistance to disease and adapt well to hot, dry semi deserts. The fertility rate of the Boer is high; with a kidding rate of 200 percent common Puberty is reached early, usually at about 6 months for males and 10-12 months for females. The Boer goat also has an extended breeding season, making possible three kidding every two years. The Boer goat is a low maintenance animal, which has sufficient milk to rear an early maturing kid. Boer goats are reported to have superior mothering skills compared to other goat breeds. Performance records for this breed indicate exceptional individuals are capable of average daily gains of over 200 g/day in a feedlot. More standard performance would be 150–170 g/day. The mature Boer buck weighs between 110–135 kg and does between 90 and 100 kg. The Boer goat also has excellent carcass qualities, making it one of the most popular breeds of meat goat in the world.

1.4 Feed Resource Improvement:

Feed shortage is a further major constraint in livestock production in Ethiopia and several activities were carried out by the NARS and CGIAR, universities, to address this problem in order to improve food security in relation to climate change. These include integration of forage legumes into cereal production systems and various forms of utilization of feed resources for livestock production.

1.5 Integration of forage legumes into cereal production systems:

Several feed resources and forages have been identified by NARS and ILRI which are playing an important role in drylands by having multipurpose value to the farmer, other than as a feed resource for his livestock. A large number of indigenous forages, which can be screened and selected for use as feed, grow in the dry rangelands of Ethiopia. The germplasm available and suitable species for use as livestock feed in arid and semi-arid environments in Ethiopia and

Africa are available. Thus large quantities of these germplasm can be evaluated and promising species identified for incorporation into livestock production systems.

Examples of the available forage resources used in the dryland areas of Ethiopia include, Acacia, Alysicarpus, Cassia, Crotalaria, Indigofera, Rhynchosia, Stylosanthes, Tephrosia, Vigna and Zornia, which are well distributed in arid and semi-arid areas. Grasses are very drought-tolerant and tend to have a wide distribution in arid areas in the Sahel. Important indigenous genera include Aristida, Cenchrus, Chloris, Echinochloa, Eragrostis, Panicum, Pennisetum and Sporobolus. Birdwoodgrass (CenchrussetigerusVahl) shows very good adaptation to drought and can grow with as little as 200 to 250 mm annual rainfall, whilst buffelgrass (C. ciliaris L.) andveldt grass (Ehrhartacalycina Sm.) require about 350 mm to grow. All these grasses species are tested in the drylands of Ethiopia and could be used to solve the feed problem and increase livestock production. Many tree and shrub species are also important feed resources in dry areas,especially for goats. The major species browsed for forage in these areas in Ethiopia are Acacia Senegal, A. tortilis, Hayne, BalanitesaegyptiacaDelile, Bauhinia rufescens Lam, Combretumaculeatum Vent, Colophospermummopane (Georgis et al 2010). Acacia species could partly help solve the shortage of energy and protein feedstuffs during the dry season andsupplement low quality forage grazed by ruminant livestock (Tolera et al., 2000).

1.6 Integration of forage legumes into cereal cropping systems:

Integration of forage legumes in cereal cropping systems enhances the quality and quantity of fodder to fill the feed gap during the dry season while improving maize grain yield from the same piece of land (Kabirizi et al., 2004). Improving forage yields and/or forage quality without adversely affecting grain yield is an attractive option to intensive smallholder farmers who constantly seek for technologies to improve productivity per unit of available land IN semi-arid areas. Fodder dry matter yield, grain yields, and cob size increase when maize is intercropped with lablab compared to maize pure stand fields. The mean crude protein content of residues from maize-lablab intercrop is 1.9 times higher than the stover obtained from maize pure stands. This technology was developed by the Livestock Nutrition Research Programme which is one of the four programmes that constitute the Livestock Resources Research Institute (NaLIRRI) located in Eastern region (Tororo District) of Uganda.

1.7 1Silage making:

Silage is produced through controlled fermentation (under anaerobic conditions) of green forage material with high moisture content. The anaerobic conditions foster rapid fermentation that produces natural organic acids, which prevent further change in plant composition. If silage is made properly, it will contain nearly all the nutritive values present in the forage that is conserved. Ensiling is the process of silage making; while a silo is the container used. It may be a trench, a pit or a polythene bag.

All pasture and fodder crops can be ensiled. The most ideal would be maize and sorghum, but these form the bulk of human food in Eastern Africa, hence cannot be used for that purpose.

High quality silage is made if grasses are harvested when flowering, legumes are harvested during pod filling and when maize/sorghum is harvested during milk-stage. Pastures under tropical conditions, particularly the grasses, have a low feeding value. The changes that take place during the process of ensiling reduce the value even further. The addition of molasses, maize bran or cassava flour will improve the quality of the silage by increasing the energy content and also act as preservative. According to the National Agricultural research organization of Uganda, silage making is widely used in Mbarara District to avoid dry season feed shortages on their farm. Most farmers use elephant grass, giant setaria and all forage legumes to make silage. All these plants are grown on their farm. The plants for making silage are cut and allowed to wilt. Using a panga, the wilted material is cut into 3–5 cm pieces. Cassava flour and often molasses are added to the material. The material is tightly packed into polythene bags.

1.8 Hay making:

This is a process whereby fodder is harvested at a time when the feeding value is high. Ideally a mixture of grasses and herbaceous legumes is desirable because legumes increase digestibility and intake of the conserved forage. Most grasses are good for hay production and are convenient for cutting. The pasture should be cut just before flowering in order to have high digestibility and high protein content. Pasture for conservation should be cut 4 to 6 weeks after a paddock is closed. During the dry season, the grass hay is fed to the cows. It is sprinkled with salty water to increase palatability. Hay is also fed to calves to help in the development of their rumens.

1.9 Use of bunched herding to restore degraded rangelands:

Animals are bunched or concentrated to graze together on a given piece of land for a short duration of time depending on the forage condition, weather conditions, as well as the changing animal needs. Cattle bomas are strategically placed across the land to restore the degraded land which involves high intensity, short duration rotational grazing. Bunched grazing ensures even use of resource which prevents under-grazing. Animals are also moved and return to a particular grazing area after grasses have recovered from defoliation and this prevents overgrazing. This has increased biomass production that results in increased animal production in terms of milk yield. This technology has gained popularity across the conservancies in the northern Kenya and pastoralists are able to see the value of animals in restoring the degraded lands with most area of the land rehabilitated hence increased milk yield.

1.10 Community-based Animal Health Workers:

Community-based Animal Health Workers is a technology that has been recognised as having a role in providing veterinary services in remote areas where many pastoralists live for a long time because they are able to penetrate into mainstream veterinary practices. They provide a surveillance role as primary disease monitors. They respond to calls for assistance faster and this has helped to save farmers livestock from succumbing to various illness. Lack of appreciation for local knowledge which can be overcome with concerted action to validate and disseminate information on indigenous practices and develop appropriate technologies that combine this know-how with modern strategies is the main challenge to this technology. KALRO and the University of Nairobi trains veterinary personnel that aid in implementation of the community based animal health workers.

1.11 Movable house for kids and lambs:

Lack of proper housing for the mobile kids and lambs as pastoralists move from one place to another led to innovation of a movable house for kids and lambs by Kenya Agricultural livestock research organization. This is a movable house made from low cost appropriate materials. The house has proper ventilation adaptable to wind and the sun. It is easy to clean. Pastoralists are able to move from one place to another with the house so that it can house the young kids and lambs that are vulnerable when pastoralists move from one place to another. Movable houses for kids and lambs have reduced the mortality of lambs and kids when pastoralists move from one place to another.

1.12 Modified ChumviKuria for camels:

The formulation ratio: 1 dicalcium phosphate: 0.992 Chalbi salt: 0.873 calcium carbonate: 0.001 Magnesium sulphate. The technology was validated through an on-station experiment and found to increase milk yield by 17% and calf growth by 25%.Mineral deficiency in the greater northern Kenya is a major nutritional limitation to productivity of camels. Majority of the camel farmers are not yet aware of the formulation.

1.13 Hemp cooling technology for camel milk marketing:

This is a fabric made from sisal fiber. Clean sisal hemp is wrapped around metal milk can. The hampered container is soaked in clean water for at least 30 minutes before the milk is introduced. The soakingof the container after wrapping assists in cooling the milk through evaporation. Milk temperatures are reduced by 13% and total bacterial counts by 44%. The technology is currently validated by the community. Poor road network, nomadism, frequent droughts and poor market linkages are the major challenges facing this technology. This technology requires mapping out of all camel movement route and establishing collection centres in tandem with the grazing points, organizing chain actors for information sharing and collective action platforms as well as training producers and traders on hygienic handling and dispensing of milk. Hemped container must be soaked in clean water at least 30 minutes before putting milk. Works well if moist most of the time, if carried when exposed to wind can cool faster over short distance and if exposed over longer distances can dry quickly and may require re-soaking. This technology resulted in availability of more fresh milk for consumption and sale to large number of consumers.

1.14 Donkey carrier for hygienic transporting camel milk in pastoral areas:

The tool is made of canvas which withstands tensile stress. It comprises of 4 chambers for carrying 4 metal cans. The bottom of each compartment is flat and semi-circular to allow for standing before placement on the donkey or camel. It has six straps for tying around the animal, a soft padding to enhance comfort. The specifications can change depending on the size of the container to be used in hauling milk. The diameter of the chambers should be slightly larger than that of the container to allow for easy loading. This technology is mostly applicable for producers who use donkeys to haul milk. There is need to extend the regulation on milk containers to the camel milk handlers as well. Introduction of metal can enhances hygienic handling of marketed milk and reduces losses along the milk productivity value chain. Poor market linkages may discourage producers from adopting the technology, and Metal cans are not easily accessible by the camel milk producers. It is therefore important to encourage input suppliers to invest in metal cans and avail them closer to producers and collectors, train artisans on design of the carrier for easy access by producers. Training on hygienic handling and dispensing of milk is also important. There is need to extend the regulation on milk containers to the camel milk handlers as well. Camel milk producers can adopt the technology only if properly linked to traders who are also willing to offer better prices for quality milk.

