Fig

Republic of Kenya

National Climate Change Action Plan

Mitigation

Chapter 3: Agriculture

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National Climate Change Action Plan:
Mitigation
Chapter 3: Agriculture

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ASB Partnership for the Tropical Forest Margins at the World Agroforestry Centre

ASB is the only global partnership devoted entirely to research on the tropical forest margins. ASB aims to raise productivity and income of rural households in the humid tropics without increasing deforestation or undermining essential environmental services.

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Table of Contents

Abbreviations

AFOLU	Agriculture, Forestry and Land Use
ASAL	Arid and Semi-Arid Land
AUSAID	Australian Agency for International Development
CDM	Clean Development Mechanism
FAO	Food and Agriculture Organization of the United Nations
GDP	gross domestic product
GHG	greenhouse gas
GoK	Government of Kenya
ICRAF	World Agroforestry Centre
IPCC	Intergovernmental Panel on Climate Change
KFS	Kenya Forest Service
MRV	measurement, reporting and verification
MT	Megatonnes
NCCRS	National Climate Change Response Strategy
NGO	non-governmental organization
REDD+	reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries
TNA	Technology Needs Assessment
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development

3.1 Introduction

This chapter is part of a larger analysis of low-carbon development options in Kenya, which covers the six mitigation sectors set out in Article 4.1 of the United Nations Framework Convention on Climate Change (UNFCCC): energy, transport, industry, waste, forestry and agriculture. The holistic, sectoral analysis aims to inform the Kenya Climate Change Action Plan and provides the evidence base for prioritizing low-carbon development options and developing proposals for Nationally Appropriate Mitigation Actions (NAMAs) and reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries (REDD+) actions.

The analysis includes a preliminary greenhouse gas (GHG) emissions inventory and reference case projecting emissions to 2030 for the entire Kenyan economy and by sector. The analysis then demonstrates how low-carbon development options can bend down emissions from the proposed reference case in each sector. Recognizing Kenya's development priorities and plans, the analysis also considers how the various options can contribute to sustainable development. The overall work concludes with the identification of priority actions to enable low-carbon development.

This chapter analyses low-carbon development options in the agricultural sector in Kenya and is one of seven sectoral chapters developed as part of the overall low-carbon scenario analysis. The analysis considers the mitigation of emissions through actions in the subsectors of crops, livestock and agroforestry. Fisheries – a subsector in the Government of Kenya's definition of the agricultural sector – is not included in this low-carbon analysis because of its low mitigation potential. The actions proposed in this sector are closely linked to those in Chapter 4, Forestry, which looks at emissions and low-carbon options for non-agricultural lands.

3.2 Agricultural Sector: Background

3.2.1 Sector Context

Agriculture is a priority of the Government of Kenya because of the sector's importance to food security, rural livelihoods and poverty alleviation. Agriculture is a key economic sector, being the backbone of Kenya's economy and the means of livelihood for the majority of the rural population. Agricultural sector output constituted 22 percent of GDP in 2011, and the sector provides over 70 percent of employment in rural areas.[1] Food security is a priority of the Government of Kenya.

The government's *Agricultural Sector Development Strategy 2010-2020*, explains that the sector has indirect economic effects. Growth in the national economy has historically been highly correlated with growth in the agricultural sector. After a significant growth slump in the 1980s and early 1990s the sector had been growing strongly, averaging a 2.4 percent annual increase in the early 2000s, but this growth slowed in the wake of the 2007 post-election violence and the 2008 global financial crisis.[2]

Farming in Kenya is primarily small-scale, with 75 percent of total agricultural output produced on rain-fed agricultural lands on farms averaging 0.3 to 3 hectares in size. Approximately 16 percent of Kenya's total land area is of high to medium agricultural ptoenential, and this land supports 80 percent of the country's population who depend primarily on subsistence agriculture for their livelihoods. The remaining 20 percent of the population live in the arid and semi-arid lands (ASALs) which comprises 84 percent of the country's land area.[3] These lands are farmed to some degree but are largely utilized as pastoral lands.

The agricultural sector is highly vulnerable to climate change. The high variability of floods and droughts experienced in Kenya in recent decades is likely to increase with climate change. Soil erosion and nutrient depletion are major issues, and food security, a stated goal of the Government, is under threat, partly due to climate change. The combination of deforestation to open up croplands, the extension of agriculture onto land with low potential, and the use of more basic farming techniques and technologies due to cost and capacity barriers make the current agricultural system unsustainable in the long term.[4]

3.2.2 Structure

Government agencies and bodies in the Kenyan agricultural sector include the following, among others:

- Ministry of Agriculture;
- Ministry of Lands;
- Ministry for Livestock Development;
- Ministry of the Development of Northern Kenya and other Arid Areas;
- Ministry of Regional Development Authorities;
- Ministry of Water and Irrigation; and
- The Agricultural Sector Coordination Unit.

The Government of Kenya supports several research institutions in the agricultural sector, such as the Kenya Agricultural Research Institute, Kenya Plant Health Inspectorate Service, Kenya Sugar Research Foundation and Tea Research Foundation. Kenya also benefits from the presence of international agricultural research institutes such as the World Agroforestry Centre and the International Livestock Research Institute.

3.2.3 Policy

In addition to the suite of programmes and interventions introduced in Vision 2030 and its first Medium Term Plan (2008-2012), which are outlined in Section 3.3, the *Agricultural Sector Development Strategy 2010-2020* sets out a detailed plan to "position the agricultural sector as a key driver for delivering the 10 per cent annual economic growth rate envisaged under the economic pillar of Vision 2030".[5] The vision of the document is "a food-secure and prosperous nation" and the strategy aims to:

- Increase productivity, commercialization and competitiveness of agricultural commodities and enterprises; and
- Develop and manage key factors of production.

The agricultural sector is a key sector for increasing GDP and employment. making it a major focal point in government (and non-governmental) projects, policy and planning.

3.3 Development Priorities of the Government of Kenya

Vision 2030 places considerable emphasis on the agriculture as a key sector for attention and intervention, emphasizing the sector's productivity, market development, value addition, and land use issues. This focus reflects the sector's importance in terms of its contribution to GDP, employment and rural livelihoods, and food security. Vision 2030 aims to achieve an innovative, commercially oriented, modern agricultural sector, setting out strategic thrusts in five areas:

- Institutional reforms – transform key institutions into complementary and high-performance entities that enable private sector agricultural growth.
- Increase productivity – increase productivity of crops and livestock.
- Land use transformation – better utilize high- and medium-potential lands.
- ASAL development – strategically develop irrigable areas of ASALs for crops and livestock.
- Increased access to markets – improve access to markets by small holders.

Several high-level interventions are outlined Vision 2030, including the establishment of disease-free zones, efforts to increase value added in agricultural sector production and supply chains, establishment of land registries, and the development of an agricultural land use master plan, among other initiatives.[6]

The first Medium Term Plan 2009-2012 also devoted considerable attention to the agricultural sector with the main objectives of securing livelihoods in rural areas and ensuring food security and employment. The Medium Term Plan outlined a range of programmes that aim to:

- Exploit the agriculture potential in ASAL areas;
- Transform agriculture from a low-income, low-efficiency and low technology sector into a vibrant modern sector supporting value-addition;
- Work towards making fertiliser and other key inputs affordable to poor farmers;
- Enhance knowledge and skills of farmers and extension staff through training and sharing knowledge; and
- Enhance the capacity of districts in food security.[7]

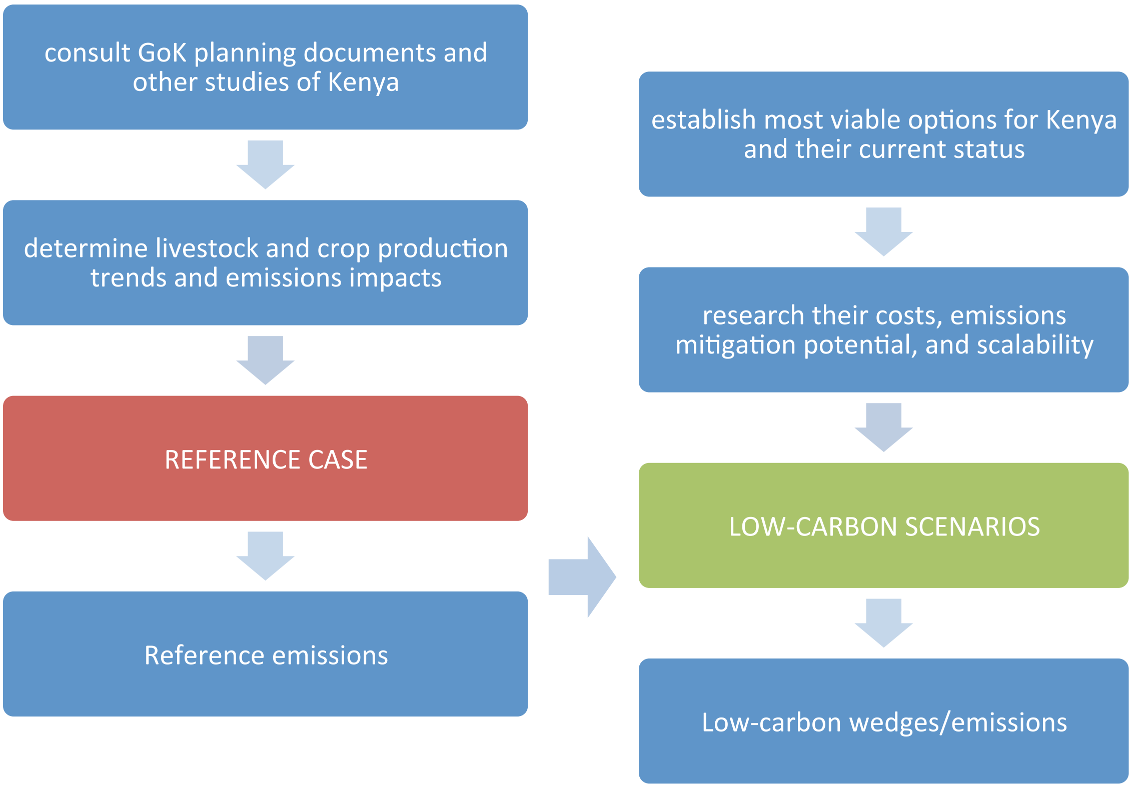
The government made progress on Vision 2030 flagship projects from 2009 to 2012. The Consolidated Agricultural Sector Reform Bill was drafted and four agricultural policy bills were passed, including the farm forestry rules. The government worked toward lower fertilizer prices by procuring fertilizers for farmers and forming a fertilizer management committee. Electronic animal identification was piloted and 302 stakeholders sensitized as part of work toward a disease-free zone in the ASAL region. In 2009, the World Health Organization for Animal Health declared Kenya free from Rinderpest. In regard to ASAL development projects, a concept paper was prepared and a pre-feasibility study undertaken for small-scale irrigation for 50 farmers in Turkana.[8]

