CLIMATE RELATED RISK AND OPPPORTUNITIES FOR AGRICULTURAL ADAPTION AND MITIGATION IN SEMI-ARID EASTERN KENYA

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Abstract

This report contains information on a field assessment of risks associated with climate variability in eastern Kenya, and the mitigation options. It also includes the compilations of climate related agricultural risks gathered from a *Kamba* radio dialogue with local communities of Eastern Kenya, aired from January to April 2012.

It highlights the significant potential in the region for mitigating climate change through improved management of agricultural land and crop and livestock husbandry practices, as well as on tapping into the wide range of traditional knowledge of the local communities. This will lead to better livelihoods of communities in the semiarid areas.

Key words

Eastern Kenya, climate change, crops, livestock, pests, diseases, agricultural land

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Acronyms

ALRMP	Arid Lands Resource Management Project
ASAL	Arid and Semi-Arid Lands
CIMMYT	International Maize and Wheat Improvement Centre
CSTI	Centre for Science and Technology Innovations
FAO	Food and Agriculture Organization of United Nations
FIPS	Farm Input Promotions Africa
GoK	Government of Kenya
HCDA	Horticultural Crops Development Authority
ICRAF	World Agroforestry Centre
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IGAD	Intergovernmental Authority on Development
IIRR	International Institute of Rural Reconstruction
INSEDA	Integrated Sustainable Energy and Ecological Development Association
IPCC	Intergovernmental Panel on Climate Change
KARI	Kenya Agricultural Research Institute
KENDAT	Kenya Network for Draught Animal Technology
MDNK	Ministry of State for Development of Northern Kenya and Other Arid Lands
MoA	Ministry of Agriculture
NEMA	National Environmental Management Authority
PMG	Producer Marketing Groups
SEI	Stockholm Environment Institute
SWCB	Soil and Water Conservation Branch

1. Seasonal Weather Changes

The recurrence and intensity of droughts has increased in eastern Kenya. It now experiences drought almost on an annual basis. About 2 million people are permanently on famine relief, with the number rising up to 5 million during severe droughts. Acute malnutrition rates are experienced by over 15% in children below five years of age. Mean total annual rainfall ranges from 500mm in the lowlands to over 1,000mm in the hilltops (Rao et al., 2011). The area is predominantly semi-arid having length of growing period (LGP) in the range 75–180 days. Up to the 1970s, both the long and short rains seasons were reliable, and the dominant Kamba community used to plant and harvest twice a year. However, from the 1980s onwards, the rainfall has been unreliable, leaving the community with one dependable annual harvest. The southward and northward movement of the inter-tropical convergence zone produces two rainy seasons a year. The first rainfall season is in March/April/May also referred to as 'long rains' (LR) and the second rainfall season occurs in October/November/December, referred to as 'short rains' (SR). The rainy seasons can be extremely wet and often late or sudden, bringing floods and inundation (Anyah and Semazzi, 2007). A general increase in the intensity of high-rainfall events, associated in part with the increase in atmospheric water vapor, is expected in semi-arid eastern Kenya (Christensen et al., 2007). The increase in the number of extremely wet seasons is increasing to roughly 20%, i.e. 1 in 5 of the seasons is extremely wet, as compared to 1 in 20 in the control period in the late 20th century (Christensen et al., 2007). This shows an overall shift in the rainfall distribution, with floods becoming more likely than the opposite extreme (KNMI, 2006).

Temperature and evaporation rates are generally high with February and September being the hottest months of the year. Minimum mean annual temperatures vary from 14oC to 22oC while maximum mean annual temperatures vary from 26oC to 34oC. Highly weathered soils (Ferralsols, Acrisols and Luvisols) dominate the area. In general, the soils are very old, low in organic matter and low in fertility. Average farm size is 2 hectares and the farmers practice mixed farming. In recent decades, however, investment and growth in rain fed agriculture in semi-arid eastern Kenya has stagnated. The outcomes of lack of investment and stagnation of agricultural production reinforce each other leading to poverty traps and vulnerability of livelihoods to climatic shocks (Reardon and Vosti, 1995; Collier and Gunning, 1999). Despite the farm size, there are very few years during which the whole farm is planted. On average, 18% of the farm is left fallow during the SR season and 34% during the LR season, reflecting the general perception that rainfall is more variable and unreliable during the LR season than during the SR season, and that the duration of the LR season is shorter. The area recently experienced four successive rain failures - the long and short rains of 2010 and 2011, resulting in 50-60% and 80-90% crop failure in the less dry and drier zones respectively.

2. Crop Failure in Eastern Kenya

The major cereals grown are maize, finger millet, and sorghum. The root crops include sweet potatoes and cassava. The legumes grown are beans, cowpeas, pigeon peas, green grams, groundnuts, chickpea and Dolichos lablab. The usage of the hybrid or composite seeds from seed companies is very low majorly due to economic constraints and their unavailability in time for planting. 95% of farmers rely on informal seed systems for seeds and planting material for most crops in Eastern province. Farmers prefer to plant local landraces conserved on their own farms, purchased from the market or exchanged with neighbors to cut down on costs of purchasing seeds, due to economic constraints. For example, they use seed from previous harvests for composites (*Katumani*), and local seed varieties for maize (*Kinyanya*), and sorghum (*Katengu* and *Kaveta*). However, recycled seed has often been exhausted through generations of cultivation. This results in persistently low yields, lack of crop variety diversity and increased proliferation of pests and diseases on farm.

The increasing temperatures and low rainfall coupled with poor soil fertility impact negatively on productivity of the various crops. The crops become more vulnerable to pest attacks and disease causing microorganisms that lead to reduced crop yield, poor quality produce and sometimes contribute to total crop failure. Few farmers use pesticides. However, imbalances in the host-natural enemy population caused by indiscriminate use of pesticides can also upset the natural ecosystem balances. Wrong diagnosis of crop pests or diseases has also resulted in misuse of pesticides, leading to increased costs of production with negative results. Some common crop pests and diseases are maize-stem borer, sorghum- shoot fly, bean stem maggots, black bean aphid, African bollworm, pod-sucking bugs, cassava white fly, cassava mosaic disease, sweet potato weevil, and post-harvest disease pathogens e.g. aflatoxin. Low crop yields in eastern Kenya have also been attributed to lack of adequate knowledge of agronomic practices. Planting dates are hugely variable, and furthermore in 18% (8 out of 45) of the seasons, planting on the dates identified is followed by a 12-day dry spell which kills germinating seeds and necessitates replanting (van de Steeg et al., 2009).

Post-harvest losses

Weather changes contribute significantly to post-harvest losses and food safety during storage. In eastern Kenya, these losses have serious impacts on food security, in that the quantity is reduced or poor quality produce makes it unfit for human consumption. The ways in which farm produce is lost or spoiled include harvesting too early or late, exposure to rain, drought and extreme temperatures, pest and disease damage, and physical damage from inappropriate handling. The rate of deterioration is highly influenced by factors and practices that increase product exposure along the value chain to extreme weather, pests, and physical damage. As a result of the changing weather patterns, grain cereals and pulses require appropriate crop protection skills, postharvest handling and processing to avoid losses. The period required for full drying of ears and grains depends considerably on weather. Poorly dried and broken grain is also more susceptible to insects e.g. flour beetles and weevils and vulnerable to molds and rotting during storage. Excessive rains during harvesting can dampen the crop resulting in formation of fungus (*Aspergillus flavus).* Also, high temperatures and high humidity during drying favors the development of the fungus (*Aspergillus flavus)*. The aflatoxin producing fungi invades all types of grain produce, and has caused over 50% grain loss in eastern Kenya in the past three years. Post-harvest losses in storage vary with crop variety, climatic conditions and storage structures. For example, on farm storage of maize accounts for 80% of all harvested maize in eastern Kenya, but suffer post-harvest storage losses of 20-30% within 6 months of harvest (KARI, 2008). Maize grain pests include weevils, larger grain borer, rats and mice. The most serious grain pathogen is fungus. At least 95% of small-scale farmers use traditional storage facilities such as cribs, baskets and gunny bags that cannot guarantee protection against the larger grain borer, which causes over 30% of the losses.

