AN ASSESSMENT OF THE FEASIBILITY OF CARBON TRADING AFFORESTATION CONTRACTS IN TRANS MARA SUB-COUNTY, KENYA.

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A Thesis Submitted in Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Agricultural Economics, University of Nairobi.

DECLARATION

This thesis is my original work and has not been submitted to any other University for any degree.

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DEDICATION

To my lovely daughters Tracy and Lorraine

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMS

AES	Agri-environmental scheme
ALRMP	Arid lands resource management program
AR	Afforestation and reforestation
ASALs	Arid and semi arid and lands
CA	Conjoint analysis
CCX	Chicago climate exchange
CDM	Clean development mechanism
CE	Choice experiment
CL	Conditional logit
CO_2	Carbon dioxide
CRT	Contingent rating
CS	Compensating surplus
CV	Contingent valuation
DAP	Di-ammonium phosphate
ET	Emission trading
EU-ETS	European Union emission trading scheme
FACE	Forest absorbing carbon dioxide emission
FGD	Focused group discussion
GDP	Gross domestic product
GEF	Global environmental facility
GHGs	Green house gases
GOK	Government of Kenya
Ha	Hectare
IIA	Independence of irrelevant alternatives
IITA	International institute of tropical agriculture
ILRI	International livestock research institute
IPCC	Inter-governmental panel on climate change
JI	Joint implementation
KARI	Kenya agricultural research institute
KEFRI	Kenya forestry research institute
KFS	Kenya forestry service

KMD	Kenya meteorological department
KP	Kyoto protocol
KShs	Kenya shillings
LULUCF	Land use, land use change and forestry
MAHARI	Maa habitat restoration initiative
MDG	Millennial development goals
MgC $ha^{-1}year^{-1}$	Megatons of carbon dioxide per hectare per year
MLND	Maize lethal necrosis diseases
MNL	Multinomial logit
MWTA	Marginal willingness to accept
NCCRS	National climate change response strategy
NCPB	National cereal and produce board
NEMA	National environmental management authority
NGOs	Non-governmental organizations
NPV	Net present value
NTFPS	Non-timber and forestry products
RPL	Random parameter logit
RRA	Rapid rural appraisal
RUM	Random utility model
TIST	International small group and tree planting program
TRC	Trypanosomiasis research centre
UNDP	United nations development programme
UNEP	United nations environmental programme
UNFCCC	United nation framework convention for climate change
UMP	United multi-purpose project
USAID	United states agency for international development
WTA	Willingness to accept
WTP	Willingness to pay

ABSTRACT

Carbon afforestation projects on marginal and degraded agricultural lands could potentially contribute to improved livelihoods to farmers through enhanced financial inflows from carbon revenue and sale of tree products while restoring and conserving the environment. Currently though, there is paucity in knowledge on the viability of these projects in Kenya. This study was carried out in Trans Mara sub-County to explore the feasibility for carbon trading afforestation projects among farmers. The specific objectives were to (i) evaluate farmersô willingness to participate in carbon trading contracts, (ii) their preferences for different features of the contracts, (iii) the influence of farmer socioeconomic characteristics on the likelihood of participation and (iv) willingness to accept (WTA), (iv) assess the potential financial benefits derivable from carbon trading afforestation contract, (v) assess farmersô perceptions of climate variability and change and (vi) their adaptation strategies.

The choice experiment method was used to design hypothetical carbon afforestation contracts that were presented to the farmers to elicit their responses. The random parameter logit models were employed to estimate farmersô willingness to participate, preferences, determinants of participation and WTA. The partial budget method, net present value and benefit cost ratio were used to analyze the financial profitability of the carbon contracts. The analysis of farmersô perception of, and adaptation strategies to climate variability and change was based on farmersô observations of climatic events over a period of the past 20 years. Data was collected from a random sample of 206 farmers in Lolgorian and Kilgoris Divisions using a semi-structured questionnaire.

The results showed that seventy nine percent of farmers would participate in carbon trading afforestation contracts. Farmers preferred shorter contracts and those without an option for cancellation, and were willing to trade-off less desirable features of the contracts with additional payments. Farmerøs age and size of land holding positively influenced the likelihood of participation in the carbon contracts. The average minimum amount of money that the farmers would be willing to accept in order to set aside an acre of land for the carbon contracts was KShs 3,591 per acre per year

A carbon trading afforestation enterprise for the multiple objectives of timber and carbon sequestration was found to be more profitable financially than the maize, beans and livestock enterprises. The tree enterprise for a management objective of carbon sequestration only was financially unprofitable at the prevailing carbon price of Kshs 860 Mg $Cha^{-1}year^{-1}$.The farmers had reasonable perceptions of the effects of climate variability and change and had taken steps to adjust their farming activities. Changes in rainfall pattern and intensity, variously described as unpredictable, delayed onset of rain, brief and intense rainfall and insufficient rainfall, were the key ways in which the changes in climate were perceived. The farmers made several adjustments to their farming practices that included change of crop varieties and livestock breeds, reduction in herd size, and farm enterprise diversification. Inadequate financial resources, information and labor were cited as the main constraints to the adoption of adaptation strategies to combat climate change.

