Working Paper

Options for Climate-Smart Agriculture at Kaptumo Site in Kenya

Charles Wambugu, Steven Franzel and Janie Rioux

East Africa Dairy Development
In partnership with

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Tel: +254(0)20 722 4000, via USA +1 650 833 6645
Fax: +254(0)20 722 4001, via USA +1 650 833 6646
Email: worldagroforestry@cgiar.org
Website: www.worldagroforestry.org

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THE AUTHORS

Charles Wambugu is a consultant, Steven Franzel works for the World Agroforestry Centre (ICRAF) in Nairobi, and Janie Rioux is a Natural Resources Officer with the Food and Agriculture Organization of the United Nations.

ACRONYMS AND ABBREVIATIONS

AI	Artificial Insemination
CA	Conservation Agriculture
CESP	Community Extension Service Provider
CITC	Christian Intermediate Technology Centre
COMPETE	Competence Platform on Energy Crop and Agroforestry Systems for Arid and Semi-arid Ecosystems
EADD	East Africa Dairy Development Project
FAO	Food and Agriculture Organization of the United Nations
FFS	Farmer Field School
GHG	Greenhouse Gases
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
ICRAF	World Agroforestry Centre
ILRI	International Livestock Research Institute
KARI	Kenya Agricultural Research Institute
KEFRI	Kenya Forestry Research Institute
KENDBIP	Kenya National Domestic Biogas Programme
KENFAP	Kenya National Federation of Agricultural Producers
KFS	Kenya Forest Service
LPG	Liquefied Petroleum Gas
MICCA	Mitigation of Climate Change in Agriculture Programme
MOALF	Ministry of Agriculture, Livestock and Fisheries
MOE	Ministry of Energy
NGO	Non-governmental organization
SEP	Special Energy Programme
SIDA	Swedish International Development Agency
SNV	Netherlands Development Organization
TP	Tubular Plastic
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change

ABSTRACT

This report identifies and assesses climate-smart agricultural practices through participatory appraisal tools with experts and farmers, as part of the MICCA pilot project in Kaptumo, Kenya. The aim is to highlight and add climate-smart practices within the ongoing development programme which aims to integrate climate change adaptation and mitigation with improving livelihoods and productivity of the dairy farming system.

Keywords: climate-smart agriculture; dairy farming; menu of practices; participatory appraisal; Kaptumo; Kenya

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1.0 INTRODUCTION

Climate change is a significant challenge to achieving sustainable food security as it reduces agricultural productivity and makes production more erratic (FAO, 2010). This phenomenon exacerbates the unreliable rainfall prevailing in many areas of the tropics. The increasing rate of change in global mean annual temperature will disturb and alter the current spatial and temporal patterns including (a) the availability of atmospheric carbon dioxide; (b) the global mean temperature and its diurnal variations; (c) the frequency and intensity of extreme weather events; (d) weather variability; and (e) the mean sea levels including inundation of human habitats and saltwater intrusions. In addition, it is likely to change the patterns of extreme events like droughts, storms and fire incidences, insects and disease infestations, etc. These changes will create stress on the resilience of the ecosystem, its constituents and especially on agriculture and food security. Thus, there is a close link between global climate change and local food security. However, opportunities exist to transform the prevailing agricultural practices towards climate-smart systems that adapt to and mitigate the effects and impacts of climate change.

Agriculture in developing countries must undergo significant transformation in order to meet the related challenges of achieving food security and responding to climate change. Projections based on population growth and food consumption patterns indicate that agricultural production will need to be increased by at least 70% by 2050 so as to meet increasing food demands (FAO, 2010). Most estimates indicate that climate change is likely to reduce agricultural productivity, production stability and incomes in some areas that already have high levels of food insecurity. The promotion of climate-smart agriculture is thus crucial to achieving future food security and climate change goals.

Climate-smart agriculture was described by FAO in 2010 as a range of agricultural strategies, approaches, practices and tools that sustainably increase productivity and resilience of agricultural production systems and help to reduce the emission of greenhouse gases (GHG), when possible. These practices help in the adaptation to, and the mitigation of, climate change and enhance the achievement of national food security and development goals. At the smallholder level, climate-smart agriculture can successfully be achieved through the application of a combination of institutional and policy options, financing mechanisms, capacity strengthening and input/information delivery systems. The implementation of projects for climate-smart agriculture can lead to the realization of some of the Millennium Development Goals such as the reduction of extreme poverty and hunger, conservation of the environment, reduction of child mortality and improvement of maternal health through access to better nutrition.

Appropriate agricultural practices have the potential to offset 5-14% (with a maximum of 20%) of the total annual CO_2 emissions (Thornton and Herrero, 2010). Grasslands, including rangelands, shrub lands, pasture lands, and croplands sown with pastures, trees and fodder crops,

represent 70% of the world's agricultural area. The soils under grasslands contain about 20% of the world's soil carbon stocks (FAO, 2010). However, these carbon stocks are at risk from land degradation. Therefore, one of the key adaptation and mitigation strategies is arresting further land degradation and restoring the degraded grasslands. This would involve improved grazing management and re-vegetation of the grasslands through the establishment of pasture enclosures, diversification of grass and forage species, postponing grazing to allow pastures to grow to maturity, ensuring even grazing of various species and improving forage productivity and efficient nutrient recycling processes. These practices are likely to contribute to increased carbon sequestration, improved land and livestock productivity and increased resilience to climate change.

The main goal of the Mitigation of Climate Change in Agriculture (MICCA) programme is to facilitate developing countries to address climate change in agriculture and move towards low carbon emission agriculture. MICCA also aims to contribute to the formation of a global network and body of knowledge to address issues related to lack of knowledge or the existence of scattered information in the area of climate change. The MICCA project intends to build upon the activities being undertaken by the EADD project, and add an explicit climate component. Barriers to the adoption of climate-smart and sustainable agricultural practices tend to be context-specific. The pilot project aims to assess the incentives and disincentives associated with applying climate-smart agricultural practices and to put efforts towards building incentives and structures that could promote the wide-scale adoption of these practices.

Appropriate tools and methods for estimation of the amount of carbon sequestration and emission of GHGs need to be identified and developed. The pilot project aims to contribute to the refinement of measurement and modelling methodologies associated with climate change mitigation and adaptation. It is envisaged that the evidence from the initiative will be used to inform decision makers to help in shaping policies with mitigation of climate change co-benefits. The project outcomes include: project beneficiaries implementing climate-smart practices in smallholder dairy systems; increased crop-livestock productivity; increased ecosystem resilience; and policy makers utilizing project evidence.

The objective of this report is to assess which climate-smart agricultural practices may be most appropriate for farmers at the Kaptumo pilot site of the MICCA project. First we present the methods used and give background information about the project and farmers' characteristics at the site. We then present five sets of potential options: agroforestry, manure management, conservation agriculture, livestock production, and energy options, and wetlands protection. Finally we discuss the farmers' listing and ranking of the practices and present a framework for assessing the potential of selected options.

2.0 METHODOLOGY

A review of the literature and key informant interviews were conducted to collect information on the MICCA pilot project, the EADD programme, farmer characteristics in Kaptumo and to prepare a menu of appropriate climate-smart agriculture options. To understand farmer characteristics in Kaptumo, the report relied heavily on the FAO socio-economic baseline survey by Zagst (2011).

The drawing up of the menu of options with farmers and other stakeholders was done through a rapid appraisal conducted in Kaptumo in March 2012. The team held discussions with farmer groups and visited individual farms. The rapid appraisal mainly centred on assessing which climate-smart practices would be most suited for the farmers. The team visited institutions that have the potential to be involved in the implementation and scaling up of climate-smart agriculture activities that were advocated by the MICCA pilot project team at ICRAF and EADD.

During the rapid rural appraisal exercise, members of two dairy groups were assembled to provide information they had on climate-smart agriculture. The two groups identified, listed and ranked the practices that they thought were important in Kaptumo area. The farmers listed the practices as they understood them and then ranked them on the basis of the ease of adoption. The listing and ranking was done through a consensus building process.

The identification and ranking of climate-smart agriculture at Kapsoiyo in Koiyo Location was done by five women and 14 men while that at Kaptumo Community Social Hall was done by 17 men and two women. It was unplanned that the numbers of women who attended were so low. The team tried to get more women involved but unfortunately they were unable to attend due to household chores.

The menu of options, shown in Table 3, was prepared by the consultant, based on farmers' perceptions in the ranking exercise and the views of researchers, extensionists and other key informants.

2.1 Background information on the EADD programme and MICCA pilot project

The East Africa Dairy Development (EADD) programme, funded by the Bill and Melinda Gates Foundation, is a partnership between Heifer International, ICRAF, ILRI, Technoserve and African Breeding Systems (ABS). It has been operational since 2008 in Kenya, Uganda and Rwanda and covers 21 sites. The overall goal of EADD is to help 179,000 families comprising roughly one million people living on smallholder farms (1-5 acres) in the East African region to come out of abject poverty by improving the management and profitability of their dairy enterprises. It also aims to assist families meet their nutritional needs, enhance dairy productivity

by increasing the volume of milk, improving the milk quality, reducing milk loss through spoilage, and increasing incomes through the production and sale of surplus milk. Through EADD, farmers would have access to production inputs through improved business delivery services, improved market access by developing local hubs of business development services and chilling plants and strengthened links for producers to formal markets through processors. The project further intended to extend the benefits to women and to minimize the additional burden that dairy activities could impose on women.