Effects of length of growing period on crops

The length of growing period (LGP) at any location is an important indicator of the yield potential of that location and determines the suitability of contrasting management practices, maturity length, crop types, and cultivars.

The eastern Kenya season-to-season variability in rainfall amounts and distribution as well as temperature fluctuations are reflected in season-to-season variability in LGP.

The changes in rainfall patterns, in addition to shifts in thermal regimes, influence local seasonal and annual water balances. These in turn affect the distribution of periods during which temperature and moisture conditions permit crop production. Such characteristics are well reflected by the LGP since the area relies on rain fed agriculture (Fischer et al., 2002). Many parts of eastern Kenya are likely to experience a decrease in their LGP.

3. Livestock Losses in Eastern Kenya

The main livestock species kept in eastern Kenya are local breeds of goats, chicken and zebu cattle. Goats are preferred by farmers due to their browsing habits, which leave grass for the cattle. The increasing climate variability and decreasing household land size holdings are major factors affecting livestock production systems in the region. The most direct impact is reduction of the quantity and quality of food and water. The resulting losses in livestock production include higher mortality rates, low or zero calving rates, reduced production of milk and weight loss in animals. The heat stress suffered by animals also reduces the rate of animal feed intake and results in poor growth performance. The animals depend on natural pastures (primarily grasses) and crop residues from cereals and legumes (Njarui et al., 2003). The frequent shortages of feed during the dry seasons imposes severe nutritional stresses to the animals resulting in low productivity (i.e. meat, milk and draught power) and even pre-disposes the animals to a number of diseases that frequently lead to high rates of mortality.

Inappropriate cultivation and overgrazing in some areas like Kitui has led to in diminished or total loss of important grass species such as *Chlorisroxburghiana spp, Eragrostissuperba spp, Cenchrusciliaris spp* and *Enteropogonmacro stachyus* (Omondi et al., 2010). The quantity of crop residues available to livestock fluctuates between seasons due to the erratic rainfall as well as its poor distribution. Over 95% of the fodder is of low nutritive value due to poor management. Increased climate variability has also led to conflicts over the limited pasture and water in the region. In addition, livestock production is affected by large losses in LGP. In their 2009 article, van de Steeg et al. estimate that cattle and goats located in eastern Kenya will be subjected to a decrease of 5 -20% changes in LGP.

4. Degradation of Agricultural Land

The increase in population by 2.5% annually in eastern Kenya will continue increasing pressure on the natural resources, which in turn will influence the magnitude of exposure to climate risks. Land degradation has contributed to reduction in productivity, thereby reducing attainable and potential crop yields. Continuous crop production has also led to soil nutrient depletion. Lack of adequate crop cover at the beginning of the rainy seasons (beginning in March and October) is mostly responsible for water erosion (El-Swaify et al, 1982). Taking into consideration the effects of erosion: the soils are often thin with poor soil structure, low organic matter and bare of vegetation, leaving a large proportion of the soil surface exposed. The water runs off easily, forming gullies and carrying valuable topsoil with it. Increased temperatures have added to water problems by causing additional loss of moisture from the soil. The increasing soil compaction and crust formation reduces infiltration and accelerates soil erosion.

Failure to intensify agricultural production in eastern Kenya has led to cropping in marginal lands that are more susceptible to rainfall variability and water and wind erosion. Increase in rainfall intensity could lead to higher rates of soil erosion, leaching of agricultural pollutants, and runoff that carries livestock waste, soil and associated nutrients into surface water bodies. Furthermore, soil degradation also results in decreased water holding capacities. This in turn leads to increased runoff during wet periods, resulting in higher overland flow rates and reduced groundwater recharge rates (Feddema and Freire, 2001). Water lost through runoff also increases deficits during dry periods, in effect increasing the duration and intensity of drought.

Soil characteristics

The dry lands of eastern Kenya have highly weathered soils (Ferralsols, Acrisols and Luvisols). In general, the soils have low organic matter and are less fertile. At the micro level, projected changes in climate may affect key soil processes such as respiration, net nitrogen mineralization and thus key ecosystem functions such as carbon storage, and nutrient turnover and availability (Rosenzweig and Hillel, 1995). Higher air temperatures will also be felt in the soil, where warmer conditions are likely to increase the natural decomposition of organic matter and the rates of mineralization that affect soil fertility (Rosenzweig and Hillel, 1995). Shifts in rates and spatial distributions of soil erosion and deposition will continue to occur in the region during the rainfall seasons. The cumulative impact of recurring droughts, cultivation of marginal lands and overstocking will lead to continued loss of soil vegetation cover. In eastern Kenya, the combination of declining per capita agricultural capacity and increasing aridity is exacerbating vulnerability and rural poverty (Funk et al., 2008).

5. Soil and Water Management

5.1 Soil and Water Conservation Techniques

There are many different types of soil and water conservation practices, whose suitability depends on various factors such as local climate, soil type, length and slope steepness, and farmers' management practices. Appropriate practices should enhance soil carbon stocks and encourage soil functional stability. Soil and water conservation practices can be divided into agronomic and mechanical measures. Generally, agronomic measures are preferred to mechanical measures because they are cheaper and need less labor. If used, mechanical measures should always supplement agronomic practices (IIRR, 2002).

Mechanical conservation

- Bunds: contour bunds, graded bunds, trench bunds, *fanya juu* terraces,[1] and stone bunds for both water harvesting and soil conservation
- Terraces: bench terraces, hillside terraces
- Water catchments such as half-moon catchments, and micro-catchments such as *Zai* pits[2] and Negarims[3]
- Gully rehabilitation by use of low cost measures i.e. Planting of vegetative materials such as mucuna, sesbania (*Sesbania sesban*) and Napier grass (*Pennisetu purpureum*) on the floor and sides of the gully, laying out check-dams using loose stone and earth-filled gunny bags (Gachene and Mureithi, 2004).

Agronomic measures

Land management practices such as well-managed proper tillage and crop spacing can facilitate management of soil moisture. The objective is to conserve and increase soil moisture by ensuring runoff is minimized and all water infiltrates into the soil.

- ***Conservation tillage***: Under conservation tillage, practices such as contour ploughing, ridging, tied ridging, minimum tillage, ripping and sub-soiling, plough planting are relevant. In Makueni and Machakos counties, ripping, tied ridges using animal drawn

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[1] Terraces are made by digging a trench and throwing the soil uphill to form an embankment
[2] Deep planting pits, compost or manure is placed in them to improve soil fertility
[3] Diamond-shaped basins surrounded by small earth bunds with an infiltration pit in the lowest corner of each

tools such as rippers, ridgers and sub-soilers are promoted by Kenya Agricultural Research Institute (KARI), Kenya Network for Draught Animal Technology (KENDAT), Food and Agriculture Organization of United Nations (FAO), Ministry of Agriculture (MOA), and Agriculture Technology Development Centre. Ridging ensures water infiltration and increase in root depth compared to flat planting. Farm Input Promotions Africa (FIPS-Africa) promotes the use of the locally made "Mole" jembe that can break the hard pan to help rainwater infiltrate and plant roots to penetrate into the sub-soil.