1.15 Evaporative charcoal milk cooler:

The tool is a $0.75m^3$ cabinet made of galvanized angle iron frame reinforced with wire mesh inside and out leaving a 10 cm –wide cavity filled with charcoal. A water reservoir at the top keeps the charcoal wet through drip system. A wind driven fan on the roof enhances air movement through the wet charcoal walls by sucking out the air in the cooler keeping the storage space below ambient temperature. Increased shelf life of milk along the value chain through reduced temperatures will increase income of farmers and traders. The experimental level where milk temperature has reduced up to 27% has been observed with the use of the technology. Lack of information, lack of skills, financing initial capital, high illiteracy levels are the main challenges to the adoption of this technology. Capacity building of farmers, milk traders and extension agents is therefore required. Provision of appropriate financial services and credit facilities to pastoralists is imperative. It is appropriate for ASALs, charcoal has to be moist for effective cooling; water dripping at the bottom can be recycled, other materials such as sand can replace charcoal.

1.16 Participatory Market Chain Approach technology:

The Participatory market Chain Approach is a technology that offers promise to fill a methodological gap to address the challenges of understanding market forces and enhancing productive participation by all market-chain actors in the production-marketing consumption continuum. It is a technology that intervenes in market chains that lack co-ordination, it creates an environment that fosters interaction among market chain actors and generates shared innovation based on learning and mutual trust. An on-going process of innovation is needed along the market chain, to enable those involved to continually identify and take advantage of new market opportunities, thus positively affecting the rural livestock keepers. This is a participatory action-research approach for identifying business opportunities in market chains that are important to small-scale farmers, and then carrying out research and development activities to exploit the opportunities.

1.17 Ultrasound pregnancy diagnosis as low-tech tool to enhance small ruminant production:

Productivity and profitability of meat and milk production from small ruminants are geared by reproductive performance. Females that fail to reproduce are only negatively impacting the environment. A major setback here is infertility but other reproductive-related problems are also important. A whole generation of easy-use, high resolution, portable ultrasound machines is now available to provide different levels of information which will translate into concrete management strategies. ICARDA has been testing field solutions for ultrasound pregnancy diagnosis to reduce reproductive losses and increase lambing rates in sheep and goat flocks – initially in with Awassi sheep in agro-pastoral systems of Jordan, Karakul sheep in Aral Sea, Angora goats in Fergana Valley and Menz sheep in Ethiopian highlands.

1.18 Improved reproductive techniques:

Genetic improvement of small ruminants has been identified as “best bet” in Ethiopia’s highland areas. As part of the Livestock and Fish small ruminant value chain development activities in Ethiopias, community-based breeding programs

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established through an earlier project (located in Horro, Menz, Bonga and Abergelle) were strengthened and new ones were established in Atsbi and Doyogena.

Community-based breeding ensures farmer participation in selection and breeding processes, from inception through to implementation. Community-based goat and sheep breeding programs (CBBP) in Ethiopia have been promoted and implemented jointly by the International Center for Agricultural Research in the Dry Areas (ICARDA), the International Livestock Research Institute (ILRI), the University of Natural Resources and Life Sciences (BOKU), and partners from the national agricultural research system. The breeding objectives are to accomplish (i) accurate control of the timing of reproductive events; (ii) maximize the number of females giving birth; and (iii) ensure the survival of newborn kids, and their ability to grow and mature into productive animals. In the context of genetic improvement, reproduction should also be a successful vehicle to effectively disseminate improved genetics in the base population. Through advances in reproductive technology, a small number of top rams and bucks can be used to serve a large small ruminant population. In addition, each ram or buck is able to produce a larger number of offspring in a given time, thus enhancing the efficiency of progeny testing. The high intensity and accuracy of selection arising from these technologies can also lead to a fast rate of genetic improvement.

2. DRYLAND FARMING

Farmers in semi arid areas are faced with regular occurrences of intra-seasonal dry spells which adversely impact crop yields. Smallholder water system innovations that have been developed by research institutions for dry lands are dominated largely by rainwater harvesting which is usually employed as an umbrella term describing a range of methods of collecting water flows and conserving various forms of run-off water originating from ephemeral water flows during rainstorms for productive use (SIWI, 2001). These innovations are none than conventional soil and water management innovations. They include all new technologies and methodologies for improved agricultural water management, for crop and livestock production. These innovations include water harvesting, drip irrigation, evergreen agriculture and conservation farming technologies aiming at improving water productivity while conserving resources (Rockstrom et al., 2004).

2.1 Drip Irrigation:

Drip irrigation is widely used in the east African dryland including Ethiopia and Sudan. All the agricultural institutions support the use of the system because of its efficiency in terms of water conservation. Drip irrigation is based on the constant application of a specific and calculated quantity of water to soil crops. The system uses pipes, valves and small drippers or emitters transporting water from the sources to the root area and applying it under particular quantity and pressure specifications. The system maintains adequate levels of soil moisture in the rooting areas, fostering the best use of available nutrients and a suitable environment for healthy plant roots systems.

With the help of national agricultural research organizations of different countries, drip irrigation has been applied in arid and semi-arid zones across East Africa as well as in areas with irregular flows of water (or in zones with underground water resources that rely on seasonal patterns such as river-flow or rainfall).

Drip irrigation technology can support farmers to adapt to water stress by providing efficient use of water supply. Particularly in areas subject to climate change impacts such as seasonal droughts, drip irrigation reduces demand for water and reduces water evaporation losses (as evaporation increases at higher temperatures). Scheduled water application will provide the necessary water resources direct to the plant when required. Furthermore, fertiliser application is more efficient since it can be applied directly through the pipes. Drip system is not affected by wind or rain.

Drip irrigation can help use water efficiently. Agricultural chemicals can be applied more efficiently and precisely with drip irrigation. In the case of insecticides, fewer products might be needed. Fertiliser costs and nitrate losses can be reduced. Nutrient applications can be better timed to meet plants' needs. The drip system technology is adaptable to terrains where other systems cannot work well due to climatic or soil conditions. Drip irrigation technology can be adapted to lands with different topographies and crops growing in a wide range of soil characteristics (including salty soils). It has been particularly efficient in sandy areas with permanent crops such as citric, olives, apples and vegetables. A drip irrigation system can be automated to reduce the requirement for labour.

Drip technology faces some possible barriers to implementation including lack of access to finance for the purchase of equipment, a higher amount of initial investment involved than other systems, and limited market for repurchased equipment. Even though several suppliers with wide experience may exist, these firms are usually focused on large land extension projects and do not cater for small and medium-sized farmer markets. Technical conditions such as soil clay presence, irregular rainfall or steep slopes can increase implementation and maintenance costs or affect drip system efficiency. Also, the yield of existing crops irrigated by gravity or another open system can be affected by changing to drip system.

2.2 Fog Harvesting:

Fogs have the potential to provide an alternative source of fresh water in dry regions and can be harvested through the use of simple and low-cost collection systems. Fog harvesting is an innovative technology based on the fact that water can be collected from fogs under favourable climatic conditions. The small water droplets present in the fog precipitate when they come in contact with objects. The fog has the potential to provide an alternative source of freshwater if harvested through the use of simple and low-cost collection systems known as fog collectors. Present research suggests that fog collectors could supply water for multiple uses in mountainous areas should the water present in stratocumulus clouds, at altitudes of approximately 400 m to 1,200 m and winds between 3 – 12 m/s and with no obstructions to wind flow. Fog can also be harvested in coastal areas where the fog moves inland driven by the wind. The water in fog is harvested through simple systems known as fog collectors. Captured water can then be used for agricultural irrigation and domestic use (UNEP, 1997). Fog harvesting technology consists of a single or double layer mesh net supported by two posts rising from the ground. If not properly maintained, water quality becomes an issue during low-flow periods. Fog water collection requires specific environmental and topographical conditions, limiting its application to specific regions. Procurement and transportation of materials is hindered by remote locations and steep terrain. Strong winds and snow fall can result in structural failure during the winter season. Water yield is difficult to predict, requiring feasibility studies prior to large scale implementation. For harvesting to be effective, frequent fogs are needed and sufficient water collected for the investment to be cost-effective. This limits the technologies to areas with specific conditions. There are few commercial producers of mesh currently in operation, with main suppliers located in the Chile. There is none in Africa, North America or Asia (FogQuest, 2011).

In Kenya the project has partners from the Pastoralists Organization for Water and Environmental Research (POWER), Jomo Kenyatta University of agriculture and technology, Kenya Meteorological Department (KMD), and the Ped-World (Germany). The local people are beneficiaries. The trial Fog Collectors have been installed at; Olteyani Primary School, Olteyani Village, Ilmasin Primary School and Kiseria. Already, the beneficiaries are excited as some water has been captured from fog, while during the rainy season; the equipment collected a lot of rainwater.

2.3 Rain water harvesting:

Rainwater harvesting is defined as a method for inducing, collecting, storing and conserving local surface runoff for agriculture in arid and semi-arid regions (Clement 2011).