In 2009, the project picked Kaptumo in Nandi South District in the Rift Valley region of Kenya. EADD identified and recruited Community Extension Service Providers (CESPs) who were essentially farmers selected to provide extension services to other farmers. The CESPs were assigned the role of mobilizing farmers and cattle registration. At the time of the rapid appraisal exercise, there were 12 CESPS in Kaptumo. ICRAF was in the process of recruiting demonstration farmers who would disseminate fodder information and also double-up as farmer trainers in the area. The criteria for selecting farmer trainers/demonstration farmers included acceptability of the farmer by the community and willingness to share information. The project intended to identify and recruit about 15 farmer trainers. The aim of establishing demonstrations of new technologies was to put in place a complete suite of fodder species and practices that can perform well in the pilot site including Napier grass, Rhodes grass, Lucerne, desmodium, calliandra (*Calliandra calothyrsus*) and sesbania (*Sesbania sesban*). Two farmers had planted calliandra and desmodium in their farms. They acquired the planting materials from as far as Eldoret, which is 65km away. It is expected that some of the demonstration farmers will ultimately graduate to model farmers who will have virtually all the EADD-recommended dairy practices.

In Kenya, the MICCA pilot project has been working closely with the East Africa Dairy Development (EADD) programme. The project selected Kaptumo as the pilot site for integrating climate-smart agriculture into the existing mixed-farming systems. The MICCA project aimed at understanding the options for reducing greenhouse gas (GHG) emissions from mixed-farming systems that was predominant in the area and how these options could be scaled up. The success of the EADD programme was quite encouraging. The EADD engaged in creating awareness of the need to improve dairy productivity, mobilized farmers into functional dairy groups, provided extension advice to farmers, and established and strengthened linkages between the farmers, milk processors and input suppliers. The project assisted some of the dairy hubs to procure and install the chilling plants. The project had not introduced the concept of climate-smart agriculture to farmers but was interested in partnering with MICCA to do so in Kaptumo.

Some of the areas identified for collaboration between the EADD programme and the MICCA pilot project at Kaptumo included:

- Intensifying the incorporation of fodder shrubs and herbaceous legumes into the mixed-farming systems to increase dairy productivity that would result in the reduction of the number of dairy cows per household and subsequently reduce the overall methane (CH_4) emission in the area. The fodder shrubs planted along soil conservation terraces would also assist in reducing soil erosion;
- Promoting zero-grazing units to facilitate efficient management of cattle manure and the installation of biogas units. This would lessen the burden on women of herding livestock and fetching fuelwood, and the time saved would enable them to become involved in economic activities;
- Creating awareness of the causes and impacts of climate change including environmental, economic, social, cultural and political impacts;
- Exploring local solutions and mechanisms that would help in the adaptation and mitigation on climate change, especially those that are based on climate-smart agriculture and agroforestry practices. These include promotion of commercial and group tree nurseries, on-farm tree planting and appropriate management of manure;
- Developing tools and mechanisms for assessing changes resulting from project interventions. These should include assessment of GHG emission under different farming systems and practices;
- Developing water harvesting and storage technologies for domestic and livestock use. The availability of water in the homestead would save women a lot of time and effort.

3.0 RESULTS

3.1 Farmer characteristics in Kaptumo

As in the rest of the East Africa, smallholder farming at Kaptumo is characterized by low land productivity resulting from complex but interlinked factors. These range from unreliable and inadequate rainfall, infertile, degraded soils, poor agronomic practices, undeveloped marketing channels and lack of access to agricultural inputs. These problems contribute significantly to food insecurity and the poverty experienced by most of the smallholder farmers in the area. Frequent droughts and subsequent crop failures have made resource-poor farmers quite vulnerable to food insecurity and severe poverty. The main staple food in the area is maize and virtually all subsistence farmers continuously grow maize on the same pieces of land every year, resulting in soil nutrient depletion, especially nitrogen and phosphorous.

Data obtained from the Livestock Extension Department indicated that Kaptumo Division has a total area of 136 km^2 (13,600 ha). It has four locations and 14 sub-locations. The total population is 55,000 people (2009 census). The division has 4,200 households with about 7,500 farm families. Rainfall ranges from 1500-2100 mm/year, and altitude from 1800-2100m above sea level. The division has two main agro-ecological zones: Upper Midland 2 (UM2) and Lower Highland 2 (LH2). The soils are sandy loam and deep fertile loam. The beneficiaries of the EADD initiative, comprising over 4000 farmers, were organized into dairy groups. It is

envisaged that the well-entrenched EADD project will provide synergies for MICCA to fast-track the project implementation process. The MICCA pilot project aims at contributing to the adaptation and mitigation of climate change in agriculture and moving towards low carbon emission farming practices. In the process, the project will succeed in attaining the FAO objectives of ensuring sustainable food security and proper household nutrition, and the ICRAF agenda of increasing tree cover on smallholder farms.

A baseline survey conducted by the MICCA project in 2011 collected data from 357 respondents in six administrative locations in Kaptumo hub. The survey revealed that the farming community believes that the climate variability contributes to low agricultural production, especially with respect to problems associated with diseases and pests. It also indicated that there was general awareness of the effects and impacts associated with climate change. These included variations in rain patterns characterized by excess rains during the wet season and prolonged dry seasons. The community associated climate change with the drying up of rivers and streams, and decline in land and livestock productivity. The adaptation and mitigation efforts are still quite low with only about 10% conserving the soil and 10% reducing the number of livestock (Zagst, 2011). Few had adopted drought-resistant crop varieties, some improved the agronomic practices and others practised organic farming by applying manure and double-digging methods aimed at improving the soil moisture retention capacity. Some of the farmers had begun storing fodder for use during the dry season. The adoption of water harvesting and conservation practices was quite low.

The survey revealed that farmers had realized that human activity was responsible for increased environmental degradation. Some of these comprised deforestation to create land for food and tea production, cultivation in areas with steep slopes, farming on swampy grounds and overstocking. The farmers were aware of sustainable solutions to mitigate these problems including conservation of the forests and wetlands, planting trees and conserving the soil on hilly areas. Other sustainable solutions to ensure food security and conservation of the environment include improved farming methods such as those of climate-smart agriculture, and selection of suitable crop and fodder species that are appropriate to different agro-ecological zones.

Members of the EADD-supported dairy groups indicated that they could easily access credit facilities, artificial insemination (AI) services, veterinary services and milk transportation services. The baseline survey indicated that there were about 155 dairy groups, each comprising about 10-15 members. About 1,600 farmers were active milk suppliers. Out of these, 50% were women. The dairy groups facilitated improvements in access to information, training facilities and milk marketing. The incomes of the farmers were on the increase as a result of increased milk production and the presence of functional groups. In a nutshell, EADD had established and developed organizational structures that were critical for MICCA to jump-start the planned activities for climate-smart agriculture.

The survey indicated that the average number of persons per household was five and the literacy level was reasonably high possibly because of the government national policy on compulsory free primary education. The majority of households (94.6%) owned radios and mobile phones, making it easy for them to access information. However, only a few households were connected to electric power.

The average farm size was two acres but the land was estimated to be moderately degraded and of low soil fertility leading to low crop yields. The soil was of low pH (acidic) in addition to being loose and poorly structured, thus making it more prone to erosion. The majority of farmers (92%) practised mixed-farming where they grew crops and kept livestock on the same piece of land. The predominant food and cash crops in the area were maize (23.2%) followed by beans (14.9%), bananas (12.2%) and tea (12.1%). Only 40% of the households indicated that they had adequate food throughout the year and a third of the farmers managed to get food for up to 6-9 months in a year. Generally, 80% of the households consumed food produced on their own farms and only the surplus food was sold. Farmers indicated that due to the decline in soil fertility, the maize yield had declined from an average of 20 bags/acre in the past to only 5-7 bags/acre. Information gathered later from a rapid appraisal exercise indicated that most of the maize grown in the area is sold while it is still green due to the presence of a ready market for the commodity. The majority of farmers were replacing maize acreage with tea due to increased tea prices.

The survey indicated that 92% of the households owned dairy cattle, 67% had chicken, 26% had goats, 27% had sheep and there were no pigs. Data obtained from the local government livestock office indicated that the cattle population in Kaptumo Division was estimated at 24,000 of which 3,000 were improved exotic breeds, 14,200 were cross-breeds and 5,000 were bulls. The bulls were for beef production. The common breeds in the area were Ayrshire, Friesian and cross-breeds of the two. The average cattle herd size was 5.4, which was quite high for smallholder farmers. The reason is due to the cultural belief that cattle numbers are an indicator of wealth and social status. This was contrary to the EADD approach to decrease the herd size and improve milk yield and quality..