- ***Conservation farming approaches***: These include such practices as crop rotation, use of cover crops (e.g. sweet potatoes, cow peas and green grams), mulching, strip cropping and intercropping system (such as growing legumes with cereals e.g. Sorghum or maize together with beans, pigeon peas, cowpeas and green grams), mixed cropping and fallow system. These are nutrient replenishment strategies that help to restore soil organic matter by providing a protective soil cover and also minimizing soil loss.
- ***Use of grass strips or trash lines***: Planting grass strips such as Napier grass or placing trash lines at intervals across the slope help to slow down water runoff.

Agro-forestry

The use of an integrated approach combining trees and shrubs with crops and/or livestock is an adaptive response to climate change for a number of reasons:

- Woody perennials are able to explore a larger soil volume for water and nutrients, provide better soil cover and reduce surface runoff, all of which reduce the impacts of either drought or extreme rainfall events.
- Woody perennials help to build soil carbon, which in turn can increase water and nutrient use efficiency.
- Trees buffer against weather-related production losses, enhancing smallholder resilience against climate impacts. If a drought destroys the annual crop, trees will still provide fruits, fodder, firewood, timber and other products that often achieve high commercial value (ICRAF, 2009).
- Planting fruit trees that withstand soil moisture stress e.g. citrus, mangoes and pawpaw.

5.2 Water Harvesting

Rainwater harvesting can be done through the construction of water pans and the diversion of roadside runoff, roof catchment and storing in tanks, rock catchment, farm ponds and soil storage. Water harvesting can be categorized into micro and macro catchment systems.

Micro-catchment

In this system, runoff is harvested from short slope catchment within the field. These include:

- V-shaped bands or negarims creating a water basin to hold water for the plants
- Contour bands, contour ridges
- *Fanya juu* terrace (0.6 m deep and 0.6 m wide). In Machakos and Kitui districts, some farmers have modified *fanya juu* to 1.5m deep and 1m wide for maximum harvesting and retention of runoff water from roads or homesteads compounds (Mutunga, 1999)

Macro-catchment

These are characterized by long slopes and external catchment systems to supply water to cultivated areas. They include semi-circular bunds, trapezoidal bunds, runoff harvested into basins and retention ditches.

5.3 Soil Fertility Management

Applying organic matter improves the soil structure, which in turn increases infiltration and the amount of water the soil can hold. It also increases the nutrient level in the soil and the activity of soil organisms. Organic matter can be added in the following ways:

- *Using compost*: This is very effective in improving depleted soils. Compost is prepared by first digging a pit that is 1.3 x 2.4 m wide and 0.3m deep, and filled with layers of organic material, which are left to decompose. The materials are watered regularly and turned twice during the decomposition process. A pit this size can produce one tone of compost. 4-8 tons per acre of compost can be applied depending on soil requirement. When planting maize two handfuls of compost is applied into each hole.

- *Use of green manure legume crops*: The leguminous plants - e.g. sesbania and calliandra - are grown with the primary purpose of incorporating them into the soil to improve soil fertility.
- *Combination of manure and fertilizers*: Use of Di-Ammonium Phosphate (DAP) and compost or farmyard manure when planting maize enriches the soil. Farmyard manure is the decomposed mixture of dung and urine of farm animals along with litter and left over material from roughages or fodder fed to the cattle; well decomposed farmyard manure contains 0.5% Nitrogen, 0.2% phosphorus and 0.5% potassium. If stored in trenches and covered well, the manure becomes ready for use in 4 to 5 months.
- *Planting in fertility pits*: Placing compost in pits (120 cm across and 60 cm holes) then planting crops inside.

6. Seed Systems

Crops differ in their susceptibility to climatic variability and pests hence the choice of appropriate planting material depends on adaptation to agro-ecological conditions. Crops selected for the dry lands should be early maturing to take advantage of the short growing period, and tolerate pests and diseases. Farmers select crops to plant by considering their taste, color, storability, grain size, processing qualities, weight, resistance to pests, and drought tolerance. The marketing of seed is through both formal and informal seed systems. These are discussed in detail below.

6.1 Formal Seed System

Formal seed systems mainly deal with hybrids and specialized horticultural crops. Seed in eastern Kenya is marketed through traders in agriculture inputs known as Agrovets or stockists. Some are agents for seed companies such as:

i. Pannar Seed Company
ii. East African Seed Company
iii. Western Seed Company
iv. Dryland Seed Company

For composite seed varieties e.g. *Katumani,* new seed is not required each year. If proper selection procedures are followed, farmers can use their seeds from their harvests for up to three seasons, after which fresh seeds should be obtained from seed companies. Hybrid seeds are high yielding, but require both manure and inorganic fertilizers, and fresh hybrid seed is required each season.

6.2 Informal Seed System

Majority of farmers rely on the informal seed system for seed and planting material for most crops in Eastern province. Farmers prefer to plant local landraces, conserved on their own farms, purchased from the market or exchanged with neighbors to cut down on costs of purchasing seeds due to economic constraints. Farmers identify and select the types of crops most likely to do well in their areas and save own seed from previous harvest for composites (*Katumani*) and local seed varieties for Maize, (*Kinyanya*, a drought resistant variety), sorghum (*Katengu* and *Kaveta*). However, recycled seed has, most often, been exhausted through generations of cultivation. The result has been persistently low yields, lack of crop variety diversity and persistent pests and diseases on farm.

6.3 Quality Seed Production and Preservation

Composite and local variety seeds can be harvested and saved for subsequent planting. For quality seeds, appropriate crop production systems such as soil fertility management, timely harvest and post-harvest handling, are important. The following measures are important in seed production:

i. Harvested seeds should be thoroughly dried in well-aerated places.
ii. Seed dressing chemical such as *Lindane, Fernazan D*, *Actellic Super* can be used or indigenous preservation technology using a coating of edible oils to prevent development of bruchids in stored bean seeds; use of wood ash in grain stored seed for planting; hot pepper, dried eucalyptus leaves, or smoke from cooking fire to preserve seeds for planting.
iii. Storing un-threshed pods as a strategy to minimize grain damage by bruchids
iv. The store should be clean, disinfected and waterproof.

6.4 Community Seed Systems

In order to make seeds accessible and available to farmers, there is opportunity for farmers to be trained and involved in seed production. A well-functioning seed system is one that uses the appropriate combination of formal, informal, market and non-market channels to efficiently meet farmers' demands for quality seeds. This works well where farmers participate directly in the seed production process (Ayieko and Tshirley, 2006).

Examples of successful seed systems include:

i. DSL a seed company located in Machakos specializes in indigenous crops for low and medium altitude Arid and Semi-Arid Lands (ASAL). The company was founded in 2004. The types of seeds sold include maize, beans, sorghum, cowpeas, pigeon peas, and green grams. DSL partners with the KARI to produce seed varieties suitable for dry land areas.