The study shows that carbon trading afforestation contracts are a feasible income earning opportunity for farmers in Trans Mara sub-County particularly among those seeking for opportunities to diversify their agricultural enterprises and those with underutilized lands. Policy and development agents at the local level would do well to link the farmers to existing carbon markets. A policy environment that enables the necessary institutional mechanisms for community participation would be needed for the carbon trading afforestation contracts to work. For them to have a wider appeal, carbon trading contracts should be designed in a manner that accounts for heterogeneity in farmersô resource endowments, size of farm and preferences.

CHAPTER 1: INTRODUCTION

1.1 Background

Climate change refers to a change of the average weather pattern for a particular region lasting for an extended period of time that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere (UNFCCC, 2005). Climate change adds to the myriad of challenges facing Kenyaøs agriculture that is largely rain-fed and therefore susceptible to weather fluctuations. Extreme weather events associated with climate change, including higher temperatures, droughts, floods and unpredictable rainfall pattern, compromise agricultural production and the overall performance of the Kenyan economy that is largely dependent on agriculture. Over the past three decades, the frequency and intensity of drought and floods in Kenya has increased and caused major socioeconomic losses as a result of crop failure, loss of livestock and other losses (Nkedianye et al., 2011; Wakabi, 2006). It is estimated that economic losses due to climate change across economic sectors in Kenya vary between US$ 1 and 3 billion per year (Government of Kenya [GOK], 2010b), which is equivalent to between 7 and 21 percent of the 2013/2014 annual fiscal budget. Minimizing the adverse effects of climate change is likely to reduce the opportunity cost of such losses and contribute to ongoing poverty reduction efforts in Kenya.

Studies indicate that the most vulnerable segment of Kenyan society to be negatively impacted by the adverse effects of climate change are farmers living in arid and semi-arid lands (ASALs) and whose livelihood is livestock-based (Galvin et al., 2001; IPPC, 2007; Little et al., 2001). In the past, these farmers, mostly pastoralists and agro-pastoralists, were able to successfully track climate variability and employed a diversity of adaptation strategies to sustain their livelihoods. These strategies included, for example, transhumance and migration; herd splitting and keeping species specific herds (Galvin, 2001; Homewood et al., 2009). Some of these strategies have increasingly become untenable due to demographic, economic and environmental changes that have taken or are taking place in most ASALs (Ekaya, 2005; Homewood et al., 2009; Musimba and Nyariki, 2003). As a result, pastoralists and agro-pastoralists have been forced to either move deeper into more arid areas or adapt other livelihood alternatives that are alien to their culture and traditions. Policy makers and development agents keen on supporting climate change adaption may not be aware of these adaptation strategies which can greatly reduce the vulnerability of these communities.

Opportunities exist for mitigating the adverse effects of climate change that can potentially benefit farmers and the general economy. One of these opportunities is offered by trading in carbon, called ñcarbon tradingò. Carbon trading is anchored within the Kyoto Protocol framework[1]. The Kyoto Protocolôs Clean Development Mechanism (CDM) and the voluntary carbon markets allow emission-reduction projects in developing countries to earn certified emission reduction (CER) credits (each equivalent to one ton of carbon dioxide) which are sold in carbon markets. Under the CDM, industrialized countries are allowed to invest in forest-based carbon sequestering activities in developing countries in exchange for carbon offsets that count against emission reduction targets specified by the Kyoto Protocol. Resource-poor farmers in developing countries can take advantage of this initiative by embarking on farm forestry projects and, as such, receive financial inflows to improve their livelihoods (Roshetko et al., 2007). Concerted effort is needed to take advantage of this untapped potential for income generation, which will also reduce the vulnerability and increase the adaptive capacity of resource-poor farmers. However, crucial to this endeavor, is the need for information on the level of interest and willingness of potential beneficiaries to participate in such initiatives as part of their livelihood diversification strategy.

Climate change and unprecedented levels of environmental degradation in the rangelands[2] in southwestern Kenya has raised serious concerns about the long-term viability of livelihoods of farmers in the region (Bhola et al., 2012). Most rangelands are increasingly becoming degraded due to agricultural and livestock intensification (De Leeuw and Reid, 1995; Mworia and Kinyamario, 2008; Nyangito et al., 2008). Destruction of forests to increase grazing possibilities and create farmland has led to severe land degradation in some parts of the southern rangelands so that it is now almost impossible to plant certain crops in such areas (Jaetzold et al., 2010). This situation is further exacerbated by the effects of climate change such as increased frequency of drought and elevated temperatures. For example, temperature data from the Narok Meteorological station for the period 1993-2008 shows that the absolute mimina has increased at an average of 1.47°C per month compared to the period between 1946 and 1976 (Jaetzold et al., 2010). These developments threaten sustainable livelihood of

[1]The Kyoto protocol (KP) is an international treaty that sets legally binding targets for industrialized countries (thought to be mainly responsible for emission of greenhouse gases, GHGs) to reduce their emissions which are responsible for global warming and climate change. In addition, the protocol offers other means of meeting their targets by way of flexible market-based mechanisms (UNFCCC, 2007).