About 64% of the households kept their cattle predominantly in paddocks, 21% grazed them on communal lands and 10% tethered the animals. The average land size used for paddock was 0.9 acres. At the time of the survey, none of the farmers had constructed a zero-grazing unit despite the promotion conducted by the EADD and the Ministry of Agriculture, Livestock and Fisheries (MOALF) staff. This may be due to lack of capital to construct the zero-grazing units and lack of water storage facilities. The project should explore the possibility of providing credit for the construction of zero-grazing units, water harvesting facilities and, where appropriate, biogas units. The project can use the 'check-off' system that enforces compliance to loan repayment plans as the agreed monthly installments will be deducted from the proceeds of delivered milk.

This approach would allow the project to promote the use of biogas, which requires a high initial investment.

3.2 Climate-smart options suitable for Kaptumo farmers

Climate-smart agriculture involves practices such as the cultivation of perennials, increasing tree and shrub cover on smallholder farms, practising conservation agriculture, ensuring better management of manure and the installation of renewable sources of energy such as biogas and solar devices. This will also involve conservation of existing woody biomass within the farms and in gazetted forests through increased use of alternative sources of renewable energy and energy conservation devices such as energy-saving cooking stoves and fireless cookers. The combination of these measures and efforts is expected to have direct and sustainable impacts on climate change adaptation and mitigation efforts. The pilot project aims to address the obstacles to the adoption of climate-smart practices and issues associated with measuring and monitoring the impacts or potential impacts of adoption and non-adoption of climate-smart agriculture.

The climate change adaptation and mitigation options highlighted below have implications on the management of natural resources. The suggested interventions mainly involve strategies to reduce the number of livestock by increasing their productivity and recommend land use changes such as incorporation of agroforestry and conservation agriculture practices in the farming system. However, assessment and quantification of the potential impacts from suggested land-use changes may not be straightforward and may present technical difficulties. It is likely that significant gaps exist between the theoretical (potential) and actual (achievable) realization of climate change adaptation and mitigation efforts. The gaps may result from existing policy barriers, and institutional, socio-cultural, educational and economic constraints (Thornton and Herrero, 2010). The baseline survey conducted in the pilot area revealed that about 90% of the respondents knew about some of the climate-smart agriculture practices including crop rotation, ridge cultivation, application of manure and planting hedge rows (Zagst, 2011).

These suggested interventions are grouped into five categories: agroforestry practices, manure management, conservation agriculture practices, improved livestock production practices, and energy conservation. Each is discussed below. The constraints and incentives for adoption are summarized in Table 1.

Table 1: Constraints and incentives to adoption of some climate-smart agriculture options at the Kaptumo Pilot Site [1]

Practices	Constraints	Incentives
Agroforestry		
On-farm tree planting	Long period before income is received Seed/seedling availability Labour for nurseries	Income diversification Multiple benefits following establishment
Improved manure and nutrient recycling practices		
Proper manure management	Knowledge Labour for collection if livestock not confined	Improved soil organic matter and crop yields
Nutrient recycling processes	Knowledge	Improved soil organic matter and crop yields
Conservation agriculture		
Conservation Agriculture	Knowledge Many prefer to feed crop residues rather than use them as mulch	Reduced tillage costs, improved soil health,
Livestock production practices		
Fodder shrubs	Knowledge	Increased protein for livestock productivity
Herbaceous legumes	Knowledge	Increased protein for livestock productivity
Improved grass such as Napier grass	Seed/planting material availability	Improved basal feed for livestock productivity
Commercial concentrates	Capital requirement	Improved protein and nutrients for livestock productivity
Livestock genetic improvement (breeding)	Knowledge Labour, capital requirement	Higher yielding livestock if managed well
Restoration of degraded rangelands	Knowledge	Improved livestock productivity
Energy conservation practices		
Energy conserving stoves & fireless cookers)	Knowledge	Reduced fuelwood requirement and improved health from reduced smoke; both benefits of particular importance to women
Biogas production	Knowledge, high capital cost, several cows in minimum or zero-grazing system required.	Cheap household energy, improved soil organic matter and crop yields
Solar energy	Knowledge, high capital cost	Cheap household energy
Biofuels	Knowledge, land requirement, high labour and capital cost, equipment required for oil extraction	Cheap household energy, livestock feed from by-products
Wind energy	Knowledge, high capital cost	Cheap household energy
Micro-hydro power	Knowledge, high capital cost	Cheap household energy

[1] The data is based on information collected from farmers, key informants and scientists

3.3 Agroforestry practices: planting trees on farms

The deliberate incorporation of appropriate species of trees and shrubs into the existing farming systems in the pilot site needs to be intensified. Trees and shrubs can be planted on farms as live fences, boundary markers, windbreaks, soil conservation hedges, fodder banks, and woodlots. The trees and shrubs planted on farms can help in the conservation and protection of natural forests as wood products and services can be obtained from the farms, thus reducing the pressure on the exploitation of forest resources. In addition, the magnitude of the problems resulting from low land productivity can be reduced by introducing appropriate tree species into the farming systems. For example, a combination of leguminous fodder shrubs and herbaceous legumes can be grown together with food crops with the aim of improving crop productivity and providing fodder for livestock. Trees can be planted along the boundaries to provide windbreaks for the crops in addition to timber, fencing materials and fuelwood.

Leguminous fodder shrubs have high nutritive value and can help to improve the diets of ruminants while they can also sequester carbon. Forages from the fodder shrubs can effectively replace some of the concentrates and part of the basal diet of dairy livestock leading to increased milk production per cow. Ultimately, this can result in the reduction of the number of cattle on the farm and thus reduce the amount of methane emission from individual farms (Thornton and Herrero, 2010). A dairy cow requires about 500 shrubs to ensure a continuous supply of forage throughout the year (Wambugu et al., 2011) and thus fodder shrubs need to be planted in large quantities on the farm. Luckily, there are several neglected niches on the farms to plant these with negligible sacrifices to food crop production (Franzel and Wambugu, 2007). Such niches include: along soil conservation terraces and the farm boundaries, around the homestead, within the kitchen gardens and in the fodder banks. It is only the forages (leaves) that are harvested to feed livestock leaving behind the woody stems above the ground and the root systems below the ground. This implies that the increased planting of fodder shrubs is likely to lead to increased wood biomass on the farm and thus will make a contribution to carbon sequestration. The amount of woody biomass from different species of fodder shrubs needs to be assessed in order to set benchmarks of carbon sequestration in dairy systems with fodder shrubs.

Some of the leguminous fodder shrubs that have been tested and proven to have a high potential for improving soil fertility and that may be used in conservation agriculture include *Gliricidia sepium,* calliandra, *Leucaena trichandra, Leucaena diversifolia*, *Chamaecytisus palmensis* (tree lucerne), sesbania and *Faidherbia albida.* The non-fodder leguminous shrubs include *Tephrosia vogelli*, *Tephrosia candida*, *Crotalaria grahamiana* and *Cajanus cajan* (pigeon pea). These species can be grown in a wide range of climatic and soil conditions. Some of these species such as calliandra and *L. trichandra* have been tried in the pilot area and have been found to have a high potential for improving dairy and maize productivity. *F. albida* is a nitrogen-fixing species with 'reversed leaf phenology' where it is dormant and sheds its leaves during the early rainy season and produces leaves during the beginning of the dry season. It does not compete with

food crops for light, nutrients and water during the growing season and has positive effects on crop yields.

The incorporation of trees and shrubs into the agricultural system helps to diversify and increase farm incomes and thus reduces the risks in agricultural production. Increases in tree and shrub cover can help to minimize the effects of extreme weather occurrences, such as heavy rains, droughts, windstorms and the effects of frost. These increases prevent erosion, stabilize soils, raise water infiltration rates, halt land degradation, enrich biodiversity in the landscape and increase ecosystem stability (FAO, 2010). Agroforestry is therefore important in helping farmers adapt to climate change by reducing their vulnerability to the effects of climate change, diversifying income sources and improving livelihoods.

Trees can improve soil fertility and soil moisture retention capacity through increasing soil organic matter. Nitrogen-fixing leguminous trees and shrubs are important for enriching soil fertility, especially in cases where there is limited access to mineral fertilizers. Improved soil fertility tends to increase agricultural productivity and may allow more flexibility in the types of crops that can be grown. For example, in some cases, agroforestry systems in Africa have increased maize yields by 1.3 and 1.6 tons per hectare per year (Sileshi et al., 2008). Fodder trees have been traditionally used by farmers and pastoralists on extensive systems but fodder shrubs such as calliandra and *L. trichandra* are now being used in more intensive systems, increasing production and reducing the need for external feeds (Franzel et al., 2003).

Agroforestry systems tend to sequester much greater quantities of carbon than the agricultural systems without trees. Planting trees in agricultural land is relatively efficient and cost effective compared to other climate change mitigation strategies, and provides a range of co-benefits important in improving the livelihoods of farmers and climate change adaptation (FAO, 2010). These co-benefits include timber, fruits and vegetables, fodder, bee forage, fuelwood, fencing materials and environmental services such as erosion control and soil fertility improvements. Agroforestry systems also provide several environmental services and benefits including sustaining and improving the biodiversity and mitigating against climate change.