   Seeds are produced through contracting local farmers or on the DSL leased farms. The seeds are then processed, packaged and distributed through Agro-dealers. The company has a retail store located in Machakos town that sells a variety of farm inputs such as horticultural seeds, fertilizer, pesticides, and other inputs. The seeds sold include maize (*KH500-21A, KDV1, KDV2,* and *KDV),* beans (*Kat B1, Kat B9, and*

Kat x5), cowpea (*K80*, and *M66*), pigeon pea (*Kat 60/8* and *Mbaazi* 1), sorghum (*Kari Mtama1*, *Seredo* and *Gadam*), and green grams (*N26*).

ii. The KARI Seed Unit in Katumani avails quality seeds of dry land crop varieties and planting materials. It assists farmers to produce seed for their own use, and avails improved fruit trees seedlings to farmers (e.g. oranges, mangoes, lemon and pawpaw). Other planting materials are improved cassava and sweet potato varieties.

iii. KARI Kiboko, a sub-center research station of KARI Katumani, plays a pivotal role in breeding of dry land crops and seed multiplication of cereals, legumes and root crops. They also develop sustainable husbandry (agronomic) packages that maximize yields at both low and optimal input levels.

iv. The government of Kenya supports existing seed marketing systems and avails seed to farmers through programs such as National Accelerated Agricultural Input Access Program (NAAIAP) through inputs vouchers for maize, sorghum and fertilizer to curb food insecurity.

v. Community-Based Seed Production Programme (CBSPP) is a farmer-group based approach to seed multiplication and bulking which is done in collaboration between Ministry of Agriculture and research institutions such as KARI, and International Maize and Wheat Improvement Centre (CIMMYT). Drought tolerant crops are promoted. The support includes training, extension, and provision of initial seed for multiplication. Some of the seeds multiplied and sold by farmers in Makueni are cowpeas, pigeon peas, beans, green grams and maize.

vi. Producer Marketing Groups (PMG). Researchers from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) were involved in developing high yielding pigeon pea varieties suitable for the semi-arid lands of Kenya. They promoted availability of improved cultivars of pigeon peas and chickpeas to enhance the production and market through farmers' groups. The program was implemented in Makueni and Mbeere. Farmers were trained in seed production and crop management and marketing techniques. The groups were provided with seed starter kits to multiply and trade among community members, by setting up small shops in the village to sell quality seeds.

vii. Community tree nurseries managed by farmers also provide propagated seedlings to farmers e.g. fruit crops pawpaw, citrus, mangoes

viii. FIPS-Africa uses its small pack promotion approach to empower farmers to use appropriate seeds and fertilizers on small plots. Farmers can buy inputs in small packs that is affordable e.g. 1 kg Mavuno planting fertilizer, 150g sachet of an appropriate maize variety (e.g. WS202 from Western Seed Co, or DK8031 from Monsanto), and a 30 seed sachet of KAT B-9/X-56 bean variety). Farmers are also trained on the correct use of seed and fertilizer.

Table 1: Seeds for Semi-Arid Areas Of Eastern Kenya

Crop	Seed variety
Cow peas	Katumani 80 (K80), Machakos 66 (M66), KVU-419, KVU 27-1
Beans	Kat B1, Kat B9, and Kat X5, KAT X69, Katumani X56
Pigeon peas	Kat 60/8 and Mbaazi 1, Mbaazi-2
Green grams	N26, N22
Dolichos lablab	DL1002 (KAT/DL-1)
***Chick pea**	Local varieties
Sorghum	Gadam, sorghum pearl, Kari Mtama1, Seredo,
Maize	KH500-21A, KDV1, KDV2, KDV, DH04, DH02, DH09, Makueni composite, DK8031
Finger millet	Katumani Pearl Millet-1, Katumani Pearl Millet-2, Katumani Pearl Millet-3, Katumani finger Millet-1, KatumaniProso Millet
Sweet potatoes	KSP 20 “Wanjugu”, Kemb 10, K04-013 SPK004
Cassava-KME 1	KME61, Mucericeri
Oil crops	Sunflower
Fruits	Mangoes, watermelon, oranges, lemon, pawpaw
Groundnuts	Makulu red, Red Valencia, ex-Cheplambus and Homabay

7. Crop Production Technologies for the Semi-Arid Lands

7.1 Cropping System

A cropping system refers to any method adopted by farmers in raising crops. This can be categorized as growing of only one type of crop (mono cropping) or growing more than one type of crop (multiple cropping). Multiple cropping is preferred because the system brings about improvement in soil fertility, and suppresses pests and diseases.

Intercropping System

Growing two or more crops on the same piece of land at the same time is important to maximize the production capacity of the land. In intercropping, legumes such as pigeon peas, cowpeas, green grams and groundnuts fix nitrogen, which can be used by the other crops. Thus they can be intercropped with maize or sorghum. Crops that cover the ground suppress weeds and reduce moisture loss from evapotranspiration. Damage by insect pests is often less serious in intercrops. The intercrops have different heights, ages and rooting patterns, so farmers can plant more crops in small units of land with minimal competition among the crops (IIRR, 2002). The intercropping systems are:

- *Mixed or multiple cropping*: This is the cultivation of two or more crops simultaneously on the same field without a row arrangement
- *Relay cropping*: This is the growing of two or more crops on the same field with the planting of the second crop after the first one has completed its development.
- *Row intercropping*: This is the cultivation of two or more crops simultaneously on the same field with a row arrangement.
- *Strip cropping*: This is the cultivation of different crops in alternate strips of uniform width and on the same field.

Integrated Farming Systems

These are systems that include livestock, crops and trees to maximize organic inputs, increase nutrient cycling, water holding capacity and productivity while increasing soil carbon sequestration.

Crop Diversity

Maintaining and growing a wide variety of crops and seeds in order to minimize the risk of total crop failure i.e. both traditional and improved seed varieties. Seeds vary in characteristics such as their response to cold, heat or drought, or their ability to tolerate specific pests and diseases.

Crop Rotation

Various crops can be grown in succession. The farm can be divided into sections and crops grown in rotation over the years. It maintains or improves soil fertility, prevents build-up of soil-borne diseases and pests, and suppresses weeds.

Table 2: A three-year crop rotation plan

Section of farm	Year one	Year two	Year three
Section one	Potatoes	Legumes, onions and root crops	Brassicas
Section two	Legumes, onions and root crops	Brassicas	Potatoes
Section three	Brassicas	Potatoes	Legumes, onions and root crops

Ratooning

Some sorghum varieties can re-grow after they are cut. This gives a quick second harvest because the roots are already developed. However, ratooning should be limited to two harvests to prevent pests from multiplying.

7.2 Cropping Pattern Adjustments

Crops can be planted further apart so that more moisture is available for each row, increasing the likelihood of survival during periods of drought. The plant population for dry lands should ensure that there is enough moisture and nutrients per plant to ensure reaching maturity before these supplies are exhausted. The Ministry of Agriculture (MoA) recommends maize spacing of 90 cm between rows and 30 cm between seeds (total population 37,000 plants/ha) for semi-arid areas.

Land preparations should start early before the rains. It is recommended that crops be sown in rows. On ridges, seed is placed in rows centered on the furrow slices. Dry planting can be done a week before the rains where the depth should be about 5.0 cm. Weeding should be at a depth of about 5 cm, and as early as possible to avoid weed competing with the crop.