- **Roof-top:**

In the roof-top method water from rainfall is collected in vessels at the edge of the roof or channelled to a storage system via gutters and pipes. Roofs can be constructed with a range of materials including galvanised corrugated iron, aluminium cement sheets, and tiles and slates. Thatch or palm leafed roofs can provide a low-cost alternative but can be difficult to clean and can taint the runoff. Rooftop collection is suitable for household level application and can provide freshwater for domestic purposes and small-scale farming (Ngigi 2011).

- **Rock Surface/Ninja weirs:**

This is a technology that was developed at the Mpala research center**.** The Nanja weirs provide the mpala village in Laikipia County Kenya with a previously unutilized source of water by capturing and storing runoff from the surrounding landscape. The Nanja weirs capture the run-off water within the Mpala area and store water, which is then used by the communities in times of drought (Ransom et al.,2012).

Rock surfaces can also be used as collection catchments. Bedrock surfaces found within rocky top slopes or exposed rock outcrops in lowlands often have natural hollows or valleys which can be turned into water reservoirs by building a dam. Developing a rock catchment area typically involves clearing and cleaning the site from vegetation and marking out the catchment area to be enclosed with gutters. Rock surfaces should not be fractured or cracked, as this may cause the water to leak away to deeper zones or underneath the dam. As with ground catchments, water is generally of lower quality than direct rainfall collection. Water quality can be improved if access to the area (for example, by animals and children) is limited

Several types of conveyance systems exist for transporting water from the catchment to the storage device, including gutters, pipes, glides, and surface drains or channels. Larger-scale conveyance systems may require pumps to transfer water over larger distances (Rockstrom et al., 2000). These should be constructed from chemically inert materials such as wood, bamboo, plastic, stainless steel, aluminium, or fibreglass, in order to avoid negatively affecting on water quality (UNEP, 2009). In the case of rock catchments, gutters can be constructed from a stone wall built with rough stones/hardcore and joined with mortar (UNEP and SEI, 2009). For household-level rainwater harvesting, gutters, down pipes, funnels and filters are required to transfer and clean collected water before it enters the storage device.

Rainwater harvesting technologies are simple to install and operate. Local people can be easily trained to implement such technologies, and construction materials are usually readily available (Fox, 2005). Rainwater harvesting is convenient because it provides water at the point of use and farmers have full control of their own systems. Use of rainwater harvesting technology promotes self-sufficiency and has minimal environmental impact. Running costs are reasonably low. Construction, operation and maintenance are not labour-intensive. Water collected is of acceptable quality for agricultural purposes. Other benefits include increasing soil moisture levels and increasing the groundwater table via artificial recharge. According to UNEP and SEI (2009), rainwater harvesting and its application to achieving higher crop yields can encourage farmers to diversify their enterprises, such as increasing production, upgrading their choice of crop, purchasing larger livestock animals or investing in crop improvement inputs such as irrigation infrastructure, fertilisers and pest management.

The main disadvantage of rainwater harvesting technology is the limited supply and uncertainty of rainfall. Rainwater is not a reliable water source in dry periods or in time of prolonged drought. Low storage capacity will limit rainwater harvesting potential, whereas increasing storage capacity will add to construction and operating costs making the technology less economically viable. The effectiveness of storage can be limited by the evaporation that occurs between rains. In water basins with limited surplus supplies, rainwater harvesting in the upstream areas may have a damaging impact downstream and can cause serious community conflict. Also, when runoff is generated from a large area and concentrated in small storage structures, there is a potential danger of water quality degradation, through introduction of agro-chemicals and other impurities (UNEP and SEI, 2009).

2.4 Slow-forming Terraces:

A terrace is a levelled surface used in farming to cultivate sloping, hilly or mountainous terrain. They can be used on relatively flat land in cases where soil and climate conditions are conducive to erosion. Terraced fields are effective for growing a wide range of crops such as rice, potatoes, maize, olive trees, and vineyards (Wakindiki et al., 2015). Terraces have four main functions: Improve the natural conditions for agricultural production; Decrease the rate of erosion; Increase soil moisture; and Generate positive environmental benefits. Description Slow-forming terraces are constructed from a combination of infiltration ditches, hedgerows and earth or stone walls. This technology decreases superficial water run-off, increasing water infiltration and intercepting the soil sediment . Slow-forming terraces are called as such because they take between three and five years, and possibly even ten years, to fully develop. Slow-forming terraces can be built where the land is marginally to steeply incline and where the soil is sufficiently deep to create a drag effect. This leads to the formation of steps as sediment accumulates due to rainfall and natural gravity. Level ditches are traced and excavated along the contour line of a slope and then an embankment of earth, stones or plants is constructed at regular intervals. Eroded soil accumulates in these buffer strips every year and terraces slowly form. To avoid intensive rains breaking buffers strips, a one to two per cent inclination is recommended. Depending on soil type, ditches should generally be dug 40 cm wide and 40 cm deep. The recommended length of the terrace is between 50 and 80 meters and the height of the slope should be the same as the height of the earth or stone ditches. The best plants to cultivate along the buffer strips should be resistant to local conditions and grow well and fast. Where possible, plants should be used that can provide wood for fuel and feed for livestock.

This technology optimises water use. Climate variability also affects the soil, since heavy rainfall coupled with poor soil management give rise to landslides and mudslides. In this respect, slow-formation terraces reduce soil erosion and, consequently, the danger of large landslides occurring. Terraces also provide a method for regulating the micro-climate for agricultural production.

Slow-forming terraces have also been shown to increase crop productivity. Research conducted in Makueni found that the highest response to the effect of slow formation terraces on productivity was for Maize, beans and potatoes also improved their productivity (Wambua et al., 2014). The most important reason for this increase is assigned to increased/enhanced water retention. The university of Nairobi department of soil science is undertaking projects to come up with the best cropping pattern on any given slope along the terraces to ensure farmers achieve maximum benefit from their farms.

Given the length of time required for results, lack of access to land or land rights could prevent a farmer from adopting this technology over traditional practices. This is because farmers with precarious forms of land tenancy tend to have shorter planning horizons and view permanent structures requiring long-term investments as riskier. The reduction in available land area for cultivation due to the space taken by the ditch and banks, or vegetation strips can be a significant disincentive for farmers with very limited access to land. Also the land cultivated is rented from another land-owner there is little incentive to invest in soil conservation.

2.5 M-Fodder technology:

M-fodder is a multiplatform system for fodder value chain analysis, marketing and market information system. It consists of 3 platforms; SMS, website and market information system (MIS). M-fodder focuses on the main sub-categories of fodder which are; hydroponics pastures and range seeds. Fodder production units mapping and data documentation, fodder producer-consumer marketing behaviour analysis, cross value chain linkage analysis. The technology comprises of three platforms; SMS, website and Market Information System (MIS). SMS technology is used for hydroponic and pastures, fodder inquiry and acquisition, fodder outsourcing, proximity production centre information, market linkage and purchase processing. MIS is used for range seed technology, range seed variety availability, price setting, marker synchronization, value chain communication platform, market analysis in terms of location, producers and consumers, buying and selling platform. This innovation is spearheaded by the University of Nairobi, Land resource management and agricultural technology department. It is aimed at bridging the gap between the livestock farmers and forage producers. Farmers with hay and grass seeds can be able to access the market easily as the livestock keepers in the dryland areas access animal feeds easily without much exploitation by the middlemen.

2.6 Use of animal impact to restore degraded rangelands:

Global discourses on the rangeland condition trends usually feature overgrazing by livestock as the main cause of range degradation. Contrary to the mainstream view where exclusion of grazing is seen as means of restoring degraded rangelands, livestock were used as a tool to impart beneficial effects to the soil and vegetation through their impact on the soil and vegetation. In this technology, animals are bunched or concentrated to graze together on a given piece of land for a short duration of time depending on the forage condition, weather conditions, as well as the changing animal needs. Cattle bomas are strategically placed across the land to restore the degraded land which involves high intensity, short duration rotational grazing. Bunched grazing ensures even use of resource which prevents under grazing, Animals are also moved and return to a particular grazing area after grasses have recovered from defoliation and this prevents overgrazing. Faecal excretion, urination and hoof action lead to incorporation and accumulation of organic matter in the soil, thereby enhancing biological activity that increases accumulation of cations such as calcium and magnesium in the soil. The compacted soil crusts are broken down by the hoof action resulting in reduced bulk density.

Increased accumulation of cations increases the aggregate stability of the soil, which enhances soil aeration. High aggregate stability enhances soil, water infiltration because of stable aggregates that do not disintegrate into individual particles that close down the soil pores causing crusts that impede water infiltration and aeration. Increased organic matter in the soil and more available water content for plant use results into more biomass productivity which increases the state and health of the range. Soil properties and range productivity can be enhanced when grazing animals are bunched to

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assert maximum impact on soil and pasture for a short duration followed by adequate rest duration to allow post-grazing pasture recovery. This technology has shown that efforts aimed at restoration and sustainable utilization of rangelands should consider livestock as an integral part of rangelands ecosystems, and therefore their exclusion as an ecological imbalance. This technology is spearheaded by the Norther rangeland trust, Mpala research centre, University of Nairobi, Princeton University and Egerton University. It has gained popularity across the conservancies in the norther Kenya and pastoralists are able to see the value of animals in restoring the degraded lands with most area of the land rehabilitated.