There is a need for public-private partnerships, especially in the propagation and distribution of tree planting materials. Some private companies and NGOs support the promotion of agroforestry practices in exchange for carbon benefits. The communities in the pilot project can be linked to such organizations in order to benefit from carbon credits and enhance the adoption of agroforestry practices in the pilot area. The Green Belt Movement is in the process of implementing a BioCarbon Fund Pilot Project in Kenya. The VI-Agroforestry project is working on reforestation and soil carbon monitoring in the East African region. Many local NGOs incorporate tree planting activities as a cross-cutting activity in their projects. The local

community needs training in agroforestry and reforestation practices, and these can be funded through carbon funds.

The baseline survey indicated that 99% of the households use wood as their main source of energy. More than three-quarters of the households said that they were involved in tree planting and protection. Baseline survey respondents indicated that a total of 24,130 trees were planted and 4917 trees were protected in 2011 by 118 farmers. These included indigenous and exotic species such as cypress, grevillea (*Grevillea robusta*), Nandi flame (*Spathodea campanulata),* eucalyptus, bottle brush, jacaranda, mahogany and several fruit species. Since many farmers are engaged in tree planting and protection, it will be easy for the project to introduce diverse tree species including fodder shrubs, fruits and timber species. The integration of trees and soil management practices on the farms can help to increase soil carbon accumulation and offset livestock-related emissions, and thus contribute immensely to climate change adaptation and mitigation.

The rapid appraisal indicated that the incidences of deforestation were on the increase. The older generation recalled that most of the farms under tea were previously under forest cover. The main cause of deforestation was the curing of tea where fuelwood was the main source of energy. The main source was indigenous species which led to the near-extinction of some of the species. Today, the source of fuelwood for tea factories is eucalyptus, which farmers sell to tea factories to earn extra income.

On-farm tree planting was on the increase as an adaptation mechanism to counter the loss of forest resources. The local community was aware of the need to protect the common natural resources such as forests and water resources. The community was opposed to the encroachment of the neighbouring Nandi forest. The decrease in deforestation and increase in on-farm tree planting are likely to lead to a net increase in tree cover on the farms. However, the MICCA pilot project needs to actualize the process by intensively creating awareness, building the technical capacity and facilitating access to tree seed and seedlings.

Commercial tree nurseries are needed to provide sustainable sources of tree planting materials in the pilot area. From experience, community commercial tree nurseries are best managed by women and youth groups and help to increase household incomes. Tree nurseries should be located close to reliable water sources such as rivers, boreholes, wells and piped water. For ease of transportation and higher survival rates, the tree seedlings need to be in bags. The nursery operators need to diversify the tree species in order to sustain and improve the tree biodiversity in the area. This should include propagation and distribution of appropriate tree species for timber, fruits and fodder. The nursery operators need to be supported in procurement of quality germplasm, development of their technical and entrepreneurial skills in addition to the development of linkages to inputs, seeds and seedling markets.

3.4 Manure management and soil nutrient recycling processes

Due to the continuous cropping in most smallholder systems in the pilot area, soil nutrients have been depleted to very low levels, thus exposing the local community to food insecurity. It is therefore important to improve and sustain land productivity through proper management of soil fertility and soil organic matter and improve the efficiency of nutrient application. This can be achieved through practising crop rotation in an agroforestry system where leguminous trees and shrubs are planted in the crop land and there is a continuous application of farm yard manure. Mixed farming of crops, trees/shrubs and livestock production enhances efficiency in nutrient recycling processes and is an effective strategy for boosting land productivity. Perennial legumes improve soil fertility through their ability to fix nitrogen from the air. Dairy livestock can thus play a significant role in animal-mediated nutrient recycling processes. Other legumes can be fed to livestock which in turn provide quality manure for crop and fodder production. Fodder and crop waste provide quality feeds for dairy livestock, which in turn provide manure to increase crop and fodder productivity. If well managed, the system can provide an efficient mechanism for nutrient recycling processes (UN Habitat, 2011).

The level of soil nutrients can be increased through composting manure and crop residuals. The composting process needs to be well managed to reduce loss of nutrients into the atmosphere. Manure management involves careful matching of nutrients with plant needs, controlled release and deep nutrient placement technologies (FAO, 2010). Use of organic manure reduces or eliminates the need for the use of synthetic fertilizers which are expensive and contribute to GHG emissions.

Farmers need to be trained on better methods of composting and managing the manure to reduce and avoid unnecessary loss of nutrients. Lots of nutrients in the manure are lost through vaporization when it is left exposed in the open, and thus contributes to the emission of GHGs. Manure produces methane and nitrous oxide, which have a negative impact on the environment. Manure can also be hazardous to human health and water quality. Placing manure in the root zone below the ground surface can help minimize the evaporation and vaporization of nutrients; thus ensuring the continuous release of adequate nutrients during the entire period of crop growth.

Efficient treatment of manure can reduce the emission of GHGs and raise agricultural productivity. For example, the installation of biogas digesters will ensure anaerobic digestion of manure leading to the production of methane which is a combustible gas that can be used to provide energy for household cooking and lighting. The slurry provides ready soil nutrients.

The baseline survey indicated that the majority of farmers (87%) in the area use manure on their own fields for crop and fodder production. Three-quarters of the farmers use manure for the

construction of walls, especially animal barns. Some of the farmers discard manure carelessly leading to environmental pollution. A few farmers use manure as a source of cooking fuel and a few have biogas units. Some farmers pile up the manure to decompose before using it on crops. However, most of the manure goes on pasture because cattle are grazed in paddocks. It is not easy to gather and collect manure when livestock is raised in paddocks or grazed on communal land. Most of the nutrients from the manure are lost when exposed to the sun or through erosion during the rainy season. To ensure better utilization of the manure, the project needs to promote confined grazing systems especially the zero-grazing units, together with breeding services. This would allow the installation of biogas units for the generation of energy. Use of biogas also enables the proper decomposition of manure for improved crop and fodder production. The rapid appraisal exercise revealed that farmers at Kaptumo pilot site apply manure on fodder, especially Napier grass. Cash crops such as tea, maize and vegetables that have a ready market were given priority in the application of inorganic fertilizer. Application of inorganic fertilizer is done in a judicious manner since it is expensive and is therefore only applied when the economic gains are quite clear.

It is necessary to conduct awareness and training on improved management and application of manure including the choice of crops to grow using that manure (Box 1). Farmers need to be educated on the best options of handling and using manure to improve soil fertility and in some cases to generate energy for domestic cooking and lighting.

Box 1. Improved practices of manure application: vegetable and fruit production in kitchen gardens ("kabugut")

The ever-increasing human population needs to be fed and this calls for strategies that will promote intensive land use systems that optimize agricultural productivity. 'Bio-intensive gardens' can be used to produce large quantities of vegetables and fruits per unit area. The gardens are established through the practices of double-digging where soils are dug deep enough to break the hardpan to allow better infiltration of soil moisture. A standard double-dug plot is 1m wide by 8m long and 0.6m deep. For such a plot the farmer needs to use five wheelbarrows of well-decomposed manure that should be mixed thoroughly with the topsoil. The soil is then levelled neatly and the seeds of appropriate vegetables planted. If termites are not a problem in the area, mulching using dry grass can be applied to ensure better retention of soil moisture and nutrients. The practice is ideal where the most limiting factor to production is land and/or labour availability.

The bio-intensive gardens are important investments for a sustained supply of household vegetables, fruits and herbs. The labour requirements and costs for establishment and management of bio-intensive gardens are minimal and thus ideal for women, the elderly and youth. Some bio-intensive gardens can be introduced in the pilot site for the production of local vegetables such as the amaranth, black night shade, *saget* and *mrenda*. Exotic vegetables include spinach, kale, lettuce, carrots, radish, rutabaga, turnips, tomatoes, beetroots, cucumber and eggplant. Herbal plants include garlic, rosemary, Russian comfrey, parsley, *dania*, stinging nettle and lemon grass. Fruits include pawpaw, passion fruits and custard apple. A combination of vegetables, fruits and herbs ensures that the household gets the required quantities of minerals, vitamins, trace elements and fibre. The bio-intensive gardens can be a sustainable source of household vegetables and fruits. There is the possibility of increasing family income through the sale of surplus produce from the kitchen gardens.

3.5 Conservation agriculture practices

Conservation agriculture (CA) involves a combination of farming practices and tools that involve minimum soil disturbances. It provides opportunities for improving food security through intensification of sustainable food production and for contributing to climate change adaptation and mitigation. Conservation agriculture is ideal in the mixed farming of crops, livestock and agroforestry farming systems. Use of cover crops to suppress weeds in CA practices helps to improve the agricultural efficiency by saving labour, time, effort and funds required for land cultivation. The saved resources can be reallocated to more profitable enterprises such as dairy farming. In broad terms, the benefits from CA can be categorized into environmental and economic benefits, but the ultimate gains are increased incomes, food security, adaptation and mitigation of climate change.