7.3 Agro-Based Weather Forecast

The availability of weather forecast information provides opportunities for farmers to consider a number of adjustments to management practices based on seasonal conditions predicted. Agriculture in the dry lands is predominantly rain-fed, meaning that if there is no sufficient rainfall within the growing season, there is loss of harvest, loss of income and food insecurity. Given the vulnerability of rain-fed farming to climate variability, application of climate forecasts is regarded as an adaptation strategy to environmental vagaries associated with extreme climate events. Since late 2006, the Intergovernmental Authority on Development's (IGAD) Climate Prediction and Analysis Centre (ICPAC) and the Kenya Meteorological Department (KMD) have worked with the Arid Land Resource Management Project (ALRMP) to provide farmers with downscaled weather forecasts in some areas. The Agro-meteorology station at Katumani is run by the KMD, which provides the agricultural sector with rain forecasting services. This is downscaled for Makueni and Machakos regions. Some farmers in Machakos and Makueni visit the centre for advice on crop and livestock management based on forecasts for their areas.

The weather forecasts provide timely climate early warning information to farmers for decision-making. The weather forecast provides information on the onset, cessation, quantity and distribution of rainfall. Early warning systems provide alerts of extreme weather events to increase preparedness and ability to deal with disasters. The information is also important to traders within commodity markets, input suppliers (to avail early maturing or drought tolerant seed varieties) and other agricultural actors to better manage their resources, so as to increase agricultural productivity and profitability.

The forecasts also help livestock keepers know when to destock or restock, in feed management i.e. planting fodder that is drought tolerant and storing fodder (e.g. crop residues, hay and silage) for later use, type of animals to keep, and diseases and pest management in livestock. Integrating meteorological and indigenous knowledge-based seasonal climate forecasts can enable farmers to identify management options for production processes and marketing.

Cropping Calendar

A well-organized agricultural calendar enables farmers in similar agro–ecological zones and livelihood characteristics to make decisions on farm operations that result in high production. Below is an example of a cropping calendar for rain-fed crop production activities developed for Sakai Community in Makueni, by the Ministry of State for Development of Northern Kenya and Arid Lands Resource Management Project (GoK – CSTI & MDNK, 2006). It gives a guideline on the main field activities within the season.

Crop production activities for Sakai Community in Makueni, 2006

- Short dry season (January to mid March 2006)
- Activities undertaken during this season include harvesting of the short rain crop (in January for pulses and February to March for cereals) land preparation for planting for the long rain season; and planting of the long rain crops at the onset of the rains.
- Long rain season (late March to mid May 2006)
- Main activities during this period include continuation of planting, in April; first weeding, pest and disease control; and second weeding, in early May.
- Long dry season (mid May to mid October 2006)
- Major activities during this period are harvesting of long rains crops, from June to July; soil and water conservation activities, in July, August and early September; post harvesting management, in July to September; harvesting of late maturing pigeon peas varieties, in August; land preparation / application of manure, in September to mid October; preparation of tree planting holes, in August; and tree planting, at the onset of short rains.
- Short rain season (mid October to late December 2006)

- Activities undertaken during this period are planting of the short rains crop, from mid-October, weeding, pest and disease control for specific crops such as cow peas, green grams and maize, in early December, when signs of pest attacks noticed.

Highlight of seasonal forecast for 2012 long rains

- April-May 2012 rain seasonal forecast;
- Onset date: third and fourth week of March;
- Seasonal length about 6 weeks;
- Cessation date: first and second week of May;
- Expected rainfall distribution: poor in space and time, and a probability of dry spells.

Agro-based advice for farmers on weather prediction for 2012 long rains

Based on advice from the District Agriculture Officer Machakos, main season activities should include:

- Planting drought tolerant crop varieties such as cowpeas -K80, M66, KVU 419, Ken kunde, green grams- N26 and Uncle, Beans-KatB1, Kat B9, Kat x56 and for black cotton soil can plant chickpeas.
- Soil and water conservation structure should be put in place for example: bench terraces, retention ditches, planting ridges.
- Early planting: pulses at the onset, cereals before the onset (one week).

7.4 Small-Scale Irrigation for Crop Production

The use of small-scale supplementary irrigation can alleviate the problem of unreliable rainfall. Small-scale irrigation schemes may be used either to provide extra water to a rain-fed crop, or to water a second crop during the dry season. This can be done either through full irrigation that provides the entire crop water requirements, or supplementary irrigation where only part of the crop water needs are provided. Irrigation can be used to grow a range of crops, e.g. pigeon pea, cassava, maize, millet, and high values vegetables (such as Okra, bitter gourd, brinjals, chilis, French beans) grown for export.

Runoff can be collected mainly from roof-tops, ground catchments as well as temporary streams (flood water harvesting), and road/footpath drainage that could be stored in tanks, reservoirs, earth dams, water pans, farm ponds and rock catchment for supplementary irrigation.

Other sources of irrigation water in semi-arid areas of eastern Kenya are rivers, springs and underground water from boreholes or wells. River flows are determined by rain. Due to frequent drought, there is a large variability of flow and a decreasing flow tendency. Groundwater is replenished by infiltration of rainfall through the soil to the underlying aquifers. Groundwater level has been falling as withdrawals have increased and infiltration has decreased, and this has led to water salinity. It makes these sources unreliable for irrigation.

Simple Irrigation Technologies

The introduction of small-scale supplementary irrigation reduces farmers' dependence on rain-fed agriculture. Simple irrigation methods have been adopted depending on the biophysical, geographic, topographic and socio-economic conditions. The following irrigation systems can be designed to distribute from catchment areas to farms:

- Surface irrigation or flood irrigation methods where water is applied and distributed over the soil surface by gravity (e.g. furrow and basin irrigation). Surface irrigation requires uniform slope in the 0-5 % range.
- Pressurized systems such as sprinkler and drip irrigation. The systems have high capital and operating costs but may utilize minimal labor and conserve water, give good returns for high value crops. Drip irrigation uses water more efficiently than sprinkler irrigation.
- Watering cans or buckets irrigation. The system is easy to handle, however needs high labor input.
- Manually operated pumps (Money Maker Deep Lift Pump pumps, Super money maker pump). Uses human power, is small, portable and easy to maintain.
- Mobile pumping schemes, canal or pipe conveyance systems. These are used for large irrigation schemes, e.g. Yatta canal farmers use the water to grow horticultural crops for local and export market, to distribute water on their farms

7.5 Controlling Crop Pests and Diseases

Non Chemical Control

Pest problems can be prevented by using good agricultural practices. Practices that reduce dependence on pesticides include:

- Planting disease resistant or tolerant varieties
- Using disease free clean planting material
- Removing infested branches and dead material from the orchard
- Maintaining soil fertility by applying organic and inorganic fertilizer
- Timely weeding
- Crop rotation
- Early planting
- Biological control
- Organic pest control (e.g. neem extracts, pyrethrum extracts)

Chemical Use

Chemicals either kill pests or inhibit their development. Pesticides are often classified according to the pest they are intended to control. Recommended insecticides, fungicides, mitecides, and bactericides, are used to control insect pests, fungal infections, mites and bacteria in crops respectively. Chemical control is also used to control weeds.

Integrated Pest Management (IPM)

IPM helps minimize the use of pesticides. It is based on ecosystem management. Non-chemical control methods are integrated with limited and selective pesticide use. Yield losses are kept within economically acceptable margins by creating ecological conditions that suppress the development of pests.

8. Post-Harvest Management

As a result of the changing weather patterns, grain cereals and pulses require appropriate crop protection skills, postharvest handling and/or processing to avoid losses in both quantity and quality.