[2]Rangeland is a collective term for native grasses and shrubs that cover an arid or semi-arid area. Rangeland can include ecosystems such as forests, woodlands, savannas, tundra, marshes and wetlands.

farmers in the rangelands and point to a need for alternative strategies where natural resource conservation and environmental rehabilitation can be combined in ways that contribute to improved livelihoods and income generation. Carbon trading through on-farm afforestation projects represents one such option that could potentially mitigate the effects of environmental degradation and climate change and offer alternative income sources to both pastoralists and agro-pastoralists in the rangelands (Lal, 1999, 2000; Olsson and Ardo, 2002).

Carbon trading afforestation projects are long-term investments in land, labor and other resources. Unlike most agricultural commodities, farm forestry projects have longer planning horizons with most benefits occurring in the distant future. Knowledge and a clear understanding of the financial profitability of these projects is a crucial aspect in informing farmersô decisions to commit their land to forestry for carbon trade as well as to policy makers and other develop agencies interested in encouraging and up-scaling carbon projects in marginal areas.

1.2 Statement of the problem

The Trans Mara sub-County has experienced adverse environmental changes in the past few decades due to human-induced factors (Jaetzold et al., 2010; Narok County Development Profile, 2013) These include, among others, a rapid growth of population and migration of communities from neighboring sub-Counties, land fragmentation and changes in land use. These have put a great strain on the fragile rangeland ecosystem, leading to depletion of the natural resource base that includes forests and water resources. A large section of the natural forest which provided multiple ecosystem services including habitat for wildlife, has been cleared through charcoal burning and wood fuel harvesting. This destruction has left huge tracts of degraded land, mainly denuded hills where very little agricultural activity is carried out.

Environmental degradation in Trans Mara has raised serious concerns about the long-term viability of livelihoods of communities in the area which are still intrinsically linked natural resources. The situation is further exacerbated by the consequences of climate change such as prolonged drought and unpredictable rainfall that are already being recorded in the County (ibid). Although there have been efforts to restore the degraded environment in the sub-County through tree planting, success has been limited. Carbon trading afforestation projects could be one of the solutions to environmental degradation in the sub-County that could simultaneously help conserve and restore the environment and benefit farmers from increased financial inflows from sale of carbon sequestration services. However considerable gaps in knowledge still remain on the feasibility of these projects and in particular whether farmers would be willing to participate in them.

There has been a fast growth in literature on micro-level vulnerability and adaptation to climatic variability and climate change in Kenya and Africa in general (Deressa et al., 2010; Juana et al., 2013; Rao et al., 2011; Silvestri et al., 2012). Even so, considerable gaps in knowledge still remain on site-specific adaptation strategies in several parts of the country. Kenya exhibits considerable variations in climatic, topographic and social diversity, all of which could shape the choice of adaptation strategies. Furthermore, since adjustments to climate change is often conceptualized as a site-specific phenomenon, more local-level analyses are often recommended to gain a better understanding and for better targeting of policies by the government and other development agencies that support climate change adaptation efforts (Boko et al., 2007; Mano and Nhemachena, 2007; Smit and Wandel, 2006).

There are a number of studies that have looked at farmers perceptions of climate change in Kenya (Kalungu et al., 2013; Ndambiri et al., 2013; Ogalleh et al., 2012). However, limited information still remains regarding farmersô perceptions of climate change and their adaptation strategies as well as barriers to adaptation in southern rangelands in Kenya where socio-economic conditions are rapidly changing and environmental degradation is at an all time high. These changes are likely to compound the climate change challenge and influence the choice of adaptation strategies. Farmers appraisal of the profitability of carbon projects relative to the existing enterprises will largely determine their willingness to adopt them and to commit to implementing them overtime (Tschakert, 2007). Currently, however, empirical evidence remains scanty on the financial profitability carbon afforestation projects to enable a thorough assessment of whether revenues from carbon project on smallholder farms can indeed increase farmersô income.