In meetings and consultations, stakeholders and government representatives repeatedly emphasized the importance of the agricultural sector for Kenyans. Agricultural performance is a key expectation under the new Constitution: every person has the right to be free from hunger and to have adequate food of acceptable quality.

3.4 Reference Case

This section briefly discusses the methodology, data and assumptions that were used to generate the GHG emissions reference case between the years 2000 and 2030. This is followed by a discussion of data availability and quality. Finally, emissions are projected out to 2030 to create the reference case against which to measure abatement potential. Figure 3.1 illustrates the methodology used to develop the reference case and low-carbon scenario (discussed in Section 3.5).

Figure 3.1: Approach for determining GHG emissions and mitigation potentials



3.4.1 Emissions reference case methodology

The reference case uses historical greenhouse gas emissions data from 2000 to 2010, which is then projected out to 2030 to provide a business as usual (BAU) reference case of expected emissions to 2030. The reference case was developed using methodologies of the Intergovernmental Panel on Climate Change (IPCC), and the 2010 figures could be used as a starting point for developing a greenhouse gas inventory.

The agriculture sector is combined with the forestry and other land use sectors (the AFOLU sector) in the IPCC 2006 guidelines for developing emission inventories.[9] This report examines the agriculture sector separately from the forestry and other land-use sector to enable an assessment of emissions in the each of the six mitigation sectors set out in the UNFCCC. Both sectors involve carbon fluxes as a result of the management of lands to some degree, and efforts have been made to avoid double counting by clearly delineating between the sectors. The forestry sector analysis includes the conversion of non-agricultural land uses to agriculture and the management of plantations. All carbon releases and sinks that are a result of a land conversion from one type to another are included in the forestry sector. The management of soils on agricultural lands, such as cultivation and tillage, are assessed in the agricultural sector as long as they do not involve conversion to a land use other than agriculture.

The agricultural sector does not include energy emissions from fuel combustion, which are included within other sectors such as transportation and energy demand sectors.

The agricultural sector is currently the largest source of GHG emissions of all analysed sectors. More than one-third of Kenya's total national emissions are from this sector alone.

The emissions baseline for the agriculture sector was developed by using a number of Tier 1 approaches from the IPCC 2006 guidelines.[10] Four different types of emission sources are considered in the analysis:

- Enteric fermentation and manure management from livestock;
- Burning of agricultural residues;
- Nitrogen fertilizer use; and
- Flooding rice.

Methodologies along with the specific data and assumptions to estimate emissions from each of these sources are elaborated in Chapter 2, Preliminary Greenhouse Gas Emissions Baseline.

3.4.2 Data availability and quality

The agricultural sector is the largest source of GHG emissions of the seven sectors considered in this low-carbon sectoral study. Despite the size and prevalence of the sector, data required to calculate GHG emissions is lacking and considerable uncertainty remains in the calculation of these emissions when compared to energy demand, energy supply, industrial processes and waste sectors.

Livestock emissions account for approximately 30 percent of total emissions in Kenya, yet it is necessary to use default emission factors that are not country specific to estimate these emissions. The uncertainty of these emission factors is reported to be in the range of 30 to 50 percent.[11] The uncertainty in the forecast baseline emissions is even greater as estimates of future populations of livestock also have considerable uncertainty. Decreasing the annual growth rate of all livestock from three percent to two percent would reduce overall agricultural emissions in 2030 by 17 percent (six megatonnes [Mt]).

The burning of agricultural residues on grazing lands and croplands also has considerable uncertainty because of the poor estimates of the total area of land where this practice occurs. Increasing the assumed area burned by 20 percent would result in overall agricultural emissions in 2030 increasing by one percent (0.4 Mt).

Uncertainty related to other emission sources including rice flooding and nitrogen fertilizer use is also high. But the small magnitude of these emissions means that even an increase of 100 percent in these emissions would increase total agricultural emissions in 2030 by less than one percent.

3.4.3 Greenhouse gas emissions reference case

The emissions baseline for agriculture is summarized in Figure 3.2. Total emissions are expected to grow from 20 Mt carbon dioxide equivalent (CO_2e) in 2010 to 27 Mt CO_2e in 2030 representing an annual growth rate of 1.6 percent. Enteric fermentation from livestock accounts for approximately 90 percent of total emissions and is the single largest source of emissions in Kenya accounting for approximately 30 percent of the total national emissions.

Figure 3.2: Total reference case emission from agriculture ($MtCO_2e$)

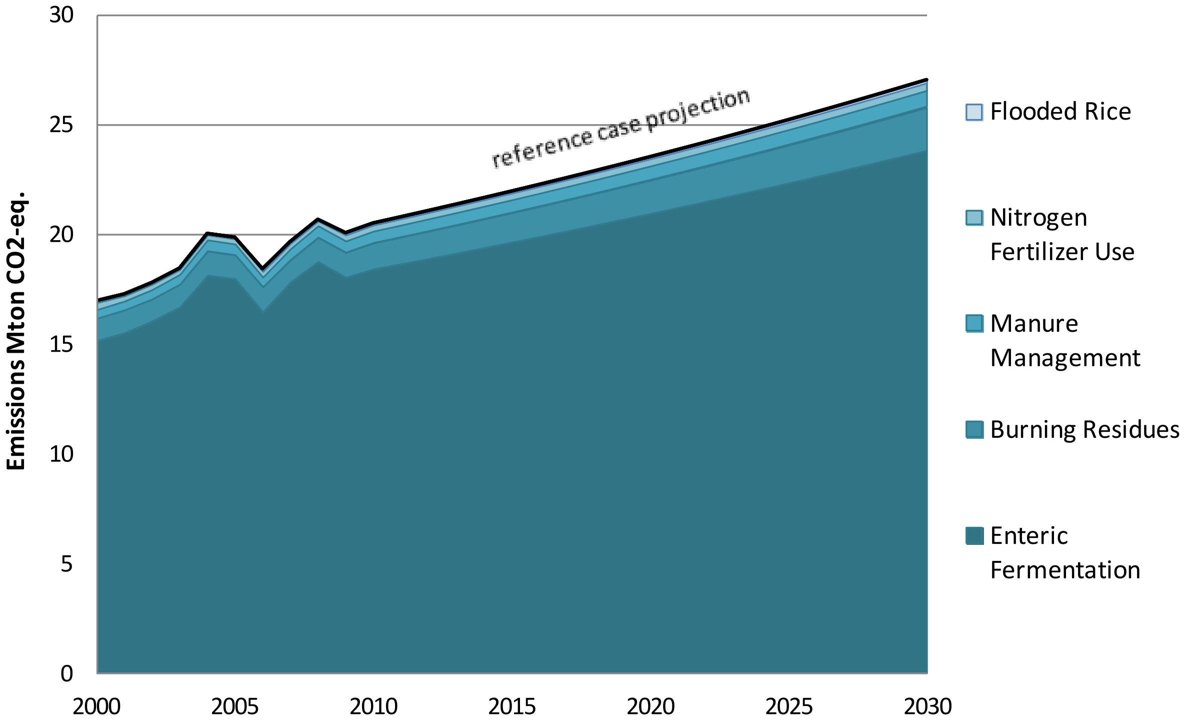


Table 3.1: Total reference case emissions from agriculture ($MtCO_2e$)

Source	2000	2010	2015	2020	2025	2030
Enteric Fermentation	15.2	18.0	19.7	21.0	22.4	23.9
Burning Residues	1.0	1.1	1.3	1.5	1.7	2.0
Manure Management	0.44	0.52	0.59	0.63	0.67	0.72
Nitrogen Fertilizer Use	0.32	0.23	0.30	0.33	0.36	0.39
Flooded Rice	0.06	0.07	0.09	0.11	0.12	0.13
Total	17.02	19.92	21.98	23.57	25.25	27.14

3.5 Low-Carbon Scenario Analysis

The low-carbon scenario analysis consisted of identifying low-carbon development options, and calculating the mitigation potential against the reference case. The resulting wedge analysis demonstrates the emission reduction potential by low-carbon technology in the sector.

3.5.1 Identification of low-carbon development options

The identification of low-carbon options for further analysis followed a participatory multi-step approach that is described in Chapter 1. The low-carbon development options considered in this section are informed by stakeholder consultations, research on the most feasible and cost-effective forestry sector mitigation options for Kenya, and where Kenya-specific data was not available, data for East Africa in general was used. Kenyan experts reviewed the reference case, low-carbon development options and their supporting assumptions at local validation meetings in Nairobi in May and June 2012, and suggested information sources and revisions to improve the analyses.