8.1. Harvesting

Efficient harvesting can reduce post-harvest losses, and preserve food quality and nutritional value of the product. Grain should be harvested at lowest possible humidity and immediately dried to safe storage humidity levels to prevent the growth of fungi. The time of harvesting is determined by the degree of maturity. With cereals and pulses, a distinction should be made between maturity of stalks (straw), ears or seed pods and seeds, because all that affects successive operations, particularly storage and preservation. In cereals, 13% moisture content is considered sufficient for satisfactory grain preservation. The period required for full drying of ears and grains depends considerably on weather. Poorly dried and broken grain is also more susceptible to insects e.g. flour beetles and weevils, and vulnerable to mold and rotting during storage.

8.2 Pre-Harvest Control of Aflatoxin

Aflatoxin-producing fungus is found in soil, decaying vegetation, hay, and grain undergoing microbiological deterioration. It invades all types of organic substrates whenever conditions are favorable for its growth. Favorable conditions include high moisture content and high temperature. Pre-harvest control is best achieved through measures such as:

- Prevention of drought stress by irrigation
- Harvesting at the correct moisture level and stage of maturity
- Use of fungus- and pest-resistant crop varieties
- Control of insect pests
- Control of fungal infection
- Timely field operations such as land preparation, crop waste removal, fertilizer application, and crop rotation

8.3 Storage

For long-term storage, grains should be dried and treated by use of storage chemicals immediately after harvest. Chemicals such as *Actellic Super* and *Sumicombi* are used at the rate of 50g per 90kg bag of grain. The grain should be accessible throughout the storage period for additional treatment if necessary to maintain the good quality, particularly with respect to heating and moisture absorption. In closed structures (granaries, warehouses) control of cleanliness, temperature and humidity is particularly important. If grain is threshed when it is too damp and then immediately heaped up or stored (in a granary or bags), it will be much more susceptible to attack from microorganisms, thus limiting its preservation. For long-term storage, metal silos that are airtight are used to minimize oxygen and kill any weevils or pests that may be inside. They also completely lock out any insect or pest that may invade the grains inside. Selection of early-maturing crop varieties is important to ensure that they mature before moisture supplies are completely exhausted. Early harvest reduces field losses due to abrupt weather changes. Use of improved cribs that are well ventilated can allow harvest at high moisture content.

9. Livestock Production

9.1 Pasture Improvement Technologies

The technologies include:

- Pitting system for pasture production developed by KARI Katumani to suit eroded grazing lands is one technique that has been used to rehabilitate degraded, eroded rangeland (e.g. *Kitui* pitting, or *Katumani* pitting). The pits collect runoff water and allow it to infiltrate, trees can be planted on the trench embankment, followed by closing the area to allow grass to regenerate
- Ripping is a good seed-bed preparation method compared to hand clearing as it enhances seedling survival
- Bulrush millet and sorghum, which withstand hot temperatures, are used as livestock feed among poultry farmers in the semi-arid Mbooni area of Machakos county
- Spreading farmyard manure on pastures just before onset of rains to enhance pasture re-establishment
- Planting grasses on water collecting structures such as trenches and *tumbukiza* holes, including Napier grass, sorghums and Rhodes grass. The *tumbukiza* method conserves soil moisture in the pits for longer periods and concentrates fertility at a point, thus resulting in higher forage production per unit area of the land, even in areas of low rainfall (Orodho, 2006).

9.2 Integrating Fodder Crops into the Farming System

This involves growing different types of grasses, trees and shrubs and cutting them when they attain maturity to feed the animals. Fodder can be produced from planted grass or from leguminous plants that are grown as:

- Cover crops within perennial crops or on soil erosion control bands
- Hedges of suitable shrubs, shade and support trees along farm boundaries Fodder hedges e.g. Calliandra, (in mixed farming zone) Leucaena, Sesbania, and Gliricidia (in mixed farming and crops zone).
- Grass planted for fodder hedges includes Guinea grass, Rhodes grass, Napier grass and Sudan grass. Hedges can be left to grow during the rainy season without cutting

them, to have maximum amount of leaves for feeding the animals during the dry season.

Integrating legume plants in a pasture improves the overall pasture quality. Use of improved grasses and legumes tolerant to drought, e.g. perennial grass-legume mixed pasture (Rhodes grass and Lucerne) or cereal-legume mixtures (sorghum and cowpeas), improves soil fertility.

9.3 Dry Season Feeds

Conservation of surplus feed during wet seasons makes it available during the dry season. Feed can be conserved either as hay (dry feed) or silage (wet feed).

Making Hay

Hay is fodder preserved by drying in the sun. Crops and grasses such as Guinea grass, Rhodes grass, Elephant (Napier) grass, sorghum, maize and leguminous fodder crops such as cowpea and lablab can be used. The fodder should be harvested when it is less moist during sunny days to prevent development of fungi such as Aspargillus, which may aggravate allergies or abortions in cattle. Hay storage can be done using:

- A simple granary-like structure (Hay shed) with raised floor above the ground. This is made of slatted frames to provide air circulation and prevents the hay from becoming wet from below. The cured hay bundles are then stacked inside this structure. The outer surface is then 'thatched' or covered with a plastic sheet to keep the rain off.
- Box-baling. It applies to small amounts of hay. The hay is hand chopped, put in wooden boxes for better compressing and then tied up in bales, which are fitted in wooden boxes.

The types of fodder material used for making hay include:

- Preserved fodder with high fiber content like crop residues and by-products are only suitable for feeding to ruminants.

  The rate of digestion of the preserved fibrous fodder can be increased by supplying a protein supplement e.g. legume residues, pods, green fodder and oilseed residues from oil extraction (i.e. cotton seed cake, sunflower seed cake).
- Legume leaf meal (hay), which consists of dried leaves from a range of tree legumes, can also be used. The leaf material is harvested, dried in the shade and tightly packed

in bags for later use. Leguminous fodder plants should be harvested at the flowering stage or when flower buds start to grow, while grasses should be harvested before flowering when the plants have maximum nutrients and green matter. Dried legumes can be stored and used during the dry season. They provide protein, carbohydrates, minerals and essential vitamins for fertility and growth.

Silage Making

The fresh fodder material is harvested, chopped and filled in pits (silos), and high-density polytubes (gauge 1000), under anaerobic conditions while still fresh; the anaerobic environment is created by lining the pit with a plastic sheet on the sides and bottom. After filling and trampling over the material to press out most of the air, the top is then also lined with plastic and covered with soil. The material is again trampled over to make sure the covering is soil, air and waterproof. The material remains preserved as long as it remains airtight. The quality of the ensiled product will depend on the quality of the material ensiled and on the fermentation process.

Use of Crop Residues

Storage of crop residues is important since it promotes efficient utilization by livestock as opposed to grazing animals on the farm, which leads to wastage. Maize stover is the principal crop residue followed by pigeon pea residues, which are obtained after threshing the grain. Bean and cowpea residues are used, though the quantity harvested is often low.

Chopping and/or shredding of fibrous feeds is important to increase intake and reduce wastage during feeding, and also improve on digestibility. Urea can also be used (with caution) to improve digestibility of very dry fibrous feeds.

9.4 Feed Supplements and Minerals

The use of commercial concentrates, i.e. dairy meal, is limited due to its high cost for smallholder farmers, and sometimes is not available. Forage legumes e.g. leucaena for livestock supplementation offer a considerable potential to alleviate and complement the low feeding value of natural pastures and crop residues. Molasses can be mixed with dry fodder to improve palatability and therefore increase intake of fibrous feeds.