1.3 Objectives

The overall objective of this study was to explore the feasibility for carbon trading afforestation contracts among farmers in Trans Mara sub-County. The specific objectives were to:

1. Assess farmersô willingness to participate in carbon afforestation contracts,

2. Evaluate farmers preferences for carbon afforestation contract attributes
3. Assess the influence of farmers socioeconomic characteristics on the likelihood of participation and willingness to accept (WTA)
4. Assess the potential financial benefits derivable from carbon trading afforestation contracts.
5. Assess farmer perceptions of climate variability and change
6. Evaluate farmers adaptation to climate variability and change

1.4 Justification

Climate change will increasingly impact negatively on agricultural livelihoods and food security in the country. Therefore, any effort aimed at promoting farm level adaptation and mitigation measures, such as farm-based afforestation projects, is expected to contribute to the governmentôs goal of ensuring food security, increasing farm incomes and reducing poverty levels as encapsulated in the Vision 2030 and the Millennium Development Goal (MDG) number one. It is anticipated that carbon forestry projects, if taken up, will improve farmer incomes through the sale of carbon credits as well as contribute to improved tree cover and stabilization of other biophysical elements of the environment thus mitigating the negative impacts of possible climate-related influences, such as droughts. Therefore, carbon projects are an important tool for poverty reduction and increased agricultural productivity through increased household income and improved environmental quality.

Kenya has a huge potential for generating carbon-emission reduction credits through afforestation, reforestation, sustainable land use, agroforestry and related livelihood activities on privately owned farm lands. With a growing interest in carbon projects in Kenya and Africa in general, it is anticipated that knowledge provided through this study would inform and guide the design of programs and projects that seek to encourage the uptake of farm-based carbon projects among smallholder farmers.

The Government of Kenya has officially recognized climate change as a significant threat to national development and the welfare of her people. The GOK has thus prepared a National Climate Change Response Strategy (NCCRS) to respond to the challenges of climate change (GOK, 2010a). The strategy seeks, among other things, to recommend robust adaptation and mitigation measures to minimize risks associated with climate change while maximizing opportunities thereof, as well as to provide the necessary policy, legal and institutional framework to combat climate change. The strategy has identified specific sectoral research needs which include evaluating the potential for remunerating farmers for forests conservation and restoration with funds from carbon markets, promoting technologies to rehabilitate naturally-degraded areas or those cleared for charcoal burning. Also acknowledged in the strategy are low levels of knowledge and information about climate change challenges and opportunities and the need for more climate-related research. This study contributes to the growing body of information and knowledge that could inform policy on climate change mitigation in the country.

Farmer perceptions of climate change is one of the key elements influencing the process of adaptation (Smithers and Smit, 2009). It has been shown empirically that farmers cope and adapt to climate change depending on how they perceive it. However, the choice of adaptation methods is influenced by a host of socioeconomic and environmental factors (Deressa et al., 2009). Many socioeconomic and environmental changes are happening in southern rangelands of Kenya that could potentially compound the climate change challenge and adversely affect the sustainable livelihoods of farmers in the region. Therefore, examining local perceptions and responses to climate change within this dynamism is important because these can help identify more precisely the kind of support these farmers require to strengthen their climate resilience.

Farmersô willingness to be involved in carbon trading afforestation projects is one of the key factors that would influence the success of these projects. It is widely recommended that both farmer factors and scheme factors be taken into consideration when attempting to understand farmer participation in agri-environmental schemes. (Brotherton et al., 1989, 1991). Farmer factors include various individual farmer and farm characteristics while scheme factors are those that may influence economic attractiveness of a particular project, and include the financial incentives offered and other design elements such as length of contract (Ruto and Garrod, 2009). An investigation of these factors would provide information that could help in the design of carbon afforestation projects that have a wider appeal to farmers thereby encouraging participation.

CHAPTER 2: LITERATURE REVIEW

2.1 Carbon trading definition and origin

Carbon trading, sometimes called ñemissions tradingò, is a market-based tool to limit the release of green house gases (GHG) in the atmosphere which are believed to be the significant driver of observed climate change. Ronald Coase was among the first writers to promote the idea of pollution trading (Coase, 1988). He believed that pollution was part of the cost of production and if it was priced as part of the process of production, market forces would eventually deter businesses from polluting the environment because it would become less and less cost-effective for them to do so. Other economists developed this theory further and suggested that although prices and pollution levels should largely be controlled by the market, the overall pollution limits have to be set by governments (Lohmann, 2006). Since then, pollution trading has been seen as a way of making it as cost-effective as possible for businesses to comply with an emissions target set by the State. Currently, carbon trading is the central pillar of international climate change mitigation policy promulgated in the Kyoto Protocol.

2.2 The Kyoto Protocol

The Kyoto Protocol (KP) is the successor of the United Nations Framework Convention on Climate Change (UNFCCC), aimed at fighting global warming. The UNFCCC is an international environmental treaty whose goal is to stabilize GHGs concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system (UNFCCC, 2005). Countries with commitments under the KP to limit or reduce greenhouse gas emissions must meet their targets primarily through national measures. As an additional means of meeting these targets, the KP introduced three market-based mechanisms, thereby creating what is now known as the ñcarbon market.ò The KP mechanisms are (i) Emissions Trading (ET), (ii) Clean Development Mechanism (CDM), and (iii) Joint Implementation (JI).