The low-carbon development options were identified and assessed in term of their:

- Mitigation impact and domestic potential;
- Development impacts and alignment with government priorities;
- Costs and other barriers;
- Feasibility of implementation; and
- Eligibility for climate finance.

This research and consultation resulted in the following low-carbon development options:

- Agroforestry;
- Conservation tillage; and
- Limiting use of fire in range and cropland management.

Other low-carbon development options were reviewed or suggested at stakeholder consultations, but not included in this analysis. The options and the reasons for not including these options are discussed in Box 4.1.

A significant omission is a low-carbon development option for the livestock sector, with enteric fermentation being the source of 90 percent of agricultural emissions in 2010. Kenyan experts were not able to definitively identify a viable low-carbon development option, and expressed that it is unlikely that much can be done in the near future to reduce theses emissions. Experts and stakeholders noted strong barriers to action in this sector, including the cultural and economic importance of cattle, and resistance to change in rural communities. However, important actions can be undertaken to build knowledge and awareness of mitigation opportunities, such as dairy herd management (improved feed and breeding of high-yielding cattle), manure management through biogas promotion, and rangeland pasture rehabilitation, management and conservation. In addition, actions to help farmers and pastoralists adapt to climate change should be undertaken in a manner that is as low-carbon as possible. Awareness raising and education actions in this sector are important to lay the groundwork for future adaptation and mitigation actions. This is particularly important because of the potential positive benefits for pastoralists in the ASALs and the large emissions generated by the sector.

3.5.2 Calculation of abatement potentials

The analysis first considered Government of Kenya publications related to the agricultural sector to derive a list of low-carbon options in the sector. Further research was undertaken to find information on emissions abatement, costs and co-benefits for the identified options. Studies specific to Kenya and East Africa were often difficult to find; and the literature review also considered studies that focused on African countries similar to Kenya or Sub-Saharan Africa as a whole. Additional sources included academic articles estimating mitigation potentials and costs. Studies on Clean Development Mechanism (CDM) activities were emphasized because of their rigorous emissions reporting methodologies.

Box 3.1: Low-carbon development options in the agricultural sector not considered in the analysis

Agricultural options proposed at local validation meetings but excluded after further analysis:

- **Livestock substitution** Experts suggested that some livestock substitution is taking place in Kenya, which could be a low-carbon option. The substitution of camels for cattle does not result in reduced emissions (assuming one camel replaces one head of cattle) because the IPCC emission factors determine that camels have greater methane emissions through enteric fermentation than cattle. The county consultations suggested that camels have greater value than cattle in Kenya, and that a farmer could keep a few camels and be better off than a farmer with a large herd of cattle, but data was unavailable to substantiate this assertion and not all experts agreed. The team also explored substitution of goats for cattle, but was unable to determine the ratio of substitution (for example, one for one, or three to one) because no studies have been undertaken and experts were not able to provide this information.
- **Reduction in the size of cattle herds** – A reduction in herd size leading to smaller and healthier herds was suggested as a strategy; with participants suggesting this was taking place in some regions, such as Mandera County. Most Kenyan experts and stakeholders agreed that such an action would not work for socio-cultural reasons linked to the importance of cattle in rural Kenya.
- **Manure Management** – Experts determined that there was limited opportunity for improved manure management, treatment or storage because the manure of most animals, particularly cattle, is deposited on open grazing land. Some opportunity may exist in larger dairy operations; but the reductions would not be substantial enough at the national level to form a wedge in the low-carbon analysis.
- **Organic agriculture** – Robust data regarding the mitigation potential of organic farming systems is scarce, and no data could be found for Kenya. Some argue that these systems can demonstrate greater energy efficiency and reduced GHG emissions per land unit and unit of production compared with conventional operations, as well as have greater carbon sequestration potential. Other studies show that energy efficiency and emissions per output are less strongly in favour of organic systems.[12]
- **Increased productivity through increased fertilizer application results in reduction of land clearing for new cropland**– A lack of data and information determined that this option could not be included. Enhanced yields are expected to result from increased nitrogen fertilizer use, and the Government of Kenya has programs to increase fertilizer usage, but it was not possible to determine if this would result in less land cleared. The IPCC reports that greater fertilizer use is expected to increase productivity and emissions, and rising populations and wealth of populations in Sub-Saharan Africa could result in intensification of agriculture and expansion to unexploited areas, leading to an increase in GHG emissions.[13] A reduction in land conversion to cropland because of increased productivity through increased fertilizer application is not likely in Kenya by 2030. To meet the goal of reducing emissions from forest conversion to cropland while increasing crop production will require additional fertilization; but more research and knowledge is needed on the relationships between crop production, fertilizer and GHG emissions to determine if this could be low-carbon option.
- **Flooding Rice** – Emissions from the flooding of rice are low in Kenya, and the potential reductions from mitigation actions would not be substantial enough at the national level to form a wedge in the low-carbon analysis.

The list of low-carbon development options was then consolidated by removing options that were subject to large barriers in the Kenyan context, or for which the available data was too limited to effectively assess the mitigation potential.

Projects and studies with rigorous abatement figures and costs were selected for further analysis. To standardize the figures, capital costs were annualized by multiplying by a capital recovery factor of 0.15 and assuming operating costs of 10 percent of the capital cost, as was done in the study of mitigation options in other sectors. Total emissions abatement from projects was divided by the expected life of the project, resulting in estimates of US$ per tonne of CO_2e mitigated per year figures, making it possible to compare and average mitigation costs.

The first step in estimating the overall scope of each low-carbon development option was assembling the best available information on the existing prevalence of the practice or technology. Based on the research, conservative assumptions were made about the economically, socially and biophysically feasible scale of implementation. Scenarios were then developed by calculating the emissions impact of the low-carbon development option relative to the reference case, described in Section 3.3; as well the aggregate cost at the identified deployment scale, with a start date of 2015 and an end date of 2025. Although in practice, deployment of any one mitigation option would include many projects tailored to specific regions and land-uses, mitigation options consider overall average costs and abatement potential for the entire deployment area.

3.5.3 Data availability and uncertainties

The calculation of the abatement potential of the low-carbon development options was impacted by limited data. Abatement potential and costs were informed by the literature on agricultural mitigation, and reasonable average abatement potentials (that is, average tonnes of carbon sequestered per hectare annually) were identified. The figures for each of the low-carbon development options were averaged to arrive at estimated abatement values. However due to variation in cited abatement estimates, actual abatement potentials differed as much as ±40 percent of the average used in this low-carbon assessment.

Limited data impacted the estimation of abatement costs, and Kenyan examples were not always available. Two studies informed the costs of agroforestry, one based on a project in Kenya and one on agroforestry projects in Sub-Saharan Africa. Three Kenyan studies informed the costs of conservation tillage, which was supplemented with information from a study that considered costs from several developing countries. The costs for limiting the use of fire on grazing land and cropland were based on two Kenyan studies. See the fact sheets in Annex 1 for a list of all supporting data.

3.6 Low-carbon Development Options

This section provides some background context for each of the low-carbon development options, explaining their current status and potential. The results of the analysis are then described in six sections:

- Scenarios;
- Mitigation potentials;
- Costs;
- Development benefits;
- Climate resilience; and
- Feasibility of implementation.

Details on each low-carbon development option are provided in the fact sheets in Annex 1.

3.6.1 Context

Agroforestry

Agroforestry is the interface between agriculture and forestry and encompasses mixed land-use practices. The term typically refers to land-use practices in which trees and other woody perennials are spatially or temporally integrated with crops and livestock on a given unit of land. It is distinct from reforestation efforts in Chapter 4, *Forestry* because it targets lands that are currently in use for agriculture and seeks to create a more balanced agro-ecological profile with agroforestry methods. This low-carbon option aims to encourage compliance with the Agricultural Farm Forestry Rules that require every land owner to maintain a compulsory farm tree cover of at least 10 percent on any agricultural land holding.[14]

Project work to promote and spread agroforestry practices is underway in Kenya. The SCC-Vi Agroforestry project in Kisumu promotes agroforestry practices in the target region by providing outreach services to farmer groups through trained community facilitators.[15] Input at the county consultations indicated that several agroforestry projects are ongoing, including in Kisii, Nyamira, Nyeri, Embu, Kisumu, Siaya, Garissa, Kakamega, Uasin Gishu, Kitale, Kericho and Bomet. In arid and semi-arid regions such as Garissa county where pastoralism dominates, agroforestry is gradually being introduced as a coping strategy against drought and hunger shocks.

The cultivation of fruit trees such as neem (*Azadirachta indica*) alongside traditional crops such as cowpeas, sorghum and millet were reported. The focus of these projects is adaptation, but there is mitigation potential because neem trees are perennial and have the potential to sequester significant amounts of carbon during their lifespan. Despite the considerable interest in agroforestry expressed at the county consultations, the extent to which agroforestry practices are employed overall on Kenyan farms is fairly uncertain, since all evidence of its deployment is anecdotal. As such, research-based assumptions were made about the existing prevalence of agroforestry in Kenya and its potential expansion. These assumptions are presented in Section 3.6.2.

In addition, data on the present level of tree cover on farms in Kenya is limited. Land-use studies usually count agricultural land as separate from forests and plantations because satellite images often cannot distinguish between trees that are on a farm and trees that exist as part of a forest. The poor understanding of the existing degree of tree cover on farms made it necessary to make simplifying assumptions, which are presented below.

Conservation Tillage

These methods of soil tillage leave at least 30 percent of crop residues on the soil surface, which enhances soil moisture conservation.[16] The reduction in tillage increases organic matter in the soil, thereby increasing the amount of carbon stored in the soil. The most pronounced type of conservation tillage is no-till, where lands are not ploughed at all and 100 percent of crop residues remain on the land.