CA practices include the following:

a) Minimum tillage that is characterized by minimal soil disturbance. Avoidance of tillage minimizes the occurrence of net loss of carbon dioxide by microbial respiration and oxidation of the soil organic matter and builds soil structure and biopores through soil biota and roots. It saves on energy used in land preparation and cultivation thereby reducing emissions from farm machinery (when used) and burning crop residues. The crop residues can be fed to livestock or used for mulching. Moreover minimum tillage helps in carbon sequestration in the soil.
b) Mulching, where crop residuals are left to provide protective cover to the soil, helps suppress weeds, reduce loss of soil moisture through evaporation, keeps the soil cooler and thus protects crops from extreme temperatures, shields the soil surface from strong winds and rain and thus reduces soil erosion and the risks of flooding. The mulch facilitates rain water infiltration and the deeper rooting of crops. It also provides a substrate for soil-inhabiting micro-organisms which helps to improve and maintain water and nutrients in the soil. This contributes to the net increase of soil organic matter derived from carbon dioxide captured by photosynthesis in plants, whose residues above and below the soil surface are subsequently transformed and sequestered by soil biota. However, adequate crop residuals may not be available for farmers who use crop residuals to feed their livestock. Since both practices of mulching and feeding livestock with crop residuals are beneficial to the farmers, there is need to strike a balance on the amount of residuals to be used as livestock feed and the amount used for mulching crops in case the farmer has practised both.
c) Cover crops can be used to suppress weeds and to facilitate retention of soil fertility and moisture in the crop land. They help to improve soil fertility and therefore allow the farmer to cut down on the amount of inorganic fertilizers required for crop production. Leguminous cover crops can have tremendous improvements to soil fertility through nitrogen fixation and decomposition of the litter. Cover crops can be used to suppress the weeds by physically shading them and through allopathic effects. Some plants produce certain types of chemicals especially through the litter fall and by so doing they eliminate other plant species (weeds). For example, a noxious weed known as striga reduces maize production drastically; it thrives best in poor soils that are deficient in nitrogen. Striga can be eliminated by introducing leguminous plants such as desmodium into the fields that are infested.

   Some of the cover crops can also be used to feed livestock. Introduction of cover crops in the farming system and the non-disturbance of the soil ensure sustained land productivity through increased soil water infiltration capacity, improved retention of soil moisture and reduced soil erosion. Cover crops reduce the rate of evaporation and thus considerably reduce moisture stress in crops, enhance the maintenance of soil fertility, improve the soil structure and increase the levels of ground water, thus ensuring continuous stream flows all year round. They assist in breaking compacted soil layers and the hard pan, therefore

increasing the percolation of water into the soil. Leguminous cover crops improve soil organic matter through nitrogen-fixation and the litter fall and since they have low C/N ratio they decompose quickly adding more organic matter to the soil. Cover crops buffer the soil pH improving nutrient availability to the crops that would otherwise be locked up in acidic soils especially the phosphorous. They protect the soil from the impacts of rain and scorching sun during the fallow period. They help in the mobilization and recycling of nutrients especially phosphorous and potassium. Cover crops capture carbon dioxide from the atmosphere and therefore help to fix carbon in the soil making the ground a sink for carbon dioxide which helps in mitigating global warming (Abrol et al., 2005).

Examples of effective cover crops include leguminous fodder shrubs such as *Gliricidia sepium, Calliandra calothyrsus, L. trichandra, L. diversifolia*, *Chamaecytisus palmensis* (tree lucerne), *Cajanus cajan* (pigeon pea) and *Sesbania sesban.* The non-fodder shrubs include *Tephrosia vogelli*, *Tephrosia candida* and *Crotalaria grahamiana*. The herbaceous legume species include *Desmodium intortum* (Green leaf desmodium), *Desmodium uncinatum* (Silver leaf desmodium), *Dolichos lablab*, *Vigna unguiculata* (cow peas) and *Vicia sativa* (common vetch).

At the time of the rapid appraisal, there were only a few farmers in the pilot site who had planted some of the cover crops for feeding livestock. These include desmodium and calliandra. The project needs to promote the planting of appropriate species and assist the farmers to access the planting materials. It would be useful for the project to conduct species screening to identify more appropriate species that have the potential to serve as both fodder and cover crops.

d) Crop rotation where a sequence is established in planting different types of crops on a given piece of land. In most cases, legumes (nitrogen-fixing crops) including trees and shrubs are planted after the harvesting of crops that do not fix nitrogen. The legumes host nitrogen-fixing bacteria in their root systems, therefore enriching the soil with nitrogen which is essential for plant growth. This cuts down the need for nitrogen-based fertilizers and thus reduces the GHG emissions induced by fertilizer production. Different types of crops take up different amounts of nutrients from the soil and thus crop rotation helps in soil nutrient management. Crop rotation over several seasons helps to minimize the outbreak of pests and diseases.

Information gathered through the rapid appraisal exercise indicated that there were diverse ways in which crop residuals were being handled by the farmers in the project site. These included burning crop residuals during land preparation before the planting of food crops. This practice was most common in the lower parts of the division especially at Kapsoas and Kapkorei locations. Some of the farmers used crop residuals especially the maize stovers for household

cooking. Some farmers fed crop residuals to livestock while others incorporated crop residuals into the soil with the aim of improving soil fertility. Few farmers used crop residuals in combination with animal manure to make compost manure. Some of the farmers were collecting crop residuals for free from their neighbors to feed their livestock. Such practices can lead to the mining of soil nutrients from one farm.

The baseline survey conducted in the pilot site revealed that more than 90% of the households had some ideas about the practices of conservation agriculture. The common CA practices known to the farmers included ridge cultivation (93.8%), planting in rows (91.0%), planting hedge rows (91.2%), application of manure (90.4%), crop rotation (83.9%) and timely weeding (80.7%). Almost all the interviewees had indicated that they apply fertilizer in their fields. The farmers diversified the crop species and varieties as a coping mechanism in case of crop failure resulting from variations in rainfall amounts and distribution. The majority of households (78%) planted up to six types of crops. Maize was the predominant crop (23.2%), followed by beans (14.9%), bananas (12.2%) and tea (12.1%). Most of the manure was being applied to the Napier grass and bananas, whereas the fertilizer and other inorganic matter were mostly applied to maize and tea, the predominant cash crops in the area.

The more affordable options include crop rotation and use of cover crops since the two have low capital and labour requirements.

3.6 Improving livestock production efficiency and resilience

Livestock, mainly ruminants, is a major source of employment, income, food and manure for crop production in the community. Estimates indicate that livestock systems occupy approximately 30% of the earth's terrestrial surface area and account for 8% of the total use of fresh water (Thornton and Herrero, 2010). However, livestock systems have been found to be responsible for the largest global source of methane emissions resulting from ruminant digestion and poor management of the manure. Their contribution towards the climate change problem is estimated to be about 14.5% of the global anthropogenic (human causes) greenhouse gas emissions (FAO, 2013). The main sources and types of greenhouse gases from livestock systems are carbon dioxide (CO_2) from land use changes (feed production, deforestation), which accounts for 9.2% of emissions from the livestock; nitrous oxide (N_2O) and methane (CH_4) from manure and storage processing, which accounts for 10% and methane production from ruminants, which accounts for 40% of emissions. Emissions from the production, processing and transport (N_2O and CO_2) of feed account for 45% of the sector's emissions (FAO, 2013).

The demand for livestock products in developing countries will nearly double by 2050 as a result of human population increases, urbanization, dietary preference, and increasing incomes (Thornton and Herrero, 2010). This poses a great challenge to ensure that livestock products will be produced in a sustainable manner without negative effects on the environment. Thornton and Herrero (2010) estimate that the maximum mitigation potential of these options in the land-based

livestock systems in the tropics amounts to approximately 7% of the global agricultural mitigation potential by 2030. Using historical adoption rates from the literature, the plausible mitigation potential of these options could contribute approximately 4% of global agricultural GHG mitigation.

Most of the areas with high livestock densities experience land degradation and deforestation as a result of overgrazing the pasture land. This requires significant changes in production technology and farming methods that are currently in place with the aim of reducing GHG emissions. There is thus need to reduce the incidences of over-grazing and deforestation. This can be achieved by increasing livestock productivity so that fewer animals are raised to produce the required milk and meat leading to a reduction in the amount of GHG emissions. The interventions mainly involve keeping fewer but more productive animals in order to reduce the overall methane, nitrous and carbon dioxide gases produced and emitted from the livestock. The interventions include intensification of livestock feeds, improved management of pastures and replacement of poor breeds with high producers. The interventions are likely to result in increased carbon sequestration through the restoration of degraded rangelands and changes in land uses. The impacts from a combination of various interventions can greatly reduce the total amount of GHG produced by livestock. However, there is need to address cultural barriers since the local community in the pilot site regards livestock numbers as a measure of wealth and a form of asset to manage risks.

However, the carbon footprint of livestock varies considerably among production systems, regions, and commodities, mainly due to differences in farming practices and supply chain management, e.g. feed production practices (FAO, 2013).