In the KP, countries fall into two categories: those with an obligation to comply with an emissions target set under the protocol, and those without. Countries with a target are mainly the industrialized countries which have been responsible for the biggest increases in greenhouse gas emissions. They are also referred to as óAnnex 1 countriesô because they are listed in Annex 1 to the KP. For most industrialized countries, the targets require reductions though some countries can increase their emissions under the targets set. The KP does not include targets for ódevelopingô countries, because of their smaller contribution to the increase in GHG emissions in the past. Each industrialized country listed in Annex 1 and that has signed the KP has to report to the UNFCCC Secretariat on its progress towards compliance with the target annually, and at the end of the first commitment period of the KP.

2.3 Carbon markets

These are markets in which buyers and sellers trade in ócarbon offsetsô or ócarbon creditsö. A ñcarbon creditò is a unit of carbon emissions reduced at source (for example, by reducing consumption of fossil fuels) or a unit of carbon dioxide that have been absorbed by forests from the atmosphere (Landell-Mills and Porras, 2002). There are two types of carbon markets, namely, (i) regulatory compliance market and (ii) voluntary markets. The regulated market is used by companies and governments that by law have to account for their GHG emissions. It is regulated by mandatory national, regional or international carbon reduction regimes. Voluntary markets represent voluntary attempts by individuals and organizations to reduce their carbon emissions (Bayon et al., 2007).

The KP is at the heart of the compliance market because it created both the demand for offsets and the mechanism to fill this demand. It provides two instruments that generate carbon offsets. The CDM regulates offset projects located in countries that do not have emissions targets while JI is the offset mechanism that allows for offset projects in countries with emission targets. The trade in credits generated by carbon offset projects under the KP is often referred to as the ócompliance marketö, because countries with a target under the protocol can count offset credits towards compliance with this target. Outside the compliance market, carbon offset credits are also traded in the óvoluntary offset marketö. These markets represent voluntary attempts by individuals and organizations to reduce their carbon emissions (Bayon et al., 2007). Developing countries can only participate in the CDM and voluntary markets. The size of the two markets differs considerably. In 2008, US$119 billion and US$704 million carbon credits were traded on regulated and voluntary markets, respectively (Hamilton et al., 2009). By February 2010, over 2500 carbon offset projects in 62 countries had been registered with the CDM. The CDM identifies over 200 types of projects from which carbon offsets can be generated. They are grouped into broad categories, including renewable energy, energy distribution, methane abatement, energy efficiency, reforestation and fuel switching (UNFCCC, 2011).

2.4 How the carbon market works

Broadly, the carbon markets consist of two types of transactions, namely (i) project-based transactions, and (ii) trade in allowances (Lecocq and Capoor, 2005).

2.4.1 Project-based transactions

These occur when a buyer invests directly in a carbon emission reduction or carbon sequestration project and gets emission credits in return. For example, a company pays money to a local community in a developing country to raise forests and then claims carbon sequestration credits in return. The local community in this case acts as a service provider, being responsible for actually generating the carbon credits. There may even be a contract that specifies the kind of service to be provided (For example ó*n*ô number of trees to be planted per hectare per year), and how benefits will be shared (For example, the investor may own the carbon credits but timber and other non-timber forest products belong to service providers). In project-based transactions, compensation to service providers may include direct payment or other development benefits such as provision of social services and infrastructure, in-kind technical assistance and support for commercialization or even expansion of rights over local natural resources (Rosa et al., 2003; Scherr et al., 2001). Carbon sequestration is just one of the several types of project-based transactions. Under the KP, afforestation and reforestation (AR) projects for carbon sequestration are collectively termed as Land Use, Land Use Change and Forestry (LULUCF) sector. Other transactions include raising energy efficiency, converting power plants from fossil fuels to renewable energy sources, and collecting methane from landfill sites.

2.4.2 Trade in emission allowances

This refers to commercial trading in carbon offsets under various regimes that have emerged in different parts of the world. These include the European Union Emission Trading Scheme (EU-ETS) under the KP, and the United States based Chicago Climate Exchange (CCX) under the voluntary markets. These systems operate like equity markets with buyers and sellers trading well-defined carbon units at particular prices. Buyers do not invest in any particular project and simply purchase carbon credits from sellers who may have actually invested in emission reduction or carbon sequestration projects.

2.4.3 Investors, service providers and intermediaries in Africa

In general, apart from buyers and sellers, carbon markets also include intermediaries and supporters. Intermediaries facilitate transactions between investors and service providers. Supporters are institutions or individuals who create an enabling environment and a legal basis for carbon markets to function (Noordwijk et al., 2003). When carbon sequestration projects are taken up by local communities, intermediaries, such as non-government organizations (NGOs), government agencies and research organizations, frequently assume additional support responsibilities, such as capacity building, monitoring and supervision.