Given the competing uses for agricultural residues as animal fodder and fuel in Kenya, no-till practices are not likely to be appropriate or feasible. Some projects in Kenya, such as the Kenya Smallholder Carbon Agriculture Project and the Kenya Agricultural Carbon Project, promote conservation tillage practices. Often conservation tillage is one element of a package of sustainable land management practices, which also might include agroforestry, inter-cropping and application of compost manure. However, as with agroforestry, little information is available about the prevalence of these practices in the country as a whole. Available information is anecdotal or specific to a project or region. Again, assumptions about the existing scale and overall potential of these practices were made.

Limiting Use of Fire in Range and Cropland Management

Limiting the use of fire in range and cropland management involves reducing the frequency and extent of fires and/or reducing the fuel load through vegetation management and burning at times of year when fewer greenhouse gases are emitted from burning. Fire is used on grass and rangelands in Kenya to clear vegetation, stimulate growth and control pests. On cropland, fire is used to attempt to regenerate soils or facilitate harvesting.[17] It serves a valid purpose as an important land management tool for pastoralists and farmers for its regenerative effects, and for grappling with invasive plants and species and conducting pest control. But burning range and croplands is also a major source of GHG emissions in Kenya due to the permanent loss of protective vegetation and crop residue cover that causes reductions in soil carbon levels. It can also negatively impact the long-term viability of the land.

3.6.2 Scenarios

As discussed in Section 3.5 describing the methodological approach, scenarios were developed for each low-carbon development option, including calculating the emissions mitigation costs, determining the appropriate scale and determining a timeframe. The scenarios for the three low-carbon development options are presented below.

Agroforestry – The agroforestry low-carbon development option would target existing arable cropland and grazing lands that have high or medium agricultural potential. The total area of arable cropland and grazing land is estimated in the Agricultural Sector Development Strategy 2010-2020 to be approximately 5,620,000 hectares. The current extent of tree cover on this agricultural land is not known; however, at least 10 percent tree cover on farms is targeted by the Agricultural (Farm Forestry) Rules 2009. Without additional information, it is assumed that achieving five percent of additional tree cover on these lands using agroforestry practices is possible and a reasonable mitigation scenario. Therefore, the low carbon scenario assumes that an additional 281,000 hectares is converted to agroforestry between the years 2015 and 2030.

Conservation Tillage – Kenya has 9,500,000 hectares of rain-fed agricultural cropland.[18] Research determined that reliable data on the prevalence of different tillage practices was not available; and it was therefore assumed that at least 25 percent of these lands employ full tillage. The literature reports that a 20 percent adoption rate is a reasonable scenario for the promotion of sustainable agricultural practices. Assuming that this figure is also a reasonable scenario for conservation tillage, converting 20 percent of rain-fed agricultural croplands from full tillage to conservation tillage would mean converting 475,000 hectares over ten years.

Limiting Use of Fire in Range and Cropland Management – The practice of using fire to manage rangelands is quite common in Kenya, with over 430,000 hectares burned each year. This results in emissions of approximately 0.26 Mt of CO_2e per year. In addition, burning agricultural residues of maize, wheat, sugarcane and rice crops is a common practice. Approximately 2,300,000 hectares of these crop residues are burned annually, leading to emissions of 0.93 $MtCO_2e$ per year.

This low-carbon development option would prevent 60 percent of the rangeland and cropland burning that occurs each year. The scale of this intervention allows targeting of burning that negatively impacts the long-term viability of the land, recognizing that a certain amount of burning (assumed to be 25 percent) is needed for regenerative effects, pest control and managing invasive plants. Reduced use of burning would be achieved through extension services to educate pastoralists and farmers on the risks associated with using burning to manage range and croplands, and on the benefits of alternative practices. It is assumed that successfully preventing 60 percent of rangeland burning would require reaching a significant portion of the approximately 854,000 pastoralist households in Kenya. In addition, stopping 60 percent of cropland burning would involve providing extension services to a significant proportion of farm-owning households in Kenya, or approximately 3.58 million households.

3.6.3 Mitigation potentials

The mitigation potential was calculated by determining the divergence (in $MtCO_2e$) from the reference case baseline that potentially could result from each low-carbon option. The wedges in Figure 3.3 reflect the amount of emission reductions that could result from each low-carbon development option. All mitigation potentials are stated in terms of their starting and ending level of emissions mitigation. Implementation of the low-carbon development options would end in 2025, but the end period for their associated emissions mitigation is 2030 because many of the reductions would not be realized for some time.

Figure 3.3 shows the low-carbon wedges in the agriculture sector. Agroforestry has the largest abatement potential with over 4 $MtCO_2e$ per year in 2030. The total abatement potential in the agricultural sector in 2030 exceeds 6 $MtCO_2e$ per year.

Figure3.3: Low-carbon mitigation option wedges in the agriculture sector ($MtCO_2e$)

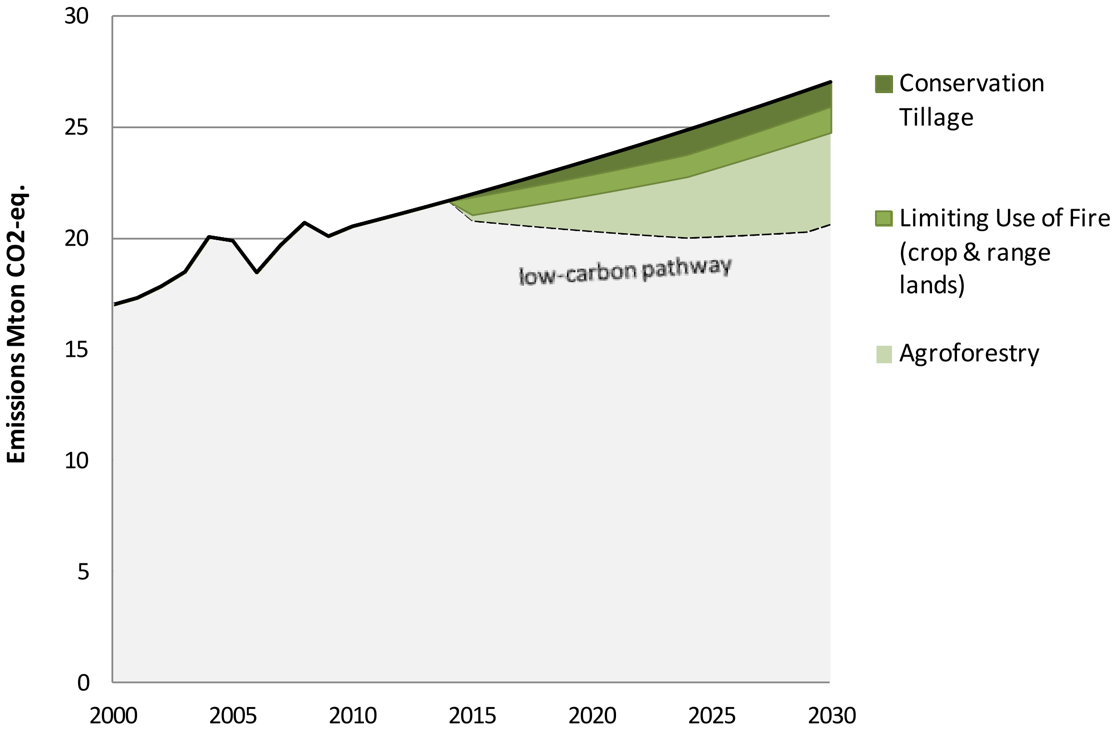


Table 3.2: Low-carbon mitigation option emission reductions in the agriculture sector ($MtCO_2e$)

Low-carbon mitigation option	2000	2010	2015	2020	2025	2030
Tillage	0.00	0.00	0.11	0.65	1.09	1.09
Limiting Use of Fire	0.00	0.00	0.81	0.91	1.04	1.18
Agroforestry	0.00	0.00	0.28	1.66	3.05	4.16

The mitigation potential of each of these low-carbon development options is briefly described below.

Agroforestry – Implementing agroforestry over 281,000 hectares between 2015 and 2030 would abate 0.28 $MtCO_2e$ in 2015, rising to 4.1 $MtCO_2e$ in 2030.

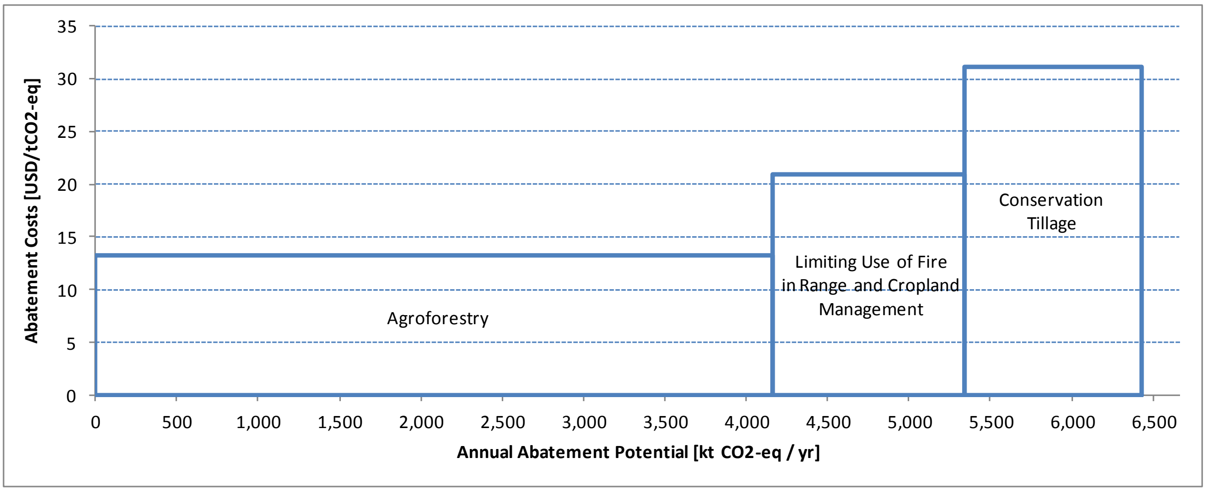
Conservation Tillage – Implementing conservation tillage practices across 475,000 ha between 2015 and 2025 would abate 0.1 $MtCO_2e$ in 2015, rising to 1.1 $MtCO_2e$ by 2030.