2.7 Mango grafting technology:

Grafting is the most reliable and economical means of propagating the mango. It consists of transferring a piece of a mature, bearing tree (scion) to a separate seedling tree (rootstock), forming a permanent union. The scion forms the canopy of the tree, while the rootstock forms the lower trunk and roots (Mng'omba et al., 2010). Grafting impart disease resistance or hardiness, contributed by the rootstock; shorten the time taken to first production of flowers or fruits by the scion, in some cases by many years; dwarfs the scion, making both its height and shape more convenient for harvesting fruit; allows scion cultivars to retain their desirable leaf, floral, or fruit characters, without the risk of these being lost through sexual reproduction(Sennhenn et al., 2014) and provides the most economic use of scion material, in cases where there is some difficulty with stem cuttings producing roots. Most farmers in the eastern semi-arid parts of Kenya have had successful years of plenty harvesting from grafting of mangos. However, sometimes the graft union fails, resulting in the main stem breaking off, dieback, poor growth or death of the top part of the plant. In contrast, the root system will often remain alive and may send up suckering shoots. It therefore requires much precision in grafting.

ILRI through LIVES project in Ethiopia is also leading a farmer-based grafted seedlings supply system that avails improved trees to farmers. The 'top-working' technique is being used to produce improved and shorter mango trees that produce uniformly sized fruits of superior quality and are easier (lessen chance of fruit damage) during harvest compared to cross-pollinated cultivars currently used by many farmers.

To ensure farmers increase their incomes and improve mango marketing systems within and outside the zone, the LIVES project has partnered with organizations such as marketing and cooperatives offices at district and zonal levels, Gamogofa fruits and vegetables cooperatives union and local traders.

2.8 Conservation Agriculture-CA:

CA is based on integrated management of soil, water and agricultural resources and its three essential features are crop rotation, minimum disturbance of soil and maintenance of a permanent soil cover. In particular, the use of cover crops ensured cost effective weed management as well as improving soil fertility (Mwangi et al,.2000). The introduction of specific soil rotations and associations, on the other hand, promoted biological sub soiling which facilitated plant root growth and water infiltration, besides breaking cycles of crop pest and disease. Small-scale farming tends to use smaller-scale methods using hand-tools and in some cases draught animals, whereas medium to largescale farming tends to use the larger-scale methods such as tractors. The overall goal of tillage is to increase crop production while conserving resources (soil and water) and protecting the environment.

Conservation tillage refers to a number of strategies and techniques for establishing crops in a previous crop's residues, which are purposely left on the soil surface. Conservation tillage practices typically leave about one-third of crop residue on the soil surface. This slows water movement, which reduces the amount of soil erosion. No-till is a way of growing crops without disturbing the soil. This practice involves leaving the residue from last year's crop undisturbed and planting directly into the residue on the seedbed. No-till requires specialised seeding equipment designed to plant seeds into undisturbed crop residues and soil. No-till farming changes weed composition drastically. Faster growing weeds may no longer be a problem in the face of increased competition, but shrubs and trees may begin to grow eventually. Cover crops – 'green manure' – can be used in a no-till system to help control weeds. Cover crops are usually leguminous which are typically high in nitrogen can often increase soil fertility. In ridge-till practices, the soil is left undisturbed from harvest to planting and crops are planted on raised ridges. Planting usually involves the removal of the top of the ridge. Planting is completed with sweeps, disk openers, coulters, or row cleaners. Residue is left on the surface between ridges. Weed control is accomplished with cover crops, herbicides and/or cultivation. Ridges are rebuilt during row cultivation. Mulch-till techniques involve disturbing the soil between harvesting one crop and planting the next but leaving around a third of the soil covered with residues after seeding. Implements used for mulch-till techniques include chisels, sweeps, and field cultivators.

Conservation tillage practices reduce risk from drought by reducing soil erosion, enhancing moisture retention and minimising soil impaction. In combination, these factors improve resilience to climatic effects of drought and floods (Smith, 2005). Improved soil nutrient recycling may also help combat crop pests and diseases (Holland, 2004).

Benefits: CA in semi-aid areas has led to reduction of soil runoff, enhancement of water infiltration into the soil, reduction of soil water evaporation by, increased soil fertility, for example maize stover cover add to the crop field the following elements: 0.7 N, 0.14 P, 1.43 K, 0.36 Ca (% of dry weight). Increased ground water quality and level, reduced sedimentation downstream, reduced greenhouse gases as a result of carbon sequestration, and increased soil micro-organism activities leading to improved soil fertility, reduced weed seed bank. This has led to several benefits such as; improved food security as a result of increased crop yield by 30-40% and better household nutrition as a result of sufficient household food reserve, improved household income as a result of the sale of surplus crop production, reduced household labour requirement by over 40% thanks to zero till and reduced mechanical weeding, reduced food deficit and over reliance on relief food (especially important for HIV/Aids infected), increased household purchasing power and improved overall economic growth in the region.

2.9 Crop Diversification and New Varieties:

The introduction of new cultivated species and improved varieties of crop is a technology aimed at enhancing plant productivity, quality, health and nutritional value and/or building crop resilience to diseases, pest organisms and environmental stresses. Crop diversification refers to the addition of new crops or cropping systems of agricultural production on a particular farm taking into account the different returns from value-added crops with complementary marketing opportunities. Major driving forces for crop diversification include; increasing income on small farm holdings, withstanding price fluctuation, Mitigating effects of increasing climate variability, balancing food demand, Improving fodder for livestock animals, Conservation of natural resources, minimizing environmental pollution, reducing dependence on off-farm inputs, depending on crop rotation, decreasing insect pests, diseases and weed problems and increasing community food security. There are many thousands of existing varieties of all of the important crops, with wide variation in their abilities to adapt to climatic conditions.

Adaptation breeding new and improved crop varieties enhances the resistance of plants to a variety of stresses that could result from climate change. These potential stresses include water and heat stress, water salinity, water stress and the emergence of new pests. Varieties that are developed to resist these conditions will help to ensure that agricultural production can continue and even improve despite uncertainties about future impacts of climate change. Varieties with improved nutritional content can provide benefits for animals and humans alike, reducing vulnerability to illness and improving overall health. The aim of crop diversification is to increase crop portfolio so that farmers are not dependent on a single crop to generate their income. When farmers only cultivate one crop type they are exposed to high risks in the event of unforeseen climate events that could severely impact agricultural production, such as emergence of pests and the sudden onset of frost or drought. Introducing a greater range of varieties also leads to diversification of agricultural production which can increase natural biodiversity, strengthening the ability of the agro-ecosystem to respond to these stresses, reducing the risk of total crop failure and also providing producers with alternative means of generating income. With a diversified plot, the farmer increases his/her chances of dealing with the uncertainty and/or the changes created by climate change. This is because crops will respond to climate scenarios in different ways. Whereas the cold may affect one crop negatively, production in an alternative crop may increase.

Challenges: The main barrier to introducing new and improved crop varieties through farmer experimentation is the misconception that local species have low productivity. In the same vein, several communities in developing countries have lost ancient knowledge about resistant species. The main barrier to diversification is market demand, which can lead farmers to produce fewer crops or monocultures and to rely on chemical inputs. In turn, this can increase vulnerability of both the agricultural system itself to external factors such as climate change, and also the farmer to price fluctuations.

Real Examples of Application Farmer experimentation on improved varieties of beans in Kenya by the University of Nairobi have reduced the spread of diseases and therefore avoided drops in crop productivity. Participative development processes have increased access to and adoption of improved varieties for small farmers (Kimani 2014).

2.10 Biotechnology for Climate Change Adaptation of Crops:

Biotechnology and genetic engineering give the prospect of making more dramatic changes to crop responses to stress than is possible with conventional breeding and making them more rapidly. Breeding for improved performance under environmental stresses involves activities which accumulate favourable alleles which contribute to stress tolerance. Biotechnological tools focus on providing the ability to directly detect and transfer genes of interest from other plant lines or organisms into the crop of interest without the continuing need to use the appearance or stress response of the plant (its phenotype) as a proxy for the presence of that gene. Phenotyping (measurement of the response of a plant line in a given environment) is still a vital part of the selection process but when a genetic region shown to be conferring an adaptive advantage has been identified, it can be transferred (even across species barriers) much more rapidly and efficiently than has been possible up to now. Superior genes or alleles can often be found within other lines or races of the same crop and their efficient accumulation can be greatly speeded by molecular breeding where the presence of desirable genes or alleles can be directly and immediately identified, even in seeds or very young plants not exposed to the stress in question.

Genes that confer a measure of biotic stress tolerance can be obtained from germ bank collections, wild relatives of the crop, or from other organisms known to perform well under water deficit/excess or high salinity or temperatures. There is a great deal of activity within the major biotechnology and the agricultural research institutes and academic institutions on transgenic research for drought-prone environments (Ortiz et al, 2007 and Varshney et al, 2011). The international donor community is supporting work in this area through the Consultative Group on International Agricultural Research (CGIAR) and in particular through the Generation Challenge Programme in which partners from the CGIAR institutions such as the International Rice Research Centre (IRRI) or the International Maize and Wheat Research Centre (CIMMYT) work with leading ARI and ARS institutes in developing countries. In addition to the plant lines coming out of these collaborations, the Genomics and Integrated Breeding Platform being developed by this programme will provide the technical suite of tools to enable any breeder to utilise these new technologies on-line. In addition, 'communities of practice' are under construction to provide the peer support which will be required for their efficient utilisation.