The World Bank is the biggest carbon investor in Africa and is continually developing new carbon sequestration projects in Africa as part of a global portfolio of carbon sequestration projects financed by its BioCarbon Fund. Investments in Africa still comprise less than 10 percent of $629 million worth of global carbon business managed by the World Bankôs carbon finance unit (World Bank, 2006). This shows that carbon projects in Africa have a long way to go before they achieve the same level of carbon investment as enjoyed by other regions, such as East Asia and the Pacific. Other major carbon investors in Africa are the Global Environment Facility, the United States Agency for International Development (USAID), the Forest Absorbing Carbon Emissions (FACE) Foundation, and the European Union. In addition, national governments of industrialized countries, such as Norway and United Kingdom (Department for International Development), are also funding carbon sequestration projects in Africa.

Local communities act as service providers for most carbon sequestration projects in Africa, indicating that many of these projects have a community development focus rather than only profit making for carbon investors. In such projects, intermediaries (such as NGOs and local governments) have taken up additional responsibilities of community organization, capacity building of community representatives, and monitoring and supervision, apart from their main role of obtaining funds from investors. Other implementing organizations include private companies or their local subsidiaries, international and local NGOs and research institutions or universities. For example, in Kenya there is the International Small Group and Tree Planting Program (TIST) (see their profile at www.tist.org).

2.5 Carbon sequestration activities

Carbon sequestration is the process of removing excess carbon dioxide (CO_2) from the atmosphere where 3.67 tons of CO_2 are equivalent to 1 ton of sequestered carbon. The Kyoto Protocol's CDM recognizes carbon sequestration through afforestation as a way to mitigate global warming and also allows industrialized countries to offset their carbon emissions by investing in forestry projects in developing countries (UNFCCC, 2003). In addition, many private organizations are voluntarily promoting carbon sequestration projects to reduce their carbon emissions.

The carbon sequestration potential of agricultural and forestry activities has been recognized for some time now. The IPCCộs Fourth Assessment Report, issued in 2007, detailed scientific evidence of carbon sequestration and storage potential through forests, and agricultural and land management practices. Research has shown that farmers can reduce GHG emissions, increase carbon sequestration, and maintain above- and below-ground carbon stocks at relatively low cost, while also improving food production and livelihoods through practices such as (Smith et al., 2007):

- Preventing deforestation which is considered to be one of the areas of greatest loss of carbon from forest sinks because preventing forest clearance to another land use would have a dramatic effect on carbon stores;
- Replanting (reforestation) is an important part of sustainably managed forests because replanting after felling trees ensures a continuous yield. Stocking with younger, more vigorous trees can increase stocks of carbon that is stored in a forest;
- Afforestation, which involves increasing land area under woodland, is a way of increasing the storage potential of carbon stocks but is dependent on the availability of land;
- Agronomy, which includes practices that increase yields and carbon sequestration through using improved crop varieties, extending crop rotations through selection of perennial crops, growing cover crops which allows for green manuring, adopting a multiple cropping and crop rotation approach (For example planting cereals, legumes and root crops in a sequence) or intercropping (planting two or more crops in the same field);

- Nutrient management, which includes identification of sites where inorganic fertilizer is used inefficiently by crops and, for those areas, switching to organic fertilizers such as manure and compost, both of which have high soil carbon sequestration potential;
- Tillage and residue management, which includes reduced tillage and no till agriculture as well as mulching, composting and integrated livestock and manure managementð all of which increase soil carbon in the upper layers of the soil, and
- Agroforestry, where woody perennials (trees, shrubs) are grown in the same land management unit with other crops.

By selecting among and adopting these management practices, where appropriate, African countries could potentially reduce GHG emissions by 2.0ï 3.5 million tons of CO_2 equivalent per hectare per year (Smith and Martino, 2007) or a total of 52.3 to 91.5 million tons of CO_2 equal to approximately 5 to 9 percent of annual African fossil fuel emissions in 2005 (Canadell et al., 2009). Even in semi-arid lands, agroforestry systems like intercropping or silvopasture with 50 trees can store 110 to 147 tons of CO_2 equivalent per hectare in the soil alone (Nair et al., 2009).

2.6 Carbon sequestration through tree planting

Trees and woodlands play an important role in the carbon cycle. As trees grow, they extract carbon dioxide from the atmosphere. Carbon is then ófixedô (stored) by the tree in its green matter (everything from leaves and branches through to the woody trunk). While some of this carbon dioxide is transferred back to the atmosphere through respiration, the tree continues to grow and increases the woody material thus locking the increasing carbon content in it until it dies and decays or is harvested and processed to another end use. Needles and leaves dropped by the tree contribute to the soil carbon store after decomposition. Additionally, trees can protect vulnerable soils by stabilization, protection from drying out, intercepting water and slowing run off and hence help to maintain carbon stocks that are stored in soil. Carbon sequestration potential by trees is recognized as one low cost means of removing excess GHG in the atmosphere (UNFCCC, 2003).