Details of some of the suggested interventions involve the following:

(a) The intensification of the diets taken by the dairy livestock can lead to an increase in milk production thereby requiring fewer animals to produce the same amount of milk. Livestock feeds in the tropics are varied and depend to a great extent on the type of production system in which the animals are kept. Most of the available feeds are derived from low quality pastures and crop residues that are fibrous and deficient in nitrogen, minerals and vitamins. However, the poor feeds can be improved by supplementing them with nitrogen, carbohydrates, minerals and vitamins. Fibrous feeds can be improved by supplementing them with urea and molasses in the form of urea-molasses mineral blocks. The mineral blocks increase production of milk and meat and promote higher reproductive efficiency in ruminant animals including cattle, sheep and goats (FAO, 2010).

The baseline survey indicated that most of the available feeds were of low quality and mainly included the natural grasses found in paddock pastures and Napier grass planted on the farms. About 64% of the farmers kept cattle in paddocks and thus practised semi-confined cattle

management systems. Adoption of a confined grazing system was very low (less than 1%). About two-thirds of the farmers fed their cattle with Napier; a third fed them with crop residues. About three-quarters of the households supplemented livestock feeds and a quarter used concentrates. Only a small fraction (4%) of the farmers processed home-made rations that mainly consisted of molasses and sweet potato vines, dairy meal and maize bi-products. It was evident that the available feeds were deficient in protein and thus limited the realization of milk production potential of the dairy cattle in the area. Therefore there is a need to supplement the available feeds with high protein feeds such as the fodder shrubs, herbaceous legumes and where necessary with commercial concentrates for high-producing animals. Research has proved that fodder shrubs and herbaceous legumes are cheap sources of protein that can substantially improve the quality of the animal diets leading to significant increases in milk production (Wambugu et al., 2011).

Dairy farmers need to be trained on the proper use of crop residues including the use of molasses to improve its palatability and digestion. Crop residues can help to increase livestock productivity and in addition crop productivity through improved nutrient recycling processes. Other strategies include improvement of pastures by planting high yielding grasses such as oats, Rhodes and Napier grass. The respondents felt that it was expensive to produce fodder on the farms. High-yielding livestock can be fed with grain-based supplements, where applicable, such as wheat bran, pollard and dairy meal, which have high energy values.

The MICCA pilot project should intensify the promotion of the use of herbaceous legumes, fodder shrubs, crop residues and encourage formulation of cheap home-made rations. In conjunction with breed improvement this would ultimately lead to increased dairy productivity resulting in reduced cattle numbers and subsequently reduced GHG emissions.

(b) Restoration of degraded rangelands has substantial climate change mitigation potential, owing to the magnitude of the degraded pastures of the rangelands in sub-Saharan Africa (Thornton and Herrero, 2010). Replacement of poor pastures with better ones coupled with the reduction of the number of livestock has the potential to reduce the destruction of forest resources in these areas because less land would be required to maintain fewer but more productive animals. The forest margins need to be sowed with improved pasture in order to save the forests from further destruction in the future.

(c) Animal genetic improvements have a limited contribution towards the reduction in the amount of methane emissions by livestock. Breeds with high milk and meat production are usually large in size and have a higher live weight of about 500kg compared to low milk producers that are smaller in size and have a live weight of about 250kg. Replacing low producing milk and meat cattle with high producing ones is likely to result in modest reductions in the amount of CH_4 produced per ton of milk or meat produced. As a result, differences in CH_4 produced per animal

per year is 38.7kg CH_4 for small cows compared to 68.5kg CH_4 for large cows, thus the CH_4 output per unit of animal product does not change significantly (Thornton and Herrero, 2010). However, the larger animals often produce many more times as much milk and meat than the smaller ones, and thus many fewer large animals are required to meet the demand. This option of substituting large animals for small ones potentially could be applied across large areas. The maximum mitigation potential is estimated to be 19Mt CO_2-eq (Thornton and Herrero, 2010).

3.7 Energy and other measures

A survey conducted by the Kenyan Ministry of Energy in 2002 indicated that about 88.4% of the rural population and 9.6% of urban population rely on fuelwood, whereas 80% of urban households and 34% of rural households rely on charcoal as their main source of cooking energy (COMPETE, 2009). Smallholder farmers in Kenya rely mainly on fuelwood, charcoal and crop residues for cooking and paraffin for lighting the house. Other convenient sources of energy such as liquefied petroleum gas (LPG) and electricity are too expensive for the majority of smallholder farmers. Over-reliance on fuelwood has resulted in the depletion of wood resources. Nation-wide, consumption of wood fuel in 1980 was estimated at 21 million tons with a per capita consumption of more than one ton in a year translating to 2.7 kg per person per day. Replacement rates within the same period were estimated at only 60%, meaning that the available wood fuel stocks were rapidly diminishing (Karanja and Kiruiro, 2003). A later study indicated that the average national fuelwood consumption was at 1.5 kg per person per day (COMPETE, 2009). This reduction in per capita consumption may be attributed in part to the increased use of improved types of cooking stoves that cut down the amount of fuelwood used in cooking.

The baseline study conducted in the pilot area indicated that almost all the households (98.6%) were using fuelwood as their main source of cooking energy and 1.4% of households were using charcoal. The average per capita wood consumption was 3.1kg per day in the baseline study, which was much higher than the national average of 1.5kg. On this question some errors might have occurred in the baseline study biasing the estimate upwards. Very few households (0.56%) were using biogas and 0.56% were using solar but in combination with either fuelwood or charcoal. Only 4.5% of the households were connected to electricity power.

The above scenario justifies the exploration and exploitation of alternative sources of energy that do not emit GHG. These are primarily bio-energy, solar, wind and hydro-power. In relative terms, biogas, solar and wind hold the greatest promise. However, their potential use is still under-exploited. Other measures include the conservation of the woody biomass through the installation of energy-saving stoves and the use of fireless cookers.

Below are the highlights for some of the cheap sources of energy and strategies that can ensure energy conservation.

Energy-saving stoves

Fuelwood is the predominant fuel of choice in the majority of households in most of the sub-Saharan African nations. The combustion of fuelwood often takes place in open stoves and is thus characterized by low energy density and low total combustion energy efficiency, often between 10% and 20% (COMPETE, 2009). As described above, almost all the households (98.6%) in the pilot area use fuelwood as their main source of energy with average per capita wood consumption of 3.1kg per day which was much higher than the national average of 1.5 kg. A survey conducted in 2006 in Kenya indicated that 96.8% of the population use fuelwood for cooking and 87.5% of that population use the traditional three-stone cooking stoves that are quite wasteful and uneconomical in the use of energy. The smoke produced in the combustion of fuelwood deposits carbon in the lungs and is known to cause chronic bronchitis, emphysema and chronic obstructive pulmonary disease. Thus, there is need to improve the cooking stoves to ensure that smoke is directed outside the kitchen. Charcoal is used by 80% of the Kenyan urban households and 34% of rural households. The annual consumption of charcoal has been estimated at 2.4 million tons valued at KSh 36 billion (Republic of Kenya, 2002). However, there is need to improve the inefficient traditional earth mound kiln that yields charcoal at the rate of about 10%-25% of the wood processed. In contrast, the Casamance earth kiln yields about 25%-31%.

Results from a study conducted by the Ministry of Energy in 2002, showed that only 4% of the population used improved stoves with an average firewood consumption of 1.2kg per person per day. Luckily, the traditional cooking stove for the Kalenjin community, in the project area, known as *chepkube* has an inherent characteristic of conserving energy. The stove has two or three chambers that keep the food warm after cooking and uses less fuelwood than other stoves, thus ensuring that most of the heat is directed to the cooking pot. Above the cooking stove, there is a place for drying fuelwood known as the *tabut,* which ensures that it burns easily with less smoke. The drying of fuelwood before it is used helps to increase its calorific value and makes it more hygienic to use as it produces less smoke. Use of energy-saving stoves is critical since they can significantly cut down the use of wood. It is expected that the majority of households can easily adopt the much improved energy-saving stoves.

Biogas energy

Biogas is generated from anaerobic digestion of organic materials ranging from animal manure, green plants, wastes from agro-industries and slaughterhouses. The biogas mainly consists of methane (CH_4) gas which is light, colorless, odorless and highly flammable. It is a combustible gas commonly used for cooking stoves and gas lamps. Biogas can be used to drive farm machinery such as the chaff-cutters and water pumps. Ordinarily, organic matter decomposes in open-air (aerobic) conditions with carbon dioxide (CO_2) and water (H_2O) as the main by-products, and with limited amounts of other gases. The composition of the biogas depends on the chemical composition of the substrate, but on average biogas from cattle waste consists of 50-

75% methane, 25-45% carbon dioxide, 2-8% water vapour and traces of N_2O, NH_3, H_2 and H_2S. Natural gas contains 80-90% methane and thus has higher calorific value than biogas. It is desirable to have higher methane content in biogas. The presence of small amounts of carbon dioxide and water vapour is unavoidable but sulphur compounds (mainly H_2S) must be minimized, particularly if the gas is meant to be used to drive farm machinery. H_2S corrodes metals leading to damage of machinery. When methane is burnt to produce energy for cooking and lighting, it is converted into CO_2 and water which are safe for the environment.