Benefits If biotechnology solutions can be delivered to farmers which mitigate the harmful effects of climate change there is great potential for maintaining food and fibre production in a degrading environment and for expanding the farmable area into currently marginal environments. This is not to imply that environmental remediation is unnecessary but it helps to provide a buffer on its urgency. The major benefit from molecular breeding to date is the speed with which multiple traits can be identified, captured and incorporated into plants and then be tested for stability and efficacy. This has increased exponentially in the last 15 to 20 years. Genetic engineering technologies allow us to utilise capacities outside the range normally available in our crop plants. Because gene insertions can now be targeted and checked in ways that were not previously possible, we can have a higher confidence in the safety of the new plant lines and can be sure that other functional plant genes have not been disrupted by the insertion.

Challenges: The global crop breeding community has found it more difficult than expected to use the outputs of molecular breeding research in its various forms for the rapid development of improved cops for poorer farmers. Even within crop species, genome structure and gene orders have proved to be more variable than expected. The prevalence of polygenic traits with strong genetics/environment interactions have been more marked than was foreseen, making successful expression of the valued trait after intra or inter-specific transfer more elusive than had been hoped. This is slowing (and deepening) research by all organisations (including commercial companies) in this area.

2.11 Agro-forestry:

Agro-forestry is an integrated approach to the production of trees and of non-tree crops or animals on the same piece of land. The crops can be grown together at the same time, in rotation, or in separate plots when materials from one are used to benefit another. Agro-forestry systems take advantage of trees for many uses: to hold the soil; to increase fertility through nitrogen fixation, or through bringing minerals from deep in the soil and depositing them by leaf-fall; and to provide shade, construction materials, foods and fuel. In agro-forestry systems, every part of the land is considered

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suitable for the cultivation of plants. Perennial, multiple purpose crops that are planted once but yield benefits over a long period of time are given priority. The design of agro-forestry systems prioritises the beneficial interactions between crops, for example trees can provide shade and reduce wind erosion.

Agro-forestry can improve the resilience of agricultural production to current climate variability as well as long-term climate change through the use of trees for intensification, diversification and buffering of farming systems. Trees have an important role in reducing vulnerability, increasing resilience of farming systems and buffering agricultural production against climate-related risks. Tree-based systems have advantages for maintaining production during wetter and drier years. Second, trees improve soil quality and fertility by contributing to water retention and by reducing water stress during low rainfall years. Tree-based systems also have higher evapo-transpiration rates than row crops or pastures and can thus maintain aerated soil conditions by pumping excess water out of the soil profile more rapidly than other production systems if there is sufficient rainfall/soil moisture (Martin and Sherman, 1992). Trees can reduce the impacts of weather extremes such as droughts or torrential rain. For example, Mbugua et al (2014), found that a combination of grass and leguminous shrubs in contour hedgerows reduced erosion by up to 70 per cent on slopes above 10 per cent inclination without affecting maize yield in Eastern Kenya. According to Ma et al, (2009), the tree components of agro-forestry systems stabilise the soil against landslides and raise infiltration rates This limits surface flow during the rainy season and increases groundwater release during the dry season.

By integrating trees in their farms and rangelands, farmers reduce their dependency on a single staple crop or having sufficient grass for their animals. For example, if a drought destroys the annual crop, trees will still provide fruits, fodder, firewood, timber and other products that often achieve high commercial value. A study of 1,000 farmers from 15 districts in Kenya found that fruit trees contributed 18 per cent of crop revenue, and tea and coffee contributed an additional 29 per cent of revenue (Place and Wanjiku, 2006).

To plan for the use of trees in agro-forestry systems, considerable knowledge of their properties is necessary. Desirable information includes the uses: the climatic adaptations of the species, including adaptations to various soils and stresses; the size and form of the canopy as well as the root system; and the suitability for various agro-forestry practices. The selection of crops also requires knowledge of uses, adaptation, and market opportunities (Martin and Sherman, 1992).

Agro-forestry can provide a more diverse farm economy and stimulate the whole rural economy, leading to more stable farms and communities. Economic risks are reduced when systems produce multiple products. Likewise, this approach prioritises conservation and rehabilitation measures such as watershed rehabilitation and soil conservation.

The drylands of Ethiopia have poor vegetation cover and have a high evapo-transpiration rate that exceeds precipitation. The identification of suitable plant species that can thrive and produce yields and contribute to farming practices add to resilience. One such plant species is the cactus pear which has many possible uses and benefits, from fresh fruits and stem segments, to vegetables or livestock feed over, to pigments and sugar, or ethanol extraction. One likely option for cultivation would be the introduction of cactus pear into farmlands as hedges or intercrops with an additional advantage in mitigating the impacts of climate change. Mekelle research centre conducted an observation on an orchard of 11 cactus pear cultivars intercropped with beans. Significant biomass of cactus pear cladodes (914.63 kg) and edible fruits (268.3 kg) was produced in addition to a significantly higher bean yield (1333.3 kg) per hectare in over eight months. Because cacti are perennial plants, they will continue to grow and will yield more fruits and biomass in the following years. Bean plots with no cactus intercrops gave significantly lower yields (700 kg/ha). Intercrops had the additional benefits of trapping moisture in the trenches and this should have contributed to better use of the poor rains of the 2008 rainy season (375mm) in the area. Cactus does have the potential for hedge-row intercropping and the combination helps increase biomass produced per hectare with the added benefits of increasing the vegetation cover. The latter is relevant to drylands where the land is bare for more than 7 months before the next crop is planted. Cactus-based agro-forestry practice can therefore be considered as an adaptation option to climate change in the drylands (Belay, 2009).

2.12 Evergreen agriculture:

Evergreen agriculture, a strategy that combines the best of conservation agriculture and agroforestry is seen as a viable option in reversing the declining trend in agro-ecosystem productivity in the drylands while contributing to increasing nature conservation and resilience to climate change. Defined as a form of conservation farming that integrates trees with

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annual food crops (Garrity et al., 2010), evergreen agriculture is a technology which ensures that there is green cover on the land throughout the year therefore enhancing essential ecosystem services. Because it integrates trees and agriculture, evergreen agriculture is essentially a form of agro forestry with the potential to deliver several benefits associated with the incorporation of trees in the farming systems. These include maintaining vegetative soil cover, nutrient supply through biological nitrogen fixation and nutrient cycling, suppression of insect pests and weeds, enhancing soil structure and water infiltration and provision of food, fuel and fiber. Other benefits include the supply of medicinal herbs for both humans and livestock, supply of fodder and shade, carbon sequestration and conservation of above and below ground biodiversity. To a significant extent dryland communities rely on tree products as one of their major sources of income. This technology is spearheaded by World Agro forestry Centre together with tertiary institutions such as Mekelle university in Ethiopia, University of Nairobi, Makerere university, and Juba.Successful projects have been in Shinyanga (Pye-Smith, 2010) area in Tanzania, West-pokot in Kenya(Garrity et al.,2010).

2.13 Community-based Agricultural Extension Agents:

Agricultural extension' describes the services that provide rural people with the access to knowledge and information they need to increase productivity and sustainability of their production systems and improve their quality of life and livelihoods. Recent developments in agricultural policies have re-emphasised the importance of extension service. However, models of extension based on government services or private agro-dealers and service providers are not sufficient to meet the needs of farmers in less favoured areas. This is due to a number of factors including the necessity to respond to the specific technological needs of farmers in different agro ecological zones, high transaction costs of reaching remote areas; the need for localised crop and livestock management solutions suited to tough environmental conditions, which are often not well understood by extension agents trained for work in high potential areas; and the challenges of finding professional extension specialists willing to live and work in remote, and sometimes insecure areas. The community-based rural agricultural extension model is based on the idea of providing specialised and intensive technical training to one or two people in a community who then promote a variety of appropriate technologies and provide technical services with occasional support and review from a supporting organisation. This model is demand-based in that the providers of service are contracted directly by farmers' groups or communities to deliver information and related services that are specified by farmers (Rivera, 2001). These models have generally experienced a high degree of success in terms of discovering or identifying productivity enhancing technologies, which are then widely adopted.

Rural agricultural extension programmes can help reduce the costs of providing extension services that emanate from the scale and complexity of centralised systems (Feder et al, 2010). Rural extentionists themselves benefit from the accumulation of new knowledge and technical skills and, through this, are able to generate additional income by charging for their services. The strengthening of social and professional networks via this model provides vital access to information and, by working directly with local producers and passing on acquired knowledge. Rural extentionists are building the technical capacity of their communities. They learn, for example, to detect illnesses amongst livestock and implement preventive measures, thereby reducing the need for costly veterinary services. Other benefits include improved self-confidence and innovation on the part of rural extentionists.

Challenges Barriers to implementation include a lack of appreciation for local knowledge. This can be overcome with concerted action to validate and disseminate information on indigenous practices and develop appropriate technologies that combine this know-how with modern strategies. A lack of access to credit by extentionists to buy basic equipment required for technical service provision can also act as a barrier to successful implementation.

In the Turkana region of northern Kenya, animal health is critical to the livelihoods of pastoralist communities. However, formal veterinary services often do not reach the remote areas where many pastoralists live. Community-based Animal Health Workers have been recognised as having a role in bridging this gap for more than a decade under national policy in Kenya, but in reality there has been little penetration of community based health workers into mainstream veterinary practices. The Kenya Agricultural Livestock Research organization has been working closely with Turkana County, agricultural department to train more CBAHWs and to provide monitoring and a referral service for complex cases. The department of veterinary sciences from the University of Nairobi trains veterinary personnel that aid in implementation of the community based animal health workers. Veterinary Practical Action Eastern Africa has also been instrumental in making links between the CBAHWs and private sector drug and vaccine suppliers (Coopers K Brand and Norbrook),

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ensuring product use training and a reliable supply chain for critical medicines. CBAHWs are now seen to provide a surveillance role on behalf of the District Veterinary Office as primary disease monitors. They are also seen to be responding to calls for assistance faster and this has helped to save farmers livestock from succumbing to various illness.