Like natural forests, planted forests take up and store carbon at high rates compared to other world land covers. Storage rates commonly range from 1 to 8 megatons of carbon per hectare per year (MgC ha^{-1} yr^{-1}, 1 megaton equals 10^6g of carbon dioxide). A typical mean carbon storage over a rotation period is from 50 to 80 MgC ha^{-1} yr^{-1} (Winjum and Schroeder, 1997).

Many studies indicate that afforestation is one of the most cost-effective options for carbon sequestration (Parks and Hardie, 1995; Sampson and Sedjo., 1997). There has been a proliferation of projects in developing countries that encourage small-scale farmers to adopt tree planting as part of the efforts to sequester carbon from the atmosphere to help mitigate climate change. Some of the projects offer cash payments to farmers on the basis of the number of trees that they maintain on the farms. In one of such project that is implemented by The International Small Group and Tree Planting program (TIST) in Kenya, farmers receive payments on a ñper-surviving-treeò basis. This way, smallholder farmers plant trees without compromising the land available for crops. This approach may prove the best balance between sequestrating carbon and farming to meet farmersô food requirements as well as generate some income to meet other essential needs (Kirby and Potvin, 2007; Roshetko et al., 2007).

2.7 Potential benefits from carbon sequestration projects in Africa

2.7.1 Sustainable development

Sustainable development is an important issue for carbon sequestration projects. Researchers have documented the livelihood and other development benefits of various carbon sequestration projects around the world (Rosa et al., 2003; Smith and Scherr, 2002). The KP stipulates that all CDM projects, including carbon sequestration activities, should achieve sustainable development benefits for host countries (UNEP, 2004).

The major developmental benefits for local communities from these projects are increased timber and non-timber and forestry products (NTFPs) from regenerated forests, employment opportunities from forestry activities, and increased incomes from the sale of carbon credits. For instance, in the Nhambita Community Carbon Project in Mozambique, local households receive a cash payment over the next seven years for carbon sequestered by various land-use activities (Jindal et al., 2006). This represents a significant increase in cash incomes for most households and addresses their felt need of obtaining access to a regular income source (Palmer and Silber, 2009). Similarly, local farmers in Kenya, Uganda, Tanzania and India receive regular payments on the basis of number of trees they can manage on their lands under TIST. These few examples demonstrate that many carbon sequestration projects have the potential to achieve sustainable development in Africa and to provide increased financial inflows for host countries.

2.7.2 Biodiversity conservation and protection of natural resources

Many natural resource management projects are not viable, either because their benefits are uncompensated environmental services or because national governments and other local agencies do not have adequate funds to undertake conservation activities. Carbon projects can address these concerns in two important ways, first by paying for some of the services such as carbon sequestration, and secondly by providing financial assistance to national governments to invest in natural resource projects (Gitman, 2003). This is particularly relevant for Africa where precious natural resources are being rapidly lost for want of conservation investments. There is evidence to show that many carbon sequestration projects in Africa have been successful in improving the local resource base in the area and in conserving precious biodiversity. For example, the World Bank BioCarbon Fundȏs Andasibe-Mantadia Biodiversity Corridor Project is expected to protect several endemic species by linking fragmented parts of Malagasy rainforest in Madagascar. Similarly, the Participatory Rehabilitation of Degraded Lands project aims to conserve biodiversity in the trans-boundary region of Senegal and Mauritania, as well as to restore natural ecosystems that would enhance carbon sinks in the area. The project is being implemented in an area of 6 million hectares along the Senegal River valley and is funded by the Global Environment Facility (GEF). Another prominent initiative is the FACE Foundation supported forest rehabilitation project on Mount Elgon and Kibale National Parks in Uganda. The project has been able to regenerate the severely degraded areas in the two parks while producing carbon credits for the investor (Jindal et al., 2008).

2.7.3 Ecological restoration

Carbon sequestration in the form of afforestation and reforestation activities often generates other co-benefits for locally valued ecosystem goods and services, such as more regular and higher quality water supplies, control of soil erosion and sedimentation and improvement of the hydrology in the area (Scherr et al., 2004). In Western Sudan, for example, a carbon sequestration project has been working toward improving local rangelands. Rangelands are the mainstay of Sudanȏs economy as they cover about 60 percent of the country and provide fodder for one of Africaȏs largest concentrations of livestock. However, many rangelands have been badly degraded due to recurrent droughts and overgrazing. The project aims to restore these rangelands through conservation activities, such as planting trees and grass to stabilize sand dunes and create windbreaks. Similarly, the afforestation and reforestation projects in Uganda and Ethiopia aim to regenerate local ecosystems. The Nile Basin

Reforestation Project (Uganda) plans to establish a mix of pine and native species to mitigate land degradation in upper catchments of the Nile River. The Humbo Assisted Regeneration Project will help to restore 15,000 ha of natural forest in the Rift Valley (Ethiopia). Both these projects are funded by the World Bankŝs BioCarbon Fund. Another example is the Western Kenya Integrated Ecosystem Management Project (Jindal et al., 2008).