Limiting Use of Fire in Range and Cropland Management - Preventing 60 percent of current rangeland burning would abate 0.16 $MtCO_2e$ in 2015, falling to 0.15 $MtCO_2e$ in 2030. Preventing 60 percent of cropland burning would abate 0.65 $MtCO_2e$ in 2015, rising to 1.0 $MtCO_2e$ in 2030.

3.6.4 Costs

The costs are reported as marginal abatement costs, illustrated in Figure 3.4, and described below. Figure 3.4 indicates that agroforestry accounts for the largest portion of abatement potential and the lowest cost, meaning that it is an attractive low-carbon development option for Kenya.

Figure 3.4: Marginal abatement cost curve for different low-carbon development options in the agricultural sector in 2030



While marginal abatement costs give an indication of the cost-effectiveness of different low-carbon options, their results should be interpreted with caution. There are uncertainties on the underlying assumptions, as discussed in sections 3.4 and 3.5. In addition, marginal abatement cost curves do not cover transaction costs, such as the costs associated with overcoming barriers; and they say nothing about the development benefits of various options. Marginal abatement costs provide only one input into a more comprehensive process of selecting priority low-carbon development options.

Agroforestry – The cost data for plantations on farms was derived from two studies.[19] Lager and Nyburg placed the cost per hectare per year at US$ 6.85, while Tennigkeit determined the cost per hectare per year at US$ 19.60. An average was used, providing an abatement cost for plantations on farms of US$ 13.25 per hectare per year.

Conservation Tillage – Limited data on the costs associated with promoting and establishing conservation tillage practices was found in the literature. Combining and averaging divergent cost data that was found for sustainable agricultural practices[20] and for conservation tillage,[21] which both require similar extension service efforts and in the case of sustainable agriculture actually includes tillage practices, provided a cost of US$31.15 per tonne of CO_2e abated per year. Per hectare costs were divergent and were averaged to arrive at a figure of US$14.36 per hectare per year.

Limiting Use of Fire in Range and Cropland Management – Little cost data was available for this type of intervention. It was assumed that providing extension services to a pastoralist household would be similar in cost to providing extension services to smallholder farmers, which were found in the literature to be approximately $10.35 per year.[22] Costs are assumed to be one half this figure for farm-owning households because a network of extension services is already in place. This would lead to an average cost for reductions to crop and rangeland burning of US$21.00 per tonne of CO_2e abated per year.

3.6.5 Development benefits

Development benefits have been qualitatively described within the study and validated with stakeholders at expert meetings and individual interviews. 3.3 provides an overview of the mitigation potential, costs, and adaptation and sustainable development impacts of the three low-carbon development options is set out in Table 9, which allows for comparability across the options.

Table 3.3: Overview of mitigation potential, costs, and adaptation and sustainable development impacts of low-carbon options in the agricultural sector

● High Positive ◓ Positive ▬ Neutral / Minor impact ◡ Negative ◓◡ Uncertain	Climate			Sustainable Development					
	Abatement potential ($MtCO_2e$)	Abatement costs (US$/$tCO_2$)	Adaptation impact	Energy security	GDP growth	Employment / Rural livelihoods	Improved land management	Environmental benefits	
Agroforestry	4.16	13.25	●	◓	◓	◓	●	●	
Conservation tillage	1.10	14.36	●	▬	◓	◓	●	●	
Limiting Use of Fire in Range and Cropland Management	1.00	21.00	◓	▬	▬	▬	●	◓	

A key selection criterion when considering low-carbon development options was that they demonstrate positive sustainable development co-benefits, which could be economic, social or environmental. Low-carbon development options were considered to have a positive development effect if: 1) such an effect was noted in Government of Kenya documents and publications, especially Vision 2030 and the Medium Term Plan; or 2) such benefits were widely noted in the literature or understood among the climate change and development community. This section presents sustainable development co-benefits of the low-carbon options and their alignment with Government of Kenya priorities.

Vision 2030 identifies agriculture as one of the key sectors to deliver the expected 10 percent annual growth rate. Government of Kenya priorities include enhancing capacity for food security, modernizing the agricultural sector, and enhancing the knowledge and skills of farmers. The importance of agricultural extension in alleviating poverty has been highlighted in the Agricultural Sector Development Strategy.

Agroforestry – The Agriculture (Farm Forestry) Rules 2009, introduced under the Agriculture Act, aim to promote and maintain farm forest cover of at least 10 percent of every agricultural land holding as a means of preserving and sustaining the environment and combatting climate change. Through Vision 2030, the Medium Term Plan, the National Climate Change Response Strategy, and other policy documents, the government has articulated the dual priorities of enhancing forest cover as well as improving the productivity and profitability of the agriculture sector.

Agriculture, because of its direct link to food security and livelihoods (farming supports about 80 percent of Kenya's population) is a priority in Kenya. The products of agroforestry, such as fruit and nuts can enhance food security and diversify farmers' income.[23] Agroforestry systems can also complement shade tolerant cash crops such as coffee.[24] Agroforestry can act as a source of sustainable fuelwood, on-farm timber and livestock fodder – alleviating pressures on neighbouring forests and contributing to improved livelihoods. Agroforestry has been shown to lead to higher soil nutrients and water retention, and nitrogen-fixing trees and shrubs can increase soil fertility and crop yields. Agroforestry systems can significantly enhance the livelihoods of smallholders.

Conservation Tillage – Conservation tillage is well aligned with the recommendations in the Technology Needs Assessment to improve tillage methods and cropping, and to more widely apply soil erosion control.[25]

Low or zero tillage techniques are important for reducing the risk of soil erosion and improving soil fertility.[26] The improvements in soil fertility can improve plant health and increase the capacity to deal with pests and disease. These techniques enhance the long-term viability of agricultural lands and protect the incomes of those who rely on them. Moreover, these techniques can improve land productivity and decrease yield variance between years.[27] They can also decrease labour requirements, raising labour productivity in the sector.[28]

Limiting Use of Fire in Range and Cropland Management –Improving incomes and food security of pastoralists, most of who reside in the ASALs, is consistent with the ASAL Development Strategy.

Limiting the use of fire to manage crop and rangelands has substantial benefits. Reducing cropland burning increases the long-term viability of the land, thus enhancing food security and agricultural incomes. For pastoralists, tree and shrub cover that accumulates as a result of not burning can provide food, fodder, fuelwood and charcoal, resulting in an additional revenue stream when sustainably harvested, In addition, the negative effects of burning are decreased. Burning causes photochemical smog and hydrocarbons, reduces soil water retention, causes nutrient depletion, and leads to soil erosion when bare scorched earth is exposed to wind and rain.

3.6.5 Climate resilience impacts of low-carbon options

An additional key criterion when selecting low-carbon development options for the agricultural sector was the presence of positive co-benefits in terms of adaptation or resilience to climatic changes. Positive adaptation benefits are seen in the three low-carbon development options, including the important effect of helping to improve the retention of water in the soils and helping to reduce soil erosion.[29] Water retention is essential in the ASALs, especially when climate conditions are expected to become more extreme. Preventing soil erosion will help to prevent nutrient depletion and enhance the long-term viability of agricultural land, which can help to enhance food security. The measures that involve adding tree cover will contribute to a strengthened network of forestlands, which has the potential to mitigate flooding events. In regard to agroforestry, trees help farmers adapt to climate change because perennial crops are better able to cope with droughts and floods than annual crops.

3.6.6 Feasibility of implementation

Feasibility of implementation is a key consideration when selecting low-carbon development options. Two initiatives that are equal in terms of co-benefits, emissions mitigation and expected cost may differ greatly in the ease of implementation. This section considers potential barriers to the successful implementation of the low-carbon development options, and the awareness of and acceptance of these solutions. For all three options, lack of financing is a critical barrier.

Agroforestry – Given the vulnerability of their practice, farmers in Kenya tend to be risk averse and reluctant to adopt new technologies.[30] The fact that agroforestry requires additional labour can act as a deterrent. Improper disease management can hinder the effectiveness of agroforestry systems. Weak access to market infrastructure may render smallholders unable to fully exploit the economic benefits of fruits, nuts, timber and fuelwood generated by trees on farms. Additional barriers are the land fragmentation that currently exists with agricultural land, making it difficult to properly identify and contact the multitude of individual farms that exist; as well as the value addition component, in that the value proposition offered by agroforestry is poorly quantified and for some farmers, poorly understood.

Increased support for research, technological development, extension services and capacity building is required to extend the practice of agroforestry. Work is needed to learn from and scale up pilot projects. Research is needed to categorize the types of agroforestry practiced in Kenya, the areas involved, and the level of carbon stock increases that could be facilitated through appropriate government programs. Research and development could help to identify the potential for agroforestry in more marginal areas (moving toward the ASALs) and to determine if there is adequate potential to warrant an agroforestry program in new areas of cultivation. Capacity is needed to develop measurement, reporting and verification (MRV) systems for agroforestry, and support is required to build the foundations and institutions for effective carbon measurement techniques.