9.5 Livestock Management Systems

Livestock producers need to adapt continuously to the changing environmental, social, economic, market and trade circumstances (Parthasarthy et al., 2005). This adaptation can take place in different forms, such as expansion of cultivated areas, intensification of production, and closer integration of crop and livestock (Powell et al., 1994). Some adaptations in livestock management systems are as follows:

- Improvement of livestock management systems i.e. Semi-zero-grazing, fodder improvement using manure, provision of stock shade, and water to reduce heat stress from increased temperature.
- Planting shed trees around livestock paddocks and pasture/grazing areas
- Adjustment of livestock numbers to the available feed supply i.e. suitable types of livestock and appropriate numbers are kept depending on the size of the farm, type and amount of feed available.
- Diversifying livestock production in order to optimize utilization of available pastures by keeping combinations of different species of livestock e.g. cattle, sheep and goats and poultry to match production with the availability of fodder on the farm. Small ruminants, such as improved breeds of sheep and goats, can be used by farmers to upgrade their stock and increase productivity.
- Local poultry and goats also play an important role as a source of climatically adapted breeding stock for farmers.
- Pasture and water management e.g. construction of water pans to harvest and store rainwater for fodder irrigation.

9.6 Livestock Insurance

Local agricultural production is exposed to vagaries of weather and disease. Insurance protects farmers from losses of their crops or animals due to natural disasters such as droughts, floods and hailstones, etc. Below are some insurance companies for agriculture:

- CIC Insurance offers livestock and crop insurance covers.
- APA Insurance recently introduced a policy cover for crop and livestock sector.
- UAP provides crop and livestock insurance covers, and also offers small-scale farmers an opportunity to pay a 5% insurance premium on their purchase of seeds or fertiliser.

10. Markets and Credit

10.1 Livestock marketing

Livestock marketing is critical for improving pastoral household income. Until 1983, most livestock trade in Kenya was handled by the government through MoA's Livestock Marketing Division, and the Kenya Meat Commission. When Kenya's economy was liberalized, these agencies closed down, leaving both positive and negative impacts. Livestock trade and processing were left to private entrepreneurs who were allowed to operate in a competitive environment. On the other hand, operation capacity, quality standards and trade practices became disorganized. Pastoralists also used traditional systems of livestock trade.

Challenges to livestock marketing

- Producers do not have access to market information leading to exploitation by middlemen
- Poor quality of live animals and small ruminant meat and meat products prevents penetration into many export markets
- Poor infrastructure for transport of livestock or livestock products from remote areas of eastern Kenya where production is concentrated to urban markets. Livestock generally trek long distances to markets, resulting in losses through death and sometimes theft
- Livestock losses through disease infections at livestock markets
- Low capacity (due to poor infrastructure) for value addition in livestock-based products hence the market is mainly for live animals

Strategies for improving cattle marketing

- Formation of cattle marketing cooperatives for farmer bargaining power and to lower transaction costs
- Access to market information and increased participation in the formal markets
- Herd diversification (variety of different stock) reduces overall herd vulnerability to drought and disease and provides a wide range of market products
- Value addition of livestock products i.e. milk, hides and skin

10.2 Credit

Farmers need credit to bridge financial gaps that they cannot overcome by themselves. Risks associated with agribusiness coupled with complicated land laws and tenure systems limit the use of land as collateral. This makes financing of agriculture unattractive to the formal banking industry. In the dry lands, uncertainty due to weather pattern poses a challenge to access and availability of loans to farmers. Farmers require startup capital to purchase farm inputs such as seeds, fertilizers, livestock, and buy livestock feeds. To increase resilience to climate change there is need to diversify the livelihoods in the semi-arid areas by investing in other income generating activities, such as buying commodities such as vegetables, eggs, cereals, etc., in order to enhance the community's ability to access food stuffs at the local market center. Savings and credit take various forms in these communities, as discussed below:

Welfare saving groups (for funeral expenses)

- Local groups with their own capital, loaning money to other villagers
- Merry-go-round groups to meet personal needs
- Local money-lenders for immediate needs. They usually charge high interest rates, but using their services is easier than going to the bank
- Borrowing from relatives, friends or from people in high-potential areas
- Savings in the form of livestock and other assets that can be sold

Micro-finance institutions and credit schemes

Micro-finance institutions lend money to registered groups using group guarantee schemes to assume debt obligation in the event of non-payment by a member of the group. The micro-finance institutions in Makueni and Machakos counties include:

- Kenya Rural Enterprise programme (K-REP)
- Small & Micro Enterprises Programme (SMEP)
- Business Initiatives And Management Assistance Services - BIMAS
- Universal traders Sacco
- Smallholder Irrigation Schemes Development Organization- SISDO
- Faulu Kenya
- Jamii bora

- Kenya Women Finance Trust (KWFT)

Government support funds

The government support is through various avenues as follows:

- Through the District Gender and Social Development Office, where registered groups are provided with grants as a revolving fund to invest in projects
- The women development fund, administered through Equity bank as a loan to women groups
- The Youth Enterprise Development Fund (YEDF), conceived by the government in June 2006, as one of the strategies for addressing youth unemployment
- Kilimo Biashara launched in May 2008 is a country wide initiative. The program provides a low interest loan facility for smallholder farms and enterprises in the agricultural value chain to enable access to resources that will improve productivity and food security as well as expand farmers' income. Loans are administered through Equity bank.

11. Conclusion

Semi-arid land ecosystems are fragile hence no single intervention can resolve the challenges. There is significant potential for mitigating climate change through improved crop and livestock practices, as well as on tapping into the wide range of traditional knowledge of the local communities. Emphasis should be on farm management options that aim at restoration of degraded agricultural land, improving food security and thus livelihoods of communities in the semiarid areas. These measures that can be used include:

- Soil and nutrient management by increasing soil organic matter using organic manures leguminous crops and application of inorganic fertilizers. Production can also be improved through tillage practices that minimize soil disturbance and early planting at onset of the rains.
- Water harvesting and use can be maximized through retention of soil moisture (mulching, permanent soil cover), capturing rainwater in the soil through ridge ploughing, planting pits, catchment ponds and increasing productivity and supplementary irrigation to supply water to crops during critical growth stages.
- Intensification of crop production through enhanced access to improved seed varieties that are drought and heat tolerant, and pest and disease resistant. Seed systems should be a combination of formal, informal, market and non-market channels where farmers can also participate in the seed production process and maintain seed diversity.
- Use of cropping systems such as multiple cropping that increases biodiversity, brings about improvement in soil fertility, and reduces persistence of pests and diseases on the farms.
- Efficient harvesting, handling and preservation of farm produce to reduce post-harvest losses. Appropriate storage facilities at farm level are important to keep surplus produce for future use using both traditional and recommended chemical preservatives.
- Diversifying livestock production in order to optimize utilization of available pastures by keeping combinations of different species of livestock. Selected livestock breeds should be well adapted to the environmental conditions in the dry land.

- Enterprise diversification to increase the efficiency of farming systems for economic resilience at the farm level. Production of high value crops and value adding of farm produce for increased income.
- Enterprise diversification can spread risk.
- Availability of timely weather forecast information to enable farmers to make timely decisions.
- Encouraging weather-related crop and livestock insurance to safe guard farmers against losses due to unfavorable climate change impacts.
- Access to finance for farmers to enhance their ability to build their assets through savings and credit. Starter capital is important to enable them purchase required farm inputs (such as seeds and fertilizers), stock livestock and buy livestock feeds.