2.14 Farmer field school, FFSs:

The Farmer Field School is a group-based learning process that has been used by a number of ntional agricultural research organizations of various governments, NGOs and international agencies originally to promote good agricultural practices (Onyango et al., 2000). They were developed in response to perception that small farmers were not managing agrochemical-based agriculture well, particularly pest management through the use of pesticides.

Many farmers did not have the resources to use pesticides, and sometimes wrong uses and storage caused the problems of poisoning. Furthermore many pests seemed to rapidly develop resistance to the pesticides. FFSs bring together concepts and methods from agro ecology, experimental education and community development, as a group-based learning process. The knowledge gained from these activities enables participants to make their own locally-specific decisions about crop management practices. Although FFSs were initiated as a training process for pest control in field crops, the principles have now been adapted to all agricultural production systems from livestock to coffee production.

Farmer field schools represent an effective mechanism for group training that can reach thousands of small-scale farmers with knowledge and technical content that each can adapt to their own unique circumstances. Beyond this, as has been indicated, these processes empower farmers, both individually and collectively, to more effectively participate in the processes of agricultural development.

Challenges:

Farmer field schools require substantial changes to the capacity of agricultural extension services, both in terms of the policies of agricultural development and the abilities of those who execute it. Re-training of agricultural extension services both represents an investment, but also resistance at all levels can be a significant impediment.

Farmer field schools (FFS) for sweet potato production and post-harvest management were established by the DFID crop protection programme in conjunction with the national research institutions in 22 communities across Kenya, Uganda and Tanzania with over 500 farmers. The first step was to develop training guide and train the trainers, the course was improved through feedback from the participants. Technically the trainers course cover areas of: sweet potato variety development, agronomy, disease and pest management, experimental design and data collection, facilitation and communication skills, planning and farming as a business, postharvest processing and sweet potato product development. Trainers or facilitators included both extension agents but also farmer facilitators.

2.15 Kitchen gardens:

The home garden includes agricultural plot which contains an ecologically balanced mixture of crops. The food crops provide a steady supply of various types of edible products, and combine well – biologically and environmentally with other components of the system. The gardens use dung from the animals as source of fertilizer (Rockstrom et al., 2002). Food production is, therefore, the primary function and role of most home gardens, and a large proportion of the production from home gardens is consumed by the gardeners themselves (Ngigi et al., 2003 Home gardens ensure almost continuous production throughout the year. The combination of crops with different production cycles and rhythms is such that an uninterrupted supply of food products is maintained, for example, Kales, tomatoes and onions as well as maize. Home gardens are also a source of medicinal plants and firewood. Gardens in these dryland areas can contribute greatly to the nutritional and economic well-being of households by reducing the level and duration of seasonal food shortages and introducing an increased variety of nutrient-rich foods into the household diet.

This technology is mostly practiced by farmers in Laikipia County, Kenya. It's a technology also demonstrated in the Mpala research centre. A major challenge is the mobility of communities who frequently move from one area to another in search of pasture and water.

2.16 Hydroponic fodder:

Hydroponic farming entails growing crops using mineral nutrient solutions in water, thus reducing the need for soil. This modern and innovative farming technology is resilient to climate change, provides superior nutritional value and faster growth at limited cost of input (ILRI, 2003). Farmers are able to cut costs by 25% once they start making their own good quality feeds. This technology is mainly supported by various organizations that are spearheading its adoption. Key among them are ILRI as well as KALRO. Major challenge is the costs involved in buying the hydroponic structures. The technology is used across Laikipia as well as Mwingi and Kitui Kenya semi-arid areas.

2.17 Mango harvesting tools:

Better harvesting techniques and post-harvest handling processes introduced by the Livestock and Irrigation Value Chains for Ethiopian Smallholders (LIVES) project supported by ILRI-Ethiopia have improved smallholder mango production in the Gamo Gofa zone of southern Ethiopia. Mango is the second most important fruit crop in the country after banana. The Gamo Gofa zone in southern region is an important mango producing region in Ethiopia and a key supplier of the fruit to the national market. Mango farming is expanding rapidly in the region. Traditionally, many farmers have relied on shaking mango trees, thrashing the branches and using scissors or hooks to cut the fruits as the main mango harvesting techniques. But these methods damage or bruise both the mature and immature mango fruits. LIVES introduced mango harvesting tool to more than 50 smallholder producers in the zone. It is a metallic fruit picker with nylon box attached to a long wooden pole that enables to reach the fruits.

While the metallic fruit picker could be designed and produced by village workshops, the wooden poles are prepared by the smallholder mango producers themselves. Smallholder farmers' education on the importance of harvesting only mature and healthy mangoes based on fruit maturity indices, such as shape and colour, is helping farmers get higher quality fruits that fetch better market prices. As part of this initiative, the project has also trained, and is working with, extension workers and zonal and district agricultural officers in sensitizing the community to adopt better production techniques such as using improved mango varieties and optimum spacing of mango trees for optimal growth and easier harvesting.

2.18 Ethiorirab bee hive:

But with a shift from traditional to improved hives, the likelihood of farmers facing acute shortage of beeswax is high and there is a need to identify sustainable ways of providing beeswax that also attracts bees and minimizes absconding. One way of achieving this is through the introduction and popularization of the 'Ethio ribrab' hive, which is a variant of the Kenyan top bar hive. The introduction of this type of hive is not meant to replace improved frame beehives but to complement them by providing beeswax made from local honeybee flora. Honey harvested from this type of hive is of better quantity and quality compared to honey from a traditional hive. The popularization of Ethio ribrab hives has also the added advantages of being made by smallholder farmers using local materials and is easy to work with and inspect the colonies. Considering the multifaceted advantages of Ethio ribrab hives, the Livestock and Irrigation Value Chains for Ethiopian Smallholders (LIVES) project in Tigray has demonstrated these hives to beekeepers, who after having received trainings, transferred colonies from traditional hives. Field observations suggest that farmers who used Ethio ribrab hives have harvested 15 to 20 kg/hive of honey and 1 to 2 kg beeswax, and this is by far more than what is possible using traditional hives.

2.19 BIOGAS:

The project has introduced a new biogas package which includes biogas electric generators, biogas pumps/compressors, desulfurizers, dehydrators, biogas storage bags and above-ground plastic digesters. The generator converts biogas to electricity enabling use of modern electric-powered innovations to alleviate the challenges of livestock production, marketing and human development in the rural communities of Ethiopia. Livestock development technologies that could be powered by the biogas generated electricity include small-scale milk machines, small scale milk coolers and, incubators and mobile phone-based advisory services. Rural communities could also access more information through television and other communication technologies powered by electricity from biogas. The biogas package is suitable for households (individual, medium-scale dairies in semi-arid areas as well as in peri-urban and urban areas) and communities (dairy cooperatives and groups in small-scale rural dairy farms). The technologies are supported by International Livestock Research institute of Ethiopia through LIVES project.

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2.20 Microdams/waterpans:

The need to conserve water resources through technologies that can easily be managed by the rural community has resulted in the use of small earth dams constructed by the local communities themselves, as sources of water supply for the development of irrigated agriculture. Water pans are water storage micro dams which are dug by communities especially in Eastern Kenya semi-arid lands that are used to conserve water resources that are managed by communities. A number of micro dams have been constructed in Ethiopia, Sudan and Uganda to be used for irrigation and water supply (domestic and cattle) purposes. The National Agricultural Research Organization of Ugandan government has increased water availability to the population with vast investments in under the Water for Production programme. A total of 425 micro-dams have been constructed in semi arid areas of Nakasongola, Mbarara, Kotido and Moroto districts (El-Sayed et al.,2007). Rural communities in Kitui Kenya come together and dig the water pans for each family and these are used to collect the runoff water during the rainy season. Water pans are able to store water for more than six months and this ensures continued supply of water across the region for irrigated agriculture. KALRO in conjunction with the community groups are encouraging the communities to have water pans to collect all the run-off water.

However, the development of small dams for irrigation is being threatened by sedimentation problems arising from the degradation of catchment areas caused by poor agricultural production, rapid population growth, poverty and wood energy demands, in appropriate runoff estimation methods resulting in over sizing or under-sizing of dams, and unreliable spillway flood estimation methods.

2.21 Improved dryland crop varieties:

The International Crop Research Institute for Semi-Arid Tropics, ICRISAT, released a number of crop varieties that would enhance farmer's yields by between 250 and 400 per cent and cut maturity time by more than half. Two pigeon pea varieties suitable for use in Kenya's arid and semi-arid regions, constituting about 89 per cent of Kenya's land mass, and developed in conjunction with the Kenya Agricultural Livestock Research Organization, KALRO, are both draught resistant and early maturing. ICRISAT's unveiled two early maturing varieties of pigeon peas, which have increased farmers' yields

- **KARI Mbaazi number 1** matures in only three months compared to the traditional variety that takes 10 months. This variety gives farmers yields of 1500 kg per hectare compared to 400 kg per hectare for the traditional variety.

- **KARI Mbaazi number 2** is a medium maturing and takes just six months. This variety gives farmers' yields of up to 200 kg per hectare.

The varieties developed by ICRISAT also meet the taste and look that pigeon pea consumers are very sensitive to over and above the varieties' abilities to withstand the harsh conditions in the semi-arid areas. These improved varieties are already being used by farmers in Makueni County, Kenya.