Several groups promote the benefits of agroforestry systems in Kenya, such as the World Agroforestry Centre, World Bank and Australian Government Overseas Aid Program. However, these techniques are relatively unknown in places where extension services are not well established.

Conservation Tillage – The main barrier to successfully introducing low or zero tillage techniques is getting farmers to understand and employ these techniques. The Food and Agriculture Organization has found that understanding of conservation tillage techniques is low in Kenya. The International Food Policy Research Institute has also found that farmers in Kenya generally do not recognize the importance of soil fertility management techniques and their synergies with adaptation. Persuading farmers to change their tillage practices (which will be very well-established and trusted) will be a challenge. Also significant will be difficulties around persuading farmers to use crop residues for this purpose since they have competing uses in Kenya as fuel and animal feed. Moreover, if farmers clear shrubs prior to practicing conservation tillage, then some of the net gains in carbon sequestration will be compromised. Trade-offs need to be considered in conservation tillage systems, which can require increased pesticide use, and higher soil carbon levels can correlate with higher nitrous oxide emissions. Finally, securing a critical mass of financing to promote conservation tillage is an important barrier.

Increased support for research (especially for the Kenyan situation), technological development, extension services and capacity building is required to extend the practice of conservation tillage. Work is needed to learn from and scale up pilot projects, and to determine the level of carbon stock increase that could be facilitated through appropriate government programs. Capacity building is needed to develop MRV systems, and support is required to build the foundations for effective carbon measurement techniques. Work is needed to disseminate knowledge around general best practices for sustainable agriculture, in addition to education on conservation tillage practices. Improved extension services are critical for educating farmers on conservation tillage.

Limiting Use of Fire in Range and Cropland Management – Convincing pastoralists and farmers of the importance and utility of limiting the use of fire in range and cropland management will be a considerable challenge. Burning practices are quite entrenched, and it could be difficult to persuade pastoralists and farmers to abandon them. A study by the International Food Policy Research Institute found that farmers in Kenya "do not fully recognize the inter-linkages between agricultural productivity, climate change adaptation and GHG mitigation," and that there is little awareness around the potential for integrated soil fertility management and synergies with adaptation. The relationship between soil fertility and rangeland resilience, and burning or leaving residues is not well understood by pastoralists and farmers.

Utilizing extension services and networks to limit use of fires in range and cropland management would require substantial scale-up and improvement of existing services, as well as capacity building for extension workers. Institutional constraints include limited ability to train in emerging areas and inadequate levels of funding for public training institutions. Remote areas and poor producers, especially those growing low-value crops with little marketable surplus are poorly served by extension services.[31]

3.7 Potential Policy Measures and Instruments

Low-carbon development in the agricultural sector can be encouraged through supportive policies, government initiatives and regulatory frameworks. Discussed below are policy measures and instruments available to encourage the implementation of the low-carbon development options in the agricultural sector in Kenya.

Information and data

An important first step in developing effective policies and programmes to promote low-carbon development in the agricultural sector is improved data and information. The data on GHG emissions and sinks could be improved, which would contribute to an improved GHG inventory. Specific needs are improved estimates of livestock populations that account for 30 percent of total emissions in Kenya, the single largest source of GHG emissions of the six sectors examined in this low-carbon assessment. Kenya-specific emission factors for the agricultural sector, particularly for livestock enteric fermentation emissions, are required.

Improved data collection and understanding is needed in regard to the low-carbon options of agroforestry, conservation tillage and limiting fire in cropland and rangeland management. Encouraging the uptake of agroforestry requires better data on the existing penetration and scale of agroforestry in Kenya. Improved knowledge of the status of the practice would assist in identifying the lands most suited for agroforestry programmes, both in terms of the ease of reaching farmers and the suitability of the land. Additionally, research is required to identify existing experience with agroforestry systems in Kenya to determine which species are best for particular land types, and the ideal mix of different species. An assessment of the current percentage of trees on farms would be helpful in determining effective interventions.

Climate resilience

Climate resilience should be the priority driver for climate change actions in the agricultural sector, incorporating low-carbon actions where appropriate. Research is needed to improve understanding of the low-carbon benefits of adaptation actions, especially in regard to the livestock sector.

Regulatory framework

Regulations and policies can contribute to low-carbon development. The farm forestry rules are expected to increase the number of trees on farms; and the raised awareness and acknowledgement of the importance of agroforestry are important first steps. Regulation could also be used to limit the use of fire as a management tool, through progressive prohibiting of burning of cropland and rangeland, with full implementation by 2030.

Financial subsidies and non-financial measures

Financial subsidies and non-financial measures are powerful instruments to influence Kenyan agricultural and land-use practices, but they also highly criticized (especially in developed countries). Paying farmers to adopt new practices could include subsidies for seeds, tools or irrigation; or funding for soil preservation, improvement of pastures and agroforestry. Support could include the provision of tree seedlings and fertilizer.

Extension Services

Successful adoption of low-carbon farming techniques requires improved and expanded extension services. Farmers need greater access to information and advice on practices and technologies for agroforestry, conservation tillage, and cropland and rangeland management. This includes strengthening existing services and extending into underserved areas, including the ASALs. Capacity building and training on low-carbon farming techniques is required for extension workers in Kenya, including identification and dissemination of locally appropriate, promising technologies and practices.

Expanding access to credit

Suitable levels of resources are also important and farmers will need access to additional financial services. Expanding access to credit can encourage the adoption of more costly low-carbon practices and technologies. In addition, greater support should be given to developers of low-carbon projects, including assistance in project development and implementation, application of MRV systems and risk management (such as guarantees or loans), to ensure that smallholders get financial benefits from mitigation activities.

Support to market-based trading schemes

Agricultural GHG offsets can be encouraged by market-based trading schemes. Offset trading, or trading of carbon credits, allows farmers to obtain credits for reducing their GHG emissions. Some research suggests there is significant opportunity for Kenya to trade in soil carbon credits, but such benefits are not likely to be realized on a large scale before 2020.[32] In addition, the payments for carbon under agricultural carbon projects should be considered a “bonus” that complements income from other sources. These mitigation activities are not, and are not expected to be, financially viable based on the income from the sale of carbon credits alone. In addition, the main compliance market, the European Union Emissions Trading Scheme does not purchase soil carbon credits and will only purchase CDM credits from least developed countries after 2012 (Kenya is not a least developed country). Currently, all sales of soil carbon credits are through the voluntary market. Kenya would be well placed to focus short-term efforts on securing grant financing for agricultural mitigation initiatives, while building the capacity to eventually access market-based financing.

3.8 Conclusion

The analysis in this chapter demonstrates how low-carbon development options in the agricultural sector in Kenya can lower GHG emissions out to 2030 and, at the same time, contribute to Kenya's sustainable development goals.

The priority low-carbon development option in the agricultural sector is agroforestry. Of the three low-carbon agricultural options analysed, agroforestry has the largest abatement potential, the lowest cost, the most significant sustainable development benefits and it increases climate resilience. Conservation tillage also has important benefits, and limiting use of fire in rangeland management could have important benefits in the ASALs. Agroforestry is aligned with Government of Kenya priorities of increasing food security and tree cover on farms.

Some experience has been gained through projects but research is needed to develop Kenya-specific information for baselines and abatement potential, as well as focused research to determine tree species suitable for marginal agricultural lands to enable expansion of agroforestry programs in the future. The introduction and implementation of successful programs for agroforestry, conservation tillage and limiting fire on cropland and rangeland requires improved agricultural extension services. Improving and extending the reaching of these services, including educating extension workers on low-carbon methods and technologies, should be a priority action for the Government of Kenya.

Annex 1: Low-Carbon Development Option Fact Sheets

Agroforestry

Agroforestry is the interface between agriculture and forestry and encompasses mixed land-use practices. The term typically refers to land use practices in which trees and other woody perennials are spatially or temporally integrated with crops and livestock on a given unit of land. It is a combination of agriculture and forestry techniques that aims to build more robust, productive, resilient and diverse agro-ecological systems. Agroforestry practices range from simple forms of shifting cultivation to complex hedgerow intercropping systems. The definition of Agroforestry used in this analysis is broad and includes all purposeful and deliberate planting and retention of trees whether for commercial crop production, sustainable fuel wood harvesting or other environmental service roles such as providing windbreaks or managing erosion.

Current situation: The agricultural sector is the largest source of GHG emissions in the Kenyan economy. Data on how widespread the incorporation of trees on agricultural lands is scarce, therefore it is difficult to assess how much how the current practice of agroforestry may be reducing GHG emissions. The Agriculture (Farm Forestry) Rules 2009 aim to promote and maintain tree cover of at least 10 percent on every agricultural land holding, but the baseline farm forest cover and the total area that is being targeted by the rules is unclear.

Low-carbon scenario: The agroforestry low-carbon development option targets existing arable cropland and grazing lands that have high or medium agricultural potential. The total area of arable cropland and grazing land is estimated in the Agricultural Sector Development Strategy 2010-2020 to be approximately 5,620,000 hectares.[33] The current extent of tree cover on this agricultural land is not known; however, it is clear that at least 10 percent farm tree cover is targeted by the 2009 farm forestry rules. Without additional information, it is assumed that achieving five percent of additional tree cover on these lands using agroforestry practices is possible and a reasonable mitigation scenario. Therefore, the low-carbon scenario assumes that an additional 281,000 hectares is converted to agroforestry between the years 2015 and 2030.