12. References

Anyah RO, Semazzi FHM (2007) Variability of East African rainfall based on multiyear RegCM3 simulations. International Journal of Climatology 27:357–371.

Ayieko M, Tschirley D (2006) Enhancing Access and Utilization of Quality Seed for improved Food Security in Kenya. http://www.tegemeo.org/documents/conference2006/presentations/SeedPresentation_Final.ppt

Christensen JH, Hewitson B, Busuioc A, Chen A, Gao X, Held I, Jones R, Kolli RK, Kwon WT, Laprise R, Magaña Rueda V, Mearns L, Menéndez CG, Räisänen J, Rinke A, Sarr A, Whetton P (2007) Regional Climate Projections. In: Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, and Miller HL (eds), Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

Collier P, Gunning J (1999) Why has Africa grown slowly? *The Journal of* Economic Perspectives 13(3): 3–22.

El-Swaify S, Dangler E, Armstrong C (1982) Soil Erosion by Water in the Tropics. 630 US ISSN 0271-9916. http://pdf.usaid.gov/pdf_docs/PNAAR134.pdf

FAO (1987) Improving productivity of dry land areas. COAG (Committee on Agriculture) report 87/7.

FAO (2008) Climate Change Adaptation and Mitigation in the Food and Agriculture Sector, Technical background document from the expert consultation, Rome. ftp://ftp.fao.org/docrep/fao/meeting/013/ai782e.pdf

Feddema, JJ, Freire S (2001) Soil degradation, global warming and climate impacts. *Climate Research* 17:209–216.

Fischer G, Shah M, Velthuizen H (2002) *Climate change and agricultural vulnerability*. International Institute for Applied Systems Analysis (IIASA), Luxemburg, Austria.

Funk C, Dettinger MD, Michaelsen JC, Verdin JP, Brown ME, Barlow M, Hoell A(2008) Warming of the Indian Ocean threatens eastern and southern African food security but could be mitigated by agricultural development. PNAS 105(32): 11081–11086.

Gachene CK, Mureithi J (2004) Lost and reclaimed: A case study of gully rehabilitation in central Kenya highlands using low-cost measures. ICSC 2004. 4th International Crop Science Congress. http://www.cropscience.org.au/icsc2004/poster/1/6/808_gacheneckk.htm

GoK – CSTI & MDNK (2009). Increasing Community Resilience to Drought in Makueni District: The Sakai Community's Experience, Kenya

Hudson W (1987) Soil and water conservation in semi-arid areas. FAO Land and Water Development Division, Food and Agriculture Organization of the United Nations Rome. http://www.fao.org/docrep/T0321E/t0321e-10.htm

ICRAF (2009) Trees on farms: Tackling the triple challenge of mitigation, adaptation and food security. Policy Brief No. 07, 2009 http://worldagroforestry.org/downloads/publications/PDFs/mitigation-adaptation-food-security.pdf

IIRR (2002) Managing Dry land Resources: A Manual For Eastern And Southern Africa. http://www.preventionweb.net/files/7981_DrylandResourcesbk.pdf

KARI (2008). Post-harvest handling and protection of maize. Information Brochure series / 18 /2008.

KNMI (Royal Netherlands Institute of Meteorology) (2006) Climate change in Africa. Changes in extreme weather under global warming, Royal Netherlands Institute of Meteorology, Brochure. Available at: http://www.knmi.nl/africa_scenarios/

Mutunga K (1997) Soil and Water Conservation Report, Water Conservation, Harvesting and Management (WCHM) Training, Soil and Water Conservation Branch (SWCB) Ministry of Agriculture, Kenyan experience update, 1995 – 1997. Nairobi.

Mwangi DM, Karanja D, Mutuku R, Maina L (2011) The Role of the Market in Addressing Climate Change in the Arid and Semi-Arid Lands of Kenya: The Case of Gadam

Sorghum, Kenya Arid and Semi-Arid lands Programme (August, 2, 2011). http://www.kainet.co.ke/kasal/

Njarui DMG, Mureithi JG, Wandera FP, Muiga RW (2003) Evaluation of Four Forage Legumes as Supplementary Feed for Kenya Dual-Purpose Goat on the Semi-Arid Region of Eastern Kenya. Tropical and Subtropical Agroecosystems 3 (2003): 65 – 71. http://redalyc.uaemex.mx/pdf/939/93912118002.pdf

Omondi F, Ekaya W, Nyatriki D (2010) Influence of seed bed preparation on morphometric characteristics of Eragrostis superba, Cenchrus ciliaris and Enteropogon macrostachyus in southeastern dry lands of Kenya. Second RUFORUM Biennial Meeting 20 - 24 September 2010, Entebbe, Uganda.http://www.ruforum.org/sites/default/files/file/Biennual%202010/Agronomy/Omondi.pdf

Opiyo FEO, Ekaya WN, Nyariki DM, Mureithi SM (2011) Seedbed preparation influence on morphometric characteristics of perennial grasses of a semi-arid rangeland in Kenya. African Journal of Plant Science Vol. 5(8), pp. 460-468, August 2011. http://www.academicjournals.org/ajps/PDF/Pdf2011/August/Opiyo%20et%20al.pdf

Orodho A (2006) The role and importance of Napier grass in the smallholder dairy industry in Kenya. http://www.fao.org/ag/AGP/AGPC/doc/Newpub/napier/napier_kenya.htm

Parthasarthy P, Birthal P, Ndjeunga J (2005) Crop-Livestock Economies in the Semi- Arid Tropics. Facts, trends and outlook. In FAO (2011). Global Livestock Production Systems. http://www.fao.org/docrep/014/i2414e/i2414e05.pdf

Powell M, Pearson A, Hiernaux P (1994) Crop-livestock Interactions in the West African. In FAO Global Livestock Production Systems http://www.fao.org/docrep/014/i2414e/i2414e05.pdf

Reardon T, Vosti SA (1995) Links between rural poverty and the environment in developing countries: asset categories and investment poverty. World Development 23(9):1495–1506.

Rosegrant MW, Cai X, Cline S (2002) World Water and Food to 2025: Dealing with Scarcity. International Food Policy Research Institute (IFPRI), Washington, DC, USA. Available at: http://www.ifpri.org/pubs/books/water2025book.htm

Rosenzweig C, Hillel D (1995) Potential impacts of climate change on agriculture and world food supply. *Consequences* 1(2): 24–32.

SEI (Stockholm Environmental institute) (2009) The Economics of Climate Change in Kenya project report in Kenya. Project Report – 2009.

UNEP (2009) Climate Change in the African Dry lands: Options and Opportunities for Adaptation and Mitigation.

Van de Steeg JA, Herrero M, Kinyangi J, Thornton PK, Rao KPC, Stern R, Cooper P (2009) The influence of climate variability and climate change on the agricultural sector in East and Central Africa—Sensitizing the ASARECA strategic plan to climate change. Research report 22. ILRI (International Livestock Research Institute), Nairobi, Kenya, ICRISAT (International Crops Research Institute for the Semi-Arid Tropics), Nairobi, Kenya, and ASARECA (Association for Strengthening Agricultural Research in Eastern and Central Africa), Entebbe, Uganda.

Vasiliniuc I, Patriche C (2009) Soil Structural Degradation Risk In Horoiata Basin (Tutova Hills). In Present Environment and Sustainable Development, NR. 3, 2009. http://pesd.ro/articole/nr.3/20.Vasiliniuc.pdf