On smallholder farms, biogas is derived mainly from anaerobic decomposition of livestock waste (dung, urine and wasted feeds). Biogas burns well when the methane content is greater than 70%. In addition to the biogas, slurry is also produced. It is high quality manure that releases nutrients that are easily absorbed by the crops. The production of biogas has a high potential to provide a cheap source of household energy for cooking and lighting in addition to improving soil fertility for increased crop production. Biogas technology works best under a confined grazing system since it enables easy collection of cow dung that needs to be placed in the bio-digester to undergo anaerobic decomposition. Biogas technology is a cost-effective investment if the bio-digester plants are properly constructed, effectively operated and well maintained.

In Kenya, biogas production was introduced more than 30 years ago, but its widespread adoption has been hampered by inadequacy of information on its production, potential benefits and the prohibitively high costs of earlier designs. Initially, there were two types of biogas systems that were promoted; i.e. the float-drum type (Indian digester) and the fixed dome type (Chinese digester). The most widely disseminated type in Kenya is the floating drum. In the late 1970s and early 1980s, the Ministry of Energy conducted studies on energy demand and supply in Kenya. In the early 1980s, the ministry demonstrated biogas production technology all over the country. Currently, only about 25% of the installed biogas units in Kenya are operational, giving the technology a negative image.

A low-cost tubular plastic (TP) bio-digester was developed in Colombia and the technology was promoted in Kenya and Tanzania in the late 1980s by FAO and the SIDA Farming Systems Programme. Experiences at KARI-Embu have indicated that a biogas system fed by two dairy cows would produce enough gas to cook light dishes such as tea, rice and porridge on daily basis. The TP bio-digester for two cows under confined grazing is about $5m^3$ and will produce cooking gas for about three hours continuously. The cost of installing a TP biogas system varies but the cost at Embu was between KSh5000 and KSh6000 in 1997 depending on whether materials were bought at wholesale or retail prices. This was about 10% of the cost of the conventional floating or fixed dome biogas units (Karanja and Kiruiro, 2003). Currently, KENFAP in collaboration with Hivos and SNV have been funded by the Dutch Ministry of Foreign Affairs to implement the Kenya National Domestic Biogas Programme (KENDBIP). The costs for installing fixed dome biogas units through KENFAP were as follows: US$730 for

4m³ units, US$990 for 8m³, US$1350 for 12m³ units. These figures were calculated at the exchange rate of KSh83 per US$1 and excluded the costs of digging the pits and payments for unskilled labour.

The baseline study at Kaptumo pilot site identified a farmer who was generating biogas from three cows kept under a semi-zero-grazing system, proving that it is technically feasible for smallholder dairy farmers to produce adequate biogas for household cooking and lighting. The cost of investment in a small biogas digester can be recovered, at least in part, from increased milk production resulting from improved feeding practices and improved dairy breeds.

Experience has indicated that continued use of the biogas units is linked to carefully planned dissemination and monitoring strategies. Most of the biogas units that were introduced in the past are still in use in areas where the project had put mechanisms in place for continued monitoring and support to the end users after the installation. The potential for the use of biogas is restricted to farmers who can afford the initial costs associated with construction of biogas units.

Solar energy

There is need to promote the use of solar energy by linking the local community to the private sector. Solar energy can be used for lighting and for heating water for bathing and milking. This type of energy is environmentally-friendly as it does not lead to the emission of GHG. Being close to the equator, the pilot site has access to solar energy for 12 hours daily, every day of the year. Solar energy is therefore in abundance, cheap and easy to access. However, an initial investment is needed by the project to attract the private sector to demonstrate the cost-effectiveness of using the solar energy. The private sector can be linked to the dairy groups so that functional mechanisms can be developed to avail credit facilities to the farmers in the form of solar devices.

Bio-energy fuel generation

Appropriate tree and shrub species such as jatropha, castor, coconut and *Croton megalocarpus* in addition to other plant species such as rapeseed, soybean, sunflower, coconut, linseed, cotton seed and ground nut can be harnessed to produce energy for lighting and cooking and for driving and lubricating automobiles and stationary machines. The plants help in carbon sequestration while their fruit is used to produce biofuels. However, the project should be careful not to promote the use of crops such as sunflower, maize and other food crops to ensure that food security is not compromised at the expense of biofuel generation.

The use of biomass energy has the potential to greatly reduce GHG emissions. Biomass generates about the same amount of carbon dioxide as fossil fuels, but every time a new plant grows, carbon dioxide is removed from the atmosphere. The net emission of carbon dioxide will be zero as long as plants continue to be replenished for biomass energy purposes. The use of

biomass feed-stocks (energy crops) can also help to increase the profitability of agricultural industries. The bi-products from oil extraction can be used as animal feed and as organic fertilizers.

Protection of the wetlands

Wetlands are found in the pilot area such as Kibirong swamps. The wetlands have been encroached by farmers for agriculture and have greatly diminished over the years. It is clear from the area topography that the Kibirong swamp is an important water catchment that needs to be protected through rewetting and re-vegetation. Possibly the community can be assisted to enact a policy that will result in the fencing of the wetlands, forbid water diversion, and plant appropriate vegetation that will restore the wetlands to their original status and contribute to carbon sequestration.

3.8 Climate-smart agriculture practices: farmers' priorities and features of main practices

As mentioned above, farmer meetings were held at Kaptumo Community Social Hall, Kaptumo Location and in Kapsoiyo village, Koiyo Location to identify climate-smart agricultural practices important to them and to rank practices based on their ease of adoption. Farmers at Kaptumo Community Social Hall appeared more knowledgeable about climate-smart agriculture practices than those in Koiyo. Rankings were fairly similar with both groups listing feeding and animal husbandry in first place, followed by agroforestry/tree planting (Table 2). Manure management was ranked third and improved stoves fourth in Koiyo while the order was reversed in Kaptumo.

Table 2: The identification and ranking of climate-smart agricultural practices by farmers according to importance and ease of adoption

Kapsoiyo Village, Koiyo Location	Kaptumo Location
1. Better feeding and improved animal husbandry	1. Better feeding, selective breeding and improved health care for livestock
2. Agroforestry practices by increasing tree planting in the crop lands	2. Reducing the rate of deforestation and increasing the rate of on-farm tree planting
3. Better management of manure	3. Use of energy conservation devices such as improved traditional stoves
4. Energy conservation practices such as use of improved stoves	4. Better management of manure through improved practices of manure composting
5. Installation of biogas units	5. Conservation agriculture practices including the minimum tillage and soil conservation practices
6. Installation of solar energy devices	6. Nutrient recycling process especially better management of crop residuals by avoiding burning of the crop residuals during land

	preparation and feeding them to livestock
	7. Installation of biogas units
	8. Installation of solar energy devices

Table 3 outlines the main features of the climate-smart practices, based on the views of farmers, scientists and other key informants. On-farm tree planting contributes significantly to greenhouse gas reduction and strategies to adapt to climate change. Resource requirements are relatively high during the first year due to establishment costs, but are low thereafter. Ease of adoption is high as many farmers have already planted trees on their farms. Manure management and soil nutrient recycling have a high potential to increase farm productivity, have a medium-to-high potential to contribute to greenhouse gas reduction and adaptation strategies and low-to-medium resource requirements. Ease of adoption is rated as medium. Conservation agriculture can also contribute significantly to greenhouse gas reduction and to adaptation strategies. But knowledge requirements are high and CA has not been adequately tested in the study area. Its ease of adoption is medium. Improved livestock practices vary considerably in their potential to reduce greenhouse gases, their contribution to strategies to adapt to climate change and their resource requirements. All are scored medium-to-high in their overall ease of adoption. Improved grasses and fodder shrubs are the practices with the highest overall ease of adoption. Energy conserving stoves make low contributions to farm productivity but have medium-to-high potential for reducing greenhouse gases and contributing to climate change adaptation. They have low resource requirements and are likely to be easily adopted. Alternative energy sources, such as biogas and solar, have little to do with increasing farm productivity but have high resource requirements and thus rank relatively low on ease of adoption.

Overall, the table shows that there are many promising climate-smart agricultural practices that farmers can adopt fairly easily. The main constraints appear to be farmers' lack of knowledge of how to implement the practices and lack of initial capital.