The national agricultural research systems (NARS) of Ethiopia have also developed important crop varieties adapted to drylands of Ethiopia. In order to address these problems drought resistant, early maturing and heat tolerant crop species and varieties have been developed by the research systems in Ethiopia. These crop technologies include cereals which are the major food crops, also grain legumes, oil crops and fiber crops. Cereals: The major cereal crops in the dryland areas are sorghum, maize, tef and millet.

These are the major food crops for human's diet and also provide feed for animals, The improved varieties developed by the NARS in Ethiopia in collaboration with CGIAR centres such as CIMMYT, ICRISAT, ICARDA.

According to the Ethiopian Institute of Agricultural Research, the major sorghum varieties innovated and recommended for dryland low rainfall areas of Ethiopia include:

- **Gambela-1107** which Yield potential ranges from 2.5–3 t/ha. and is relatively resistant to most pest and diseases of sorghum. Well adapted in semi-arid areas and is grown in areas such as areas Gambella, Yabello, Jijga Kobo, Shewa robit.

- **76-T1-23 I** which is an early maturing variety of between 60–70days suitable for dry semi-arid areas. It grown in North Wello in Kobbo Alamata area, Cheffa area, north Shewa and Meiso area.

- **Melko-1** is an early maturing, drought and heat resistant variety suitable for dry semi-arid areas with short growing season. Its grown in north Shewa and Kobbo

- **Gubiye and Abshir** are also an early maturing variety, drought and heat resistant. It's highly resistant to parasitic weeds such as striga. Mainly grown in north Shewa, Kobbo and Meiso areas and well adopted by farmers and other dry-semi-arid areas.

- **Macia** is a variety with a high yield potential of about 3 t/ha. It a good quality plant crop residue for livestock because of its juicy broad leaves. It is widely adapted in semi-arid areas.

- **Seredo** is a bird resistant, drought tolerant, with high tannin content variety. Well adapted in the dry semiarid areas.

- **Teshale** is an early maturing plant of between 100–120 days. It has a high yield potential of about 3.0–4.5 t/ha, these variety has a high biomass production making it suitable for livestock feed of North Wello and north Shewa.

- **WSU-387-Melkam**Is an early maturing plant with 118 days to maturity. Has a potential yield of 3.7–5.8t/ha and high biomass production hence used for livestock feed? Planted in North Wello and north Shewa.

- **AreaYeju** is an early maturing plant with 120 days to maturity. Has a potential yield of 5.0 t/ha, and is mainly grown in semi-arid areas.

- **Misiskir** is an early maturing plant with 126 days to maturity. Has yield potential 4.1 t/ha. Grown in Wello, SIrinka area, most suitable for dry semi-arid areas.

- **Girana**-1 is an early maturing plant with 122 days to maturity, Has a potential yield of 4.1 t/ha. and suitable for dry semi-arid areas.

- **Gedo** is an early maturing plant with 134 days to maturity. Has a potential yield of 4.1 t/ha. It's grown in wello and SIrinka area. It is suitable for dry semi-arid areas.

- Others include Abshir, Gobie,Birhan, Harma.

These innovations are early maturing and well adapted to the dryland areas of Ethiopia. They have a high yielding capacity disease and pest resistance. Lack of improved seed and limited availability of other inputs such as fertilizer limit the benefit of farmers from the technology leading to food insecurity (Georgis et al., 2010),

The maize varieties improved by Ethiopia Institute of Agricultural Research in conjunction with other research organizations and recommended for dryland low rainfall areas of Ethiopia include:

- **Melkassa-1** which has a maturity of 85 days with potential yield of 2.5–3.5 t/ha. It's well adapted to low rainfall, semi-arid areas of Ethiopia with rainfall ranging 450–570 mm.

- **Melkassa- 2** This variety is an early maturing plant about 130 days; with potential yield of 4–4.5 t/ha; It's highly resistant to rust and blight, mainly grown in kobo and Meiso.

- **Melkassa-3** Is an early maturing plant with 125 days to maturity; has potential yield of 4.0–5.0 t/ha; and it is highly resistant to rusts and blight. Suitable for Kobo, Yabelo, Sirinka and Mieiso areas.

- **Melkassa-4**Is an early maturity within 105 days and resistant to rust. It has a yield potential of 3–3.5in farmers' fields; was developed for drought stressed midaltitude areas of Ethiopia, Melkassa, Mieiso, Ziway and Wolenchiti.

- **Melkassa-5** Matures within 125 days, planted in drought stressed mid-altitude areas of Ethiopia, Melkassa, Mieiso, Ziway, Wolenchiti and Shewa.

- **Melkassa-6Q**Is an early maturing about 120 days with yield potential of 3–4 t/ha. It is suitable for low rainfall areas (500–800 mm) which include Melkassa, Mieiso, Ziway, Wolenchiti and Shewa Robit.

- **Melkassa-7**Is an early maturing about 120 days, with a yield potential of about 3–4 t/ha; recommended for low rainfall areas (500–800 mm) which include; Melkassa, Mieiso, Ziway, Wolenchiti and Shewa and Robit.

Tef varieties were also developed in Ethiopia. Tef is an important crop for drought prone areas where climate variability and change is a major threat. The varieties developed by the research institutions include:

- **Sidama DZ-Cr-385** has a Grain yield potential of 1.2–1.8 t/ha. It provides high biomass for animal feed and other purposes and suitable for areas with 300–600mm of rainfall suitable dryland semiarid areas.

- **DZ-Cr387 Ril 127 (Gemechis)** has a yield potential of 1.2–1.4 t/ha in farmers yield. It is adapted in almost all semi-arid areas.

- **DZ-Cr-37 (Tsedey)** Grain yield potential is 1.4–2.2 t/ha suitable for areas receiving 300 to 700 mm of rainfall. It is adapted in almost all semi-arid areas.

- **DZ-01-96 (magna)** Grain yield potential is 1.4–2.8 t/ha with a straw yield of 8.2–9.0, suitable for areas with rainfall of 300–700 mm, high quality tef.

- **HO-Cr-136 (Amarech)** has a yield potential of 1.2–1.4 t/ha in farmers yield. It is adapted in almost all semi-arid areas receiving rainfall of between 300–800 mm.

- **DZ-01-1681 (key tena)** Grain yield potential is 1.6–2.5 t/ha with a straw yield of 8.4–9.3, seed with areas rainfall of 300–500 mm.

- **DZ-01-354 (Enatit)** Grain yield potential is 1.7–2.8 t/ha with a straw yield of 8.5–13.0, suitable for areas receiving low rainfall of 300–700 mm.

- **DZ-01-99** has a Grain yield potential of 1.7–2.2 t/ha. with a straw yield of 8.5–13.0, found in areas receiving low rainfall of 300–700 mm.

- **DZ-Cr-44** Grain yield potential is 1.7–2.8 t/ha.

Through selection of crop species and varieties for drought, heat resistance and early maturing several species and varieties of beans have also developed. According to MOAR 2008, the varieties developed include:

- Awash-1 which is grown mainly as an export crop with a yield potential of 1.2–1.5 t/ha in farmers' fields. The variety is adapted semi-arid areas with low elevation and rainfall and short growing period (very maturating 75–90 days) particularly Nazret and Awassa.

- Awash Melka Days to maturity 95–100, it is an early maturing grain yield ranges that ranges from 2.2–3.2 t/ha. It is suitable for all semi-arid areas of the country.

- Argene: The days to maturity are 85–90 with grain yield that ranges from 2.0–2.2 t/ha.

- TA01JI: Is an early maturing plant with 85–90 days to maturity. The grain yield ranges from 2.2–2.5 t/ha.

- Chore has 87–109 days to maturity with grain yield that ranges from 2.0–2.3 t/ha, Suitable for all the dryand wet semi-arid areas.

- Other bean varieties developed include the Nasir, Dimtu, Goberasha, Ayenew,Gofta, Tabor, Wedo, Melka-Dima and Ibado.

Cowpeas varieties have also been developed for the dry areas(Wegary, 2010). With common dryland varieties from the research centre include:

- Black eye bean: This is well adapted to semi-arid areas which receive 300–600 mm of rainfall such as Kobo-Alamata plain, Shewa Robit, semi-arid areas of Tigray, Jijiga areas in theSomali region and Borena areas. It is an early maturing plant of 80 to 85 days to maturity.The yield potential ranges from 1.6–2.0 t/ha.

- TVU: Is a drought resistant, early maturing plant that takes between 80–85 days to maturity. It's a high fodder production plant.

- White wonder trailing Is a high quality grain and fodder, that matures faster with 65–90 days to maturity. It has a grain yield of 1.8–2.0 t/ha. It is most suited to all dryland area lowland areas.

- Assebot: Has 75–80 days to maturity with grain yield of 1.7 t/ha in farmers field.

Due to the shortage of oil crops in the drylands of Ethiopia, NARS has developed improved varieties of Sesame (*Sesamum indicum*) and ground nut (*Arachis hypoaea*). Sesame is mostly grown as a rainfed crop in the Semi-arid regions. It has some commercial value in the Kobbo-Alamata plain and Zobul areas in northern Ethiopia. Sesame is predominantly drought resistant and very intolerant to water logged soils. They are early ranging from 95 to 122 days to maturity which matches the short growing period of the drylands. Varieties developed include:

- **T-85**: It is drought, pest and disease resistant in the drylands, It is early maturing with high market potential. The grain yield is about 0.5t/ha, and it is adapted in areas receiving 500–700 mm of rainfall. Well adapted to the arid and dry semi-arid areas.

- **Kelafo-74**: Is an early maturing and drought resistant plant that yield about 0.3 t/ha in the farmers field, It is well adapted to the arid and dry semi-arid areas particularly the Kelafo area in the Somali region.