Development benefits and priorities

Development benefits: Agriculture, because of its direct link to food security and livelihoods (farming supports about 80 percent of Kenya's population) is a priority in Kenya. Agroforestry products, such as fruits and nuts, can enhance food security and diversify farmers' income. Agroforestry can be as a source of sustainable wood fuel, on-farm timber and livestock fodder. Agroforestry systems can also complement shade-tolerant cash crops such as coffee and cacao. Agroforestry systems can significantly enhance the livelihoods of smallholders by providing potential sources of income from the sustainable harvest of forest products. These systems lead to higher soil nutrient and water retention, and nitrogen-fixing trees and shrubs can increase soil fertility and crop yields. Tree cover can also provide environmental services such as reducing soil erosion. In addition, agroforestry can alleviate pressures on neighbouring forests by providing communities with sustainable supplies of fuelwood.

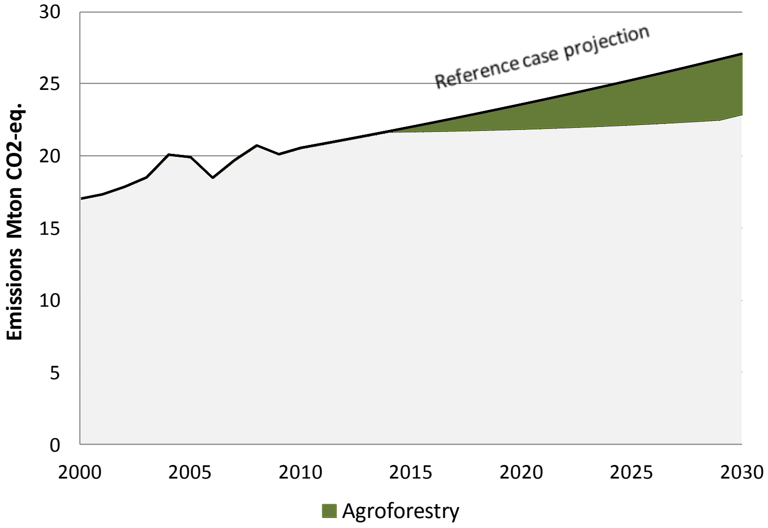
Alignment with Government of Kenya priorities: The Agriculture (Farm Forestry) Rules 2009, introduced under the Agriculture Act, aim to promote and maintain farm forest cover of at least 10 percent in every agricultural land holding. This is as a means to preserve and sustain the environment and combat climate change. Vision 2030 articulates the dual priorities of enhancing forest cover within the country as well as improving the productivity and profitability of the agriculture sector.

Links to adaptation: Agroforestry is a mitigation activity that can enhance local adaptive capacity, for example by using trees to create living barriers to support nutrient cycling and counter soil erosion. Agroforestry can increase water infiltration and retention in the soil profile, which is very important in dry climates. Trees help farmers adapt to climate change because perennial crops are better able to cope with droughts and floods than annual crops. Additional tree cover on farms can also provide a more sustainable wood harvest, decreasing pressure on natural forests.

Abatement potential and costs

Greenhouse gas abatement:

Implementing agroforestry across 281,000 ha between 2015 and 2030 would abate 0.3 Mt of CO_2e in 2015 and rising to 4.2 Mt of CO_2e by 2030.



Costs:

Many different types of agroforestry practices and systems can be implemented in Kenya depending on the climatic and soil conditions and the types of crops and livestock that are present. As a result, agroforestry has a wide range of abatement potentials. Low density, interspersing of trees with crops will have a much lower abatement potential than the planting of fast growing trees in woodlots. The average of the mitigation potential reported in four different studies were used to determine an average abatement potential in Kenya. Each of these studies focuses on different types of agroforestry systems, from hedgerow intercropping to planting of woodlots on cropland and grazing lands in Kenya. The average potential mitigation used in the analysis was 14.8 t CO_2e per hectare per year. Mitigation costs were based on those reported from two available studies, providing a mitigation cost of US$13.25 per tonne per year.

Scenario	2010	2015	2020	2025	2030
Land area converted to Agroforestry (hectares)	-	18,700	112,400	206,000	281,000
Abatement potential ($ktCO_2e$)	-	280	1,660	3,050	4,160

Supporting data

Study name	Tonnes of CO_2e mitigated per hectare per year	Cost per CO_2e per year	Reference
How to Make Carbon Finance Work for Smallholders in Africa	-	US$6.85	Lager and Nyburg, 2010
Land-based Agricultural Carbon Finance: Potential, Operations and Economics	4 soil and biomass C	US$19.60	Tennigkeit, 2012
Potential of agroforestry for carbon sequestration and mitigation of greenhouse gas emissions from soils in the tropics	7.34 soil and biomass C	-	Mutuo *et al.*, 2005
Baseline GHG Emissions from the Agricultural Sector and Mitigation Potential in Countries of East and West Africa	14 soil C only	-	Brown *et al.*, 2012
VCS Validation Report for TIST Program in Kenya	33.92 soil and biomass C	-	VCS, 2011

Feasibility of implementation

Barriers: The literature reports that farmers in Kenya are reluctant to adopt new systems and technologies due to risk aversion. The fact that agroforestry requires additional labour can act as a deterrent. Improper disease management can hinder the effectiveness of agroforestry systems. Weak access to market infrastructure may prevent smallholders to fully exploit the economic benefits of fruits, nuts, timber and wood fuel generated by trees on farms. Finally, securing a critical mass of finance is a key barrier. Scarcity of agricultural land and food security can also be a barrier if more arable land is converted to tree cover and away from cropland or grazing land. Promotion of agroforestry systems may face opposition from farmers and may be exacerbated by continued growth and pressures from rural population. Income from agroforestry products may not be sufficient to offset costs of adopting agroforestry practices, and support may be required. Species selection is also important, since some tree species require significant quantities of water. Inadequate management techniques can increase the risks of fire and disease outbreaks. Weak access to market infrastructure may render communities unable to fully exploit the economic benefits of reforestation.

Increased support for research, technological development, extension services and capacity building is required to extend the practice of agroforestry. Work is also needed to identify agroforestry practices that are suitable for different types of farm holdings in Kenya. Supporting pilot projects to gain experience with different agroforestry practices and identify the abatement potential, development benefits and barriers to implementation are key. Research and development is also needed to identify the potential for agroforestry in more marginal areas (moving toward the ASALs) and to determine if there is adequate potential to warrant agroforestry programs in new areas of cultivation. Capacity is needed to develop MRV systems for agroforestry, and support is required to build the foundations for effective carbon measurement techniques. Finally, securing adequate financing is a critical barrier.

Awareness and acceptance: A number of groups promote the benefits of agroforestry systems in Kenya (World Agroforestry Centre and the World Bank). However, these techniques are relatively unknown for farm holdings where government support for agroforestry practices is not already established. Programs should be established in collaboration with local farmers to ensure they do not diminish food production and enhance livelihoods. Persuading farmers to adopt agroforestry practices will require substantial education programs, demonstration projects and economic incentives.

Conservation Tillage

Conservation tillage agricultural practices, often called low or zero tillage, involve farmers leaving crop residue on the soil and preparing their land using minimum or zero tillage, disturbing the soil as little as possible. These practices can vary in the amount of tillage that they employ, with zero tillage being the extreme. Reduction of soil disturbance and improved residue management has a significant impact on soil carbon sequestration.

Current situation: The agricultural sector is the largest source of GHGs in the Kenyan economy. Nitrous oxide emissions from soil cultivation are a major component of these emissions. Data on existing agricultural practices is quite scarce and there is little available information on the prevalence of specific tilling techniques. However, given the potential of soil cultivation methods to sequester carbon, low or zero tillage practices could drive important changes to the sector's emissions profile.

Low-carbon scenario: Kenya has 9,500,000 hectares of rain-fed agricultural cropland. Limited data exists on the prevalence of different farming practices, and it was therefore assumed that 25 percent of these lands employ full tillage. The literature reports that a 20 percent adoption rate is a reasonable scenario for the promotion of sustainable agricultural practices. Assuming that this figure is also a reasonable scenario for conservation tillage, converting 20 percent of rain-fed agricultural croplands from full tillage to conservation tillage would mean converting 475,000 hectares over ten years.

Development benefits and priorities

Development benefits:

- Reduces the risk of soil erosion and improves soil fertility.
- Improved soil fertility can improve plant health and increase capacity to deal with pests and diseases.
- Enhances the long-term viability of agricultural lands and protect the incomes of farmers.
- Improve land productivity and decrease yield variance between years.
- Can decrease labor requirements, raising labor productivity in the sector.

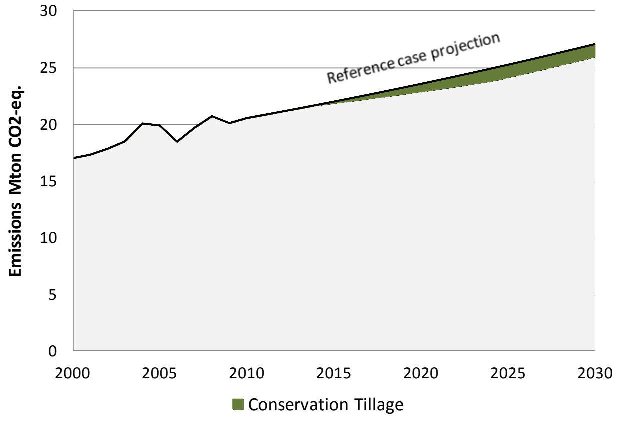
Alignment with Government of Kenya priorities: Agriculture is a priority sector in Vision 2030. Sustainable agricultural practices, including conservation tillage, are well aligned with programmes in the Medium Term Plan, such as enhancing capacity for food security, modernizing the sector, and enhancing the knowledge and skills of farmers. They also align with recommendations to improve tillage methods and cropping, and to more widely apply soil erosion control, as stated in the Technology Needs Assessment.