Table 3: Features of climate-smart agriculture options at Kaptumo Pilot Site[2]

Practice	*Potential to increase farm productivity*	*Potential to reduce CO_2*	*Potential to reduce CH_4*	*Potential to reduce N_2O*	*Contribution to Adaptation to Climate Change, e.g. increased rainfall variability*	*% of Kaptumo farmers using option*	*Land reqt*	*Labour reqt*	*Capital reqt*	*Knowl reqt*	*Overall ease of adoption*	*Remarks*
Agroforestry												
On-farm Tree planting	Medium	High	High		High	High	Medium	Medium	Medium	Medium	High	Easy to initiate but benefits long-term
Improved manure and nutrient recycling practices												
Proper manure management	High	Medium	Medium	Medium	High		Low	Medium	Medium	High	Medium	Easy but often ignored
Nutrient recycling processes	High	Medium	Medium	Medium	Medium		Low	Low	Low	High	Medium	Reqs awareness & education
Conservation agriculture												
Conservation Agriculture	High	High	Medium	Medium	High	Low-medium	Low	Low	Low	High	Medium	Reqs awareness/ education
Livestock production practices												
Fodder shrubs	High	Medium	Medium	Medium	High		Low	Low	Low	Medium	High	Easy to establish
Herbaceous legumes	High	Medium	Medium	Medium	Medium	Very low	Low	Low	Medium	Medium	Medium	Germplasm required
Improved grass such as Napier grass	Medium	Low	Low	Low	Low	67%	Medium	Medium	Low	Medium	High	Community knows benefits of Napier grass
Commercial concentrates	High	Medium	Medium	Medium	High	25%	Low	Low	High	High	Medium	Expensive to buy and transport

[2] Information is based on data collected from farmers, key informants and scientists

Practice	*Potential to increase farm productivity*	*Potential to reduce CO_2*	*Potential to reduce CH_4*	*Potential to reduce N_2O*	*Contribution to Adaptation to Climate Change, e.g. increased rainfall variability*	*% of Kaptumo farmers using option*	*Land reqt*	*Labour reqt*	*Capital reqt*	*Knowl reqt*	*Overall ease of adoption*	*Remarks*
Livestock genetic improvement (breeding)	High	Low	Low	Low	Low	High	Medium	Low	High	High	Medium	Can lead farmers to keep fewer but high producing animals
Restoration of degraded rangelands	Medium	Medium	Medium	Medium	Medium		Medium	Medium	Medium	Medium	Medium	Only small section of pilot site is eligible
Energy practices												
Energy conserving stoves & fireless cookers)	Low	High	Medium		High		Low	Low	Low	Medium	High	Well promoted & easy to avail devices
Biogas production	Medium	Medium	High	Medium	High	0.56	Low	Medium	High	High	Low	Expensive initially. Past failures
Solar energy	Low	High	High	High	High	0.56	Low	Low	High	Medium	Low	Not well known
Bio- fuels	Medium	High	High	Medium	High		High	Medium	Medium	Medium	Low	Expensive initially. Awareness reqd
Wind energy	Low	High	High	High	High		Low	Low	High	Medium	Low	Expensive initially. Awareness reqd
Micro-hydro power	Low	High	High	High	High	Few	Low	Low	High	Medium	Low	Mainly involves the govt

3.9 Relevant institutions that can support the MICCA Pilot Project

Key institutions that could support the pilot project include the Ministry of Agriculture, Livestock and Fisheries, Kenya Forest Services (KFS), and the county administration. Local NGOs that may have extension services in the area could also be quite instrumental in the dissemination and adoption process. Other organizations in the area are discussed below.

Baraton University

The university is located about 5km from Kapsabet town. It majors in training agricultural students mainly at diploma and degree levels. The university has two relevant faculties that can partner with the MICCA project. These include the Faculty of Agriculture and the Faculty of Science and Technology. The institution has good training facilities including halls, accommodation facilities, a demonstration farm of 350 acres, livestock with 160 dairy cows and 1,800 poultry. Vegetables are produced under greenhouses. The university plans to install biogas, wind and solar energy units. It also intends to generate adequate biogas energy for cooking and driving various farm machinery including the chaff-cutter and machines for processing cheese, ice cream and milk pasteurization. Installation of biogas and solar energy would assist the institution to save on the costs of milk production and processing.

Moi University/Christian Intermediate Technology Centre (CITC)

The Centre is based at Kapsabet Town and is sponsored by the Anglican Church and Moi University. It specializes in appropriate technologies such as making energy conservation devices, constructing biogas units, using cheaper materials for house construction, and promoting cheap water pumps and water harvesting techniques. MICCA can partner with the Centre to improve the traditional cooking stoves locally known as *chepkube*. The Centre can also partner with MICCA to develop low cost biogas units and solar technologies. The Centre has technicians that are well trained in biogas production technologies.

CITC and Baraton University can be used as training and demonstration centres for energy-saving devices and the generation of renewable energies including biogas, solar and wind power. Wind energy can be tapped mainly during the dry season in the months of December to March, but the solar and biogas energies can be generated throughout the year.

Kapcheno Dairies

The dairy society receives 4,000 litres per day during the dry season and more than 9,000 litres during the wet season. The management hopes to recruit more members and improving dairy productivity through better livestock feeding regimes. The MICCA project can use the dairy society to train farmers and to distribute fodder planting materials. The installation of biogas and solar units in addition to the distribution of energy-saving stoves can be implemented through Kapcheno Dairy Society.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The Capacity Needs Assessment conducted by the MICCA programme in partnership with EADD identified the project entry points and recommended capacity development activities aimed at promoting climate-smart agricultural practices. Constraints identified in agricultural production included a decline in crop yields resulting from soil erosion, misuse of fertilizers and inappropriate use of manure. There was need to train the community on proper management of organic and inorganic fertilizers, application of soil conservation measures and the proper handling of crop residuals.

To ensure success in adoption of climate-smart agriculture and other practices that have a low or no emission of GHG, the MICCA project should strive to build the technical capacity of the beneficiaries to enable them to handle the challenges of adaptation and mitigation of climate change. Awareness creation and training on climate change adaptation and mitigation is critical and should include mechanisms and systems of information sharing through farmer exchange visits, demonstrations and on-farm trials. One sure way of catalyzing the adoption rate is to involve the beneficiaries in the farmer-to-farmer extension approach. The dairy groups can be used for the training of trainers in a similar way to the Farmer Field School (FFS) approach, where selected farmers facilitate the learning process of their peers. There is a need to empower the farmer trainers at the village level by helping them to test and adopt recommended technologies. For instance, a farmer trainer should be encouraged to plant adequate fodder shrubs and herbaceous legumes that have tangible impacts on milk production. This will help to demonstrate to other farmers the potential benefits from the adoption of such innovations and technologies. The farmer trainers should be encouraged to install biogas and solar units. Selected farmer trainers who have demonstrated some propensity to venture into entrepreneurship need to be encouraged to sell fodder seed and seedlings so as to enhance seed supply in the pilot area.

There is need to avail micro-credit facilities to ensure that the farmers are in a position to purchase, install and maintain the recommended devices and structures. The administration of the credits and enforcement of the repayment should be done through the dairy groups or through credit institutions. The possibility of using a check-off system should be explored whereby the installments for loan repayment are deducted from milk sales.

The project should develop and put in place mechanisms and systems of monitoring and evaluating the its performance. This should be participatory by providing effective channels for feedback between the project and its beneficiaries. Networks on climate change need to be developed and strengthened so as to enhance information sharing and coordination of climate change projects by linking the stakeholders and practitioners from different areas. The newly formed Climate Change Unit in the Ministry of Agriculture, Livestock and Fisheries (MOALF) could play such a role. It is important to initiate collaboration and partnerships between the project and relevant institutions such as Baraton University, Moi University/CITC and KENFAP,

in addition to the government and NGO extension services such as MOALF and the Ministry of Energy (MOE). These institutions can be involved in the training and establishment of demonstration sites on renewable energies including biogas, solar, wind and energy conservation devices.

Some of the institutions such as Baraton University and the CITC have the capacity to train extension staff, technicians and artisans on the installation of renewable energy devices and equipment. There is need to improve the rate of information dissemination by ensuring better extension coverage that will improve awareness creation and capacity building, thus increase the rate of technology adoption in agroforestry practices, the use of fodder shrubs and installation of renewable energy devices and equipment. This may necessitate the establishment of demonstrations at the institutions and community level.

There is a need to distribute more audio-visual aids especially posters, pamphlets, leaflets and technical manuals to improve the dissemination process. The targeted beneficiaries of extension materials include the extension staff, farmer extension providers, dairy groups, etc. The identification and recruitment of demonstration farmers, especially those knowledgeable on agroforestry practices including planting of fodder shrubs and herbaceous legumes, should be fast-tracked.

The project needs to put in place mechanisms for sustainable seed and seedling supply in the pilot area. There is a need to bulk and multiply quality genetic materials of fodder shrubs, herbaceous legumes and tree species. This may involve the identification, recruitment and training of seed dealers and tree nursery operators so as to easily avail fodder and tree planting materials to the farming community.

Finally, there is a broad range of available climate-smart agricultural practices which can help farmers and communities to benefit in terms of increased food security, incomes and resilience, while at the same time reducing greenhouse gas emissions. Farmers are eager to test and adopt the practices and look forward to working with project staff to help them do so.

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World Agroforestry Centre

United Nations Avenue, Gigiri • PO Box 30677 • Nairobi, 00100 • Kenya
Telephone: +254 20 7224000 or via USA +1 650 833 6645
Fax: +254 20 7224001 or via USA +1 650 833 6646
Email: worldagroforestry@cgiar.org • www.worldagroforestry.org