- **Mehado-80**: Has a grain yield potential of 0.4–1.0 t/ha and 1.5–2.2 t/ha under rain-fed and irrigated farming respectively.

- **Abasena:** Yield under rainfed is 0.6–1.2 t/ha and under irrigation 1.2–1.9 t/ha; oil content43–47%. It is well adapted to dry lands with 90-115 days to maturity.

- **Argene**: The yield potential under irrigation is 1.5–1.8 t/ha; and has oil content of about 43–46% . It is suitable for all dryland areas.

- Serkamo: Has yield potential of about 1.5–1.8 t/ha under irrigation with oil content of 43–46%.

The varieties of ground nuts improved include:

- Nc-4X, NC-343, Roba, Sedi, Manipeter. They have 130 to 165 days to maturity; most of them are drought, heat and disease resistant. They are mostly adapted to the Haraghie area including Bable, Besidimo dry semi-arid areas.

2.22 Tied ridges in-situ soil and water harvesting:

Tied ridges as water harvesting technique has proven to be very effective for soil and water conservation in Ethiopia and many other African countries. The technique has been extensively tested and evaluated with smallholder farmers in Kenya, Ethiopia, Eritrea, Zimbabwe, Uganda, Tanzania, Burkina Faso, Nigeria and other areas in Africa (Georgis, 2003). The experimental evidence of the effectiveness of tied ridges for soil and water conservation and its impact in yield increase and water use efficiency is well demonstrated..Tied ridging is a type of surface configuration whereby the ridges are “tied” to each other at regular intervals by cross-dams, blocking the furrow and can be used when surface run-off is to be prevented. The basic concept is a shovel dragged over the bottom of the furrow, collecting soil formed by lifting the shovel. Simpler units (also suitable for animal traction) operate a shovel attached to a frame which jumps at regular intervals as a result of the action of a triangle or off-center support wheel. Tested by farmers under local farming conditions, the technology was developed by CIMMYT/ECAMAW and ILRI and disseminated through methods including field demonstrations and days, print extension material such as leaflets and brochures the media and annual review meetings to share experiences among researchers and other stakeholders. The technology is currently being used in Ethiopia, Kenya, and Tanzania (Georgis, 2003).

3. ALTERNATIVE LIVELIHOODS

3.1 Honey production:

With growing commercialization and integration of communities living in the drylands, into money economy, Bee keeping is an important economic activity in pastoral areas (Wilson 2006).The contributions of beekeeping in poverty reduction, sustainable development and conservation of natural resources have been well recognized and emphasized. As the drylands are endowed with varied ecological zones and different flora, they have huge potential for beekeeping

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(Gibbon, 2001). Ethiopia's wide climatic and edaphic variability for example, have endowed it with diverse and unique flowering plants, thus making it highly suitable for sustaining a large number of bee colonies and the long established practice of beekeeping. The knowledge and skill of honey production and honey and beeswax extraction of farmers is still very traditional especially (MoARD, 2006). Kerealem (2005) showed that adoption rate of improved box hives is low in Ethiopia. The large honey producers are using traditional hives (MoARD, 2003).

Kenya Agricultural Livestock Research Organization (KALRO) has identified possibilities for commercial honey production and potential actors. The organization is also involved in finding markets for honey produced by the pastoral communities in Kenya. Most of the rural beekeepers cannot afford to invest in inputs, process, pack, and transport their products to market to maximize profit. Moreover, lack of proper marketing channels, lack of trained development agents, poor market infrastructure are generally the major factors hampering the apiculture development in the region. Lack of appropriate production technologies, weak market and absence of value chain development largely resulted in much lower contribution of the honey sub-sector, much lower than its potential (Wilson, 2006 and Tallonitire, 2006).

The traditional beehives are not comfortable for sanitation and high level of production. The introduction of new movable frame hive technology to increase quantity and quality of honey production in Ethiopia by the Ethiopian agricultural research organizations has not been fruitful. To increase the yield and improve the quality of honeybee resources in the region, the Ethiopian research organizations introduced modern (Kenya top-bar) beehives and accessories (Yirga et al. 2010). However, because this equipment is relatively expensive to buy, most smallholders could not increase their income as had been expected. Modern bee-keeping is relatively expensive that requires a good financial base, which most farmers often lack.

3.2 Ethioribrab' hive:

With a shift from traditional to improved hives, the likelihood of farmers facing acute shortage of beeswax is high and there is a need for sustainable ways of providing beeswax that also attracts bees and minimizes absconding (Ande et al. 2008). One way of achieving this is through the introduction and popularization of the 'Ethioribrab' hive, which is a variant of the Kenyan top bar hive. The introduction of this type of hive complements improved frame beehives by providing beeswax made from local honeybee flora (Getachew et al. 2014). Honey harvested from this type of hive is of better quantity and quality compared to honey from a traditional hive. The popularization of Ethioribrab hives has also the added advantages of being made by smallholder farmers using local materials and is easy to work with and inspect the colonies. Considering the multifaceted advantages of Ethioribrab hives, the Livestock and Irrigation Value Chains for Ethiopian Smallholders (LIVES) project in Tigray has demonstrated these hives to beekeepers, who after having received trainings, transferred colonies from traditional hives. Field observations suggest that farmers who used Ethioribrab hives have harvested 15 to 20 kg/hive of honey and 1 to 2 kg beeswax, and this is by far more than what is possible using traditional hives.

3.3 BIOGAS:

This technology has introduced a new biogas package which includes biogas electric generators, biogas pumps/compressors, desulfurizers, dehydrators, biogas storage bags and above-ground plastic digesters. The generator converts biogas to electricity enabling use of modern electric-powered innovations to alleviate the challenges of livestock production, marketing and human development in the rural communities of Ethiopia (Wolde-Georgis, 2010). Livestock development technologies that could be powered by the biogas generated electricity include small-scale milk machines, small scale milk coolers and, incubators and mobile phone-based advisory services. Rural communities could also access more information through television and other communication technologies powered by electricity from biogas. The biogas package is suitable for households (individual, medium-scale dairies in semi-arid areas as well as in peri-urban and urban areas) and communities (dairy cooperatives and groups in small-scale rural dairy farms). This technology supported by International Livestock Research Institute of Ethiopia through LIVES project.

3.4 Gum Arabic:

Trade in gum arabic has remained informal due to inadequate marketing arrangements attributed to limited participation of gum arabic collectors in the development of the sector (Lelol 2010).Kenya Forestry Research Institute (KEFRI, is promoting sustainable management of A. senegal trees for gum production as alternative livelihood to the pastoral communities through training of farmers on proper methods of establishment and management of gum trees as well as improved tapping techniques, sorting and storage of gum. They are aimed at promoting sustainable management of gum producing trees for improved yield and quality of gum arabic. KEFRI is involved in the training of local farmers on gum arabic production and marketing with the ultimate aim of providing an alternative livelihood source for the local communities (Wekesa et al 2006). This is achieved by imparting proven technologies and skills to extension staff and gum producers on the sound production of gum arabic. Farmers are also trained on improved gum harvesting techniques and value addition in order to increase returns for the collectors of gum. The training is organised at two levels: Training of trainers (TOTs) and training of local communities.

3.5 Poultry farming:

Pastoral communities have been organized into groups especially women by KALRO to keep poultry as an alternative source of income. Groups have been trained on proper housing and feeding of birds to increase their income. Improved indigenous cockerels were provided by KALRO which yield more eggs (Ndathi 2003). All poultry keeping groups have constructed improved chicken houses which have reduced predation by hawks, snakes and the honey badger; afford better control of water and feed resources and thus lessen disease, give better protection from strong wind, cold and rain and thus increase survival rates and improve general management. This has resulted in increased income generation and communities are no longer affected by the effects of droughts. High rates of disease and related mortality, poor housing and feeding, poor breeds, lack of markets and lack of training and education are constraints to effective poultry production. Groups have been trained in appropriate housing, feeding with locally available materials, brooding and hatching management and egg storage.

3.6 Green charcoal making:

Green charcoal is made using *Prosopisjuliflora* (Mathenge plant). To make the briquettes they crash the mathenge (*Prosopisjuliflora)* chips into powder, carbonise it and bind them with Arabica gum and using a moulding machine they mould them into different shapes depending on the kind of moulding machine used. Charcoal is ‘green’ because it is carbonised and smokeless so it does not release carbon monoxide to the environment. It burns for four hours unlike the other charcoal. This results in more money saved because of the less charcoal used, its environmental friendly because it is 100% smokeless hence reducing pollution. Prosopisjuliflora is an invasive species that has cause a lot of challenges to the people of arid and semi-arid areas in Kenya especially areas such as Garissa and Margat (Ali et al. 2012). It has also been a challenge to the animals because it has affected the production of forage in areas where it grows (Swallow, 2005). Its use for making charcoal briquettes is there an advantage to the communities in these areas. Green charcoal briquettes which are made from carbonised agricultural waste can be used as drop-in replacements for traditional charcoal, requiring no new stove technologies or changes in cooking methods, which significantly decreases key obstacles that plague new cooking stoves and alternative fuel technologies (Kituyi, 2004).

3.7 Tanning:

Communities in drylands have practiced tanning of leather for a very long period of time which was used in beadwork products. However, products that were made from skin that was not fully tanned were not durable and would be damaged when wet. KALRO has been involved in the training of women on leather tanning and also setting up of a rural tannery. Communities of Marsabit in Kenya have been able to produce beadworks such as bangles, necklaces and rings that are of good quality and are durable to fetch better prices on the market.

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