Links to adaptation: Actions that increase soil carbon sequestration have strong mitigation and adaptation synergies. Conservation tillage has been shown to enhance soil structure and thus water holding and retention capacity, making agriculture more resilient to extreme weather events such as heavy rains and drought. The increase in moisture conservation in dry climates can limit soil erosion, as well as make agricultural lands more resilient to changes in climate. The improvements in soil fertility improve plant health and productivity, and increase capacity to deal with pests and disease, which is crucial in the context of adaptation.

Abatement potential and costs

Greenhouse gas abatement:
Implementing conservation tillage practices across 475,000 ha between 2015 and 2025 would abate 0.1 MT of CO_2e in 2015 increasing to 1.1 MT of CO_2e by 2025; a substantial figure given that net emissions from soil are presently 1.8 MT of CO_2e per year.

Costs:
Very little data on the costs associated with promoting and establishing conservation tillage practices was found in the literature. Combining cost data that was found for sustainable agricultural practices with conservation tillage provides a cost of $31.15 per tonne of CO_2e mitigated.



Scenario	2010	2015	2020	2025	2030
Full till Land area converted to conservation tillage (hectares)	-	47,700	286,200	477,000	477,000
Abatement potential - $ktCO_2e$	-	110	650	1,100	1,100

Supporting data

Project/study name	Tonnes of CO_2e per hectare per year	Cost per hectare per year	Cost per tonne of CO_2e mitigated	Reference
Kenya Smallholder Carbon Agriculture Project (KSCAP)	1.4	$14.49	$10.35	Woelcke and Tennigkeit, 2010
Kenya Agricultural Carbon Project (KCAP)	1.33	$8.33	$6.25	Lager and Nyburg, 2010
An Assessment of Opportunities for Low Carbon Growth in Kenya	1.35	$20.25	$15.00	Stockholm Environment Institute, 2009
Baseline GHG Emissions from the Agricultural Sector and Mitigation Potential in Countries of East and West Africa	2.28			Brown, Grais, Ambagis and Pearson, 2012
Climate Smart Agriculture			$93	McCarthy, Lipper and Branca, 2011

Feasibility of implementation

Barriers:

The main barrier to successfully introducing low or zero tillage techniques is getting farmers to understand and employ these techniques. Persuading farmers to change their tillage practices (which are very well-established and trusted) will be a challenge. Also there will be significant difficulties persuading farmers to use crop residues for this purpose, since they have competing uses in Kenya as fuel and animal feed. Moreover, if farmers clear their shrubs prior to practicing conservation tillage, then some of the net gains in carbon sequestration will be compromised. Finally, securing a critical mass of financing for conservation tillage is an important barrier. Trade-offs need to be considered in conservation-tillage systems, which can require increased pesticide use. Also there is the trade-off that higher soil carbon levels can correlate with higher N_2O emissions; further research is needed specifically for the Kenyan situation.

Increased support for research, technological development, extension services and capacity building is required to extend the practice of conservation tillage. Work is needed to learn from and scale up pilot projects, and to determine the level of carbon stock increase that could be facilitated through appropriate government programs. Capacity building is needed to develop MRV systems, and support is required to build the foundations for effective carbon measurement techniques.

Awareness and acceptance:

The Food and Agriculture Organization has found that understanding of conservation tillage techniques is low in Kenya. The International Food Policy Research Institute has also found that farmers in Kenya generally do not recognize the importance of soil fertility management techniques and their synergies with adaptation. Work is needed to disseminate knowledge around general best practices for sustainable agriculture, in addition to education on conservation tillage practices. Improved extension services are critical for educating farmers about conservation tillage practices.

Limiting Use of Fire in Range and Cropland Management

Fire is widely used on grass and rangelands in Kenya to clear vegetation, stimulate growth, and control pests. On cropland, fire is used to attempt to regenerate soils or facilitate harvesting. Burning lands in this way is a significant source of GHG emissions in Kenya (methane and nitrous oxide emissions). Burning also can contribute to the permanent loss of protective vegetation and crop residue cover that can lead to reductions in soil carbon levels. Limiting the use of fire in range and cropland management involves reducing the frequency and extent of fires, or reducing the fuel load through vegetation management and burning at times of year when less GHG emissions will be emitted from burning.

Current situation: Over 430,000 hectares of rangelands are burned each year in Kenya. This results in emissions of approximately 0.26 Mt of CO_2e per year. In addition, burning agricultural residues of maize, wheat, sugarcane and rice crops is also common practice. Approximately 2,300,000 hectares of these crop residues are burned annually, leading to 0.93 Mt of CO_2e emissions per year.

Low-carbon scenario: This mitigation option would prevent 60 percent of the rangeland and cropland burning that occurs each year. This would be achieved through extension services to educate pastoralists and farmers on the risks associated with using burning to manage range and croplands, and on the benefits of alternative practices. It is assumed that successfully preventing 60 percent of rangeland burning would require reaching 20 percent of pastoralists (since it is likely that a small share are responsible for much of the burning), which was found in the literature to be a reasonable scenario in providing successful outreach services. This would require reaching 20 percent of the approximately 854,000 pastoralist households in Kenya (about 170,000 households). In addition, stopping 60 percent of cropland burning would involve providing extension services to almost all farm-owning households in Kenya, or approximately 3.58 million households, because not all farmers will adopt the new practices.

Development benefits and priorities

Development benefits:

- Reducing cropland burning increases the long-term viability of the land, thus enhancing food security and agricultural incomes.
- For pastoralists, the tree and shrub cover that accumulates as a result of not burning can provide food, fodder, wood fuel and charcoal, resulting in an additional revenue stream when sustainably harvested.
- The negative effects of burning are decreased. Burning causes photochemical smog and hydrocarbons, reduces soil water retention, causes nutrient depletion, and leads to soil erosion when bare scorched earth is exposed to wind and rain.

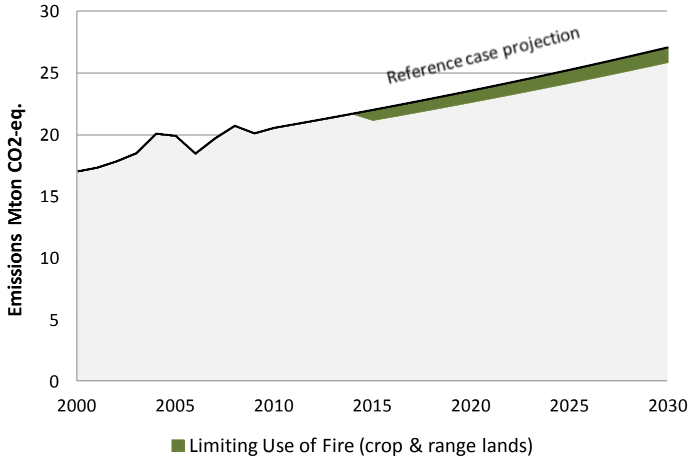
Alignment with Government of Kenya priorities: Vision 2030 identifies agriculture as one of the key sectors to deliver its targeted 10 percent annual GDP growth rate. The importance of agricultural extension in alleviating poverty has been highlighted in the Agricultural Sector Development Strategy. Improving incomes and food security of pastoralists, most of who reside in the ASALs, is consistent with the ASAL Development Strategy.

Links to adaptation: Reductions in the frequency and/or extent of fires will improve hydrological functioning, making lands more robust and resilient under drying conditions. Such lands are also less prone to soil erosion and nutrient depletion.

Abatement potential and costs

Greenhouse gas abatement:
Preventing 60 percent of current rangeland burning would abate 0.16 Mt of CO_2e in 2015, falling to 0.15 Mt in 2030. Preventing 60 percent of cropland burning would abate 0.65 Mt of CO_2e in 2015, increasing to 1.0 Mt CO_2e in 2030.

Costs:
It is assumed that providing extension services to a pastoralist household cost the same as providing extension services to smallholder farmers, which have been found in the literature to be approximately US$10.35 per year. Costs are assumed to be one half this figure for farm-owning households due to the network of existing extension services. This would lead to an average cost for reducing crop and rangeland burning of US$21.00 per tonne of CO_2e abated per year.



Scenario	2010	2015	2020	2025	2030
Limiting the use of fire on grazing land (hectares)	-	261,600	259,200	256,500	254,600
Limiting the use of fire on crop land (hectares)	-	902,000	1,051,000	1,224,000	1,426,000
Abatement potential ($ktCO_2e$)	-	806	912	1,063	1,180

Supporting data

Project/study name	Cost of outreach per farm/ household	Cost per tonne of CO_2e mitigated (calculated)	Reference
Kenya Smallholder Carbon Agriculture Project (KSCAP)	US$10.35		Woelcke and Tennigkeit, 2010
Restocking and Poverty Alleviation: Perceptions and Realities of Livestock-Keeping Among Poor Pastoralists in Kenya		US$9.20	Heffernan, 2001

Feasibility of implementation

Barriers: Many of these practices would be best instituted by providing outreach to farmers. In many cases this can involve utilizing existing extension services and networks, which would require substantial scale-up and improvement, as well as capacity building for extension workers. Institutional constraints include limited ability to train in emerging areas and inadequate levels of funding for public training institutions. Remote areas and poor producers, especially those growing low-value crops with little marketable surplus are poorly served by extension services. Getting the right solutions to the right places and convincing pastoralists and farmers of their importance and benefits will be a challenge. Burning practices are quite entrenched, and it could be difficult to persuade pastoralists and farmers to abandon them.

Awareness and acceptance: A study by the International Food Policy Research Institute found that farmers in Kenya "do not fully recognize the inter-linkages between agricultural productivity, climate change adaptation and GHG mitigation," and the relationship between soil fertility and rangeland resilience, and the benefits of not burning residues is not well understood by pastoralists and farmers.

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