2.7.4 Improved land productivity through soil carbon sequestration

SSA contains large tracts of degraded lands with extremely low agricultural productivity. For instance, average crop yields in SSA are a meager 1.5 t/ha for maize, 0.8 t/ha for sorghum and 0.7 t/ha for millet (Lal, 2010). This is due to poor soil quality, which occurs when soil organic carbon is lost to the atmosphere, thus leading to desertification. Estimates of the affected area range from 3.47 to 3.97 billion hectares (Lal, 2010). The process can be reversed through improved agricultural practices, such as conservation tillage, soil erosion control, establishment of appropriate shrubs and woody perennials, soil fertility enhancement, and crop residue management. This process not only restores soil quality by increasing its organic content, but it also aids in mitigating climate change by returning more carbon to the soil. Thus, carbon sequestration activities that improve soil carbon content have the potential to improve productivity of large tracts of land in Africa.

2.8 An overview of carbon sequestration economics and policy

The earliest works in carbon sequestration economics focused on estimating the cost-effectiveness of the sequestration option, specifically to examine whether expansion of forest sinks could play a major role in the effort to slow down the accumulation of atmospheric carbon dioxide (e.g., Van Kooten, 2000; Plantinga et al., 1997; Stavins and Richards, 2005; Sedjo, 2001; Richards and Stokes, 2004; Parks and Hardie, 1995, Newel, 2000). In general, these studies each follow a similar pattern: they posit a government program such as subsidies, government purchases, or contracts, to promote a particular forest practice such as afforestation of agricultural land, modification of forestry management practices, or preservation of forestland, for a particular geographic context, which can vary in scope from sub-national to global. With the outline of the hypothetical program roughly in place, the analyses proceed to attach costs to the various inputs to production including land, labor, and materials.

Parks and Hardie (1995) derived the supply schedules for carbon sequestered in trees planted on marginal agricultural land in the United States of America. The schedules were used to develop criteria for enrolling lands in a national carbon sequestration program modeled after the Conservation Reserve Program. Alternative criteria were compared based on cost and carbon sequestered. The results suggested that carbon sequestration policies should focus on establishment of soft wood forest on pasture land and should select lands based on minimizing cost per ton of carbon sequestered. Costs per ton for establishing new forests on pasture land (where net opportunity costs are low) compared favorably with technologies that reduce carbon sources rather than establishing sinks. Cost-effectiveness, combined with the wide range of other environmental benefits that could be provided by new forests suggested that some level of afforestation belonged in a comprehensive strategy to offset U.S. carbon emissions.

Plantinga et al. (1999) used an econometric approach to estimate the costs of reducing carbon dioxide concentrations through afforestation in the states of Maine, South Carolina and Winconsin in the US. They found that marginal costs per metric ton of carbon rose in all the three States. The cost of afforestation programs compared favorably to costs of alternative mitigation approaches such as substitution of alternative fuels for coal, increased residential energy efficiency and fuel switching.

Kerr et al. (2001) developed a dynamic spatially explicit model to estimate the difference between the economic yields of cleared versus forested land in Costa Rica as a means of gauging the cost of conserving potentially deforested land in that country. Using this information on carbon pools they calculated a land-use baseline that provides a prediction of the deforestation that will occur in the absence of an international program. The study suggested that the model can be usefully employed in developing countries and in cases of forest management.

Adams et al. (1993) examined the social costs of sequestering carbon in tree plantations on U.S. agricultural land and harvesting's effects on timber prices and on private timber producers' welfare. The analysis linked a model of the U.S. agricultural sector that included the land base in major production areas with a model of the U.S. softwood economy. Using data on planting, maintenance, and harvesting costs for tree plantations and carbon sequestration rates, the models estimated the price and welfare effects of alternative carbon sequestration goals. Results indicated a range of outcomes. Consumers paid higher prices for food as farmers diverted land from crops to trees. However, wood products consumers gained from falling timber prices if the trees entered commercial markets. Agricultural producers and landowners gained from higher commodity prices, but private forest owners lost. Large tree planting programs implied that policymakers must compensate private commercial tree planting to prevent farmers from displacing present tree plantations. In general, these past studies on carbon sequestration economics have suggested that there are substantial opportunities for sequestering carbon in forests (Richards and Stokes, 2004).

Whereas cost-effectiveness analyses dominated research on carbon sequestration economics initially, there has been increasing attention on landownersô willingness to participate in carbon sequestration activities and program design issues (Engel et al., 2008; Wunder et al., 2008; Landell-Mills & Porras, 2002)**.** Since participation in carbon sequestration activities on private land are voluntary means that socially-efficient outcomes will only be achieved if sufficient landowners enroll in the relevant programs, and fulfill their management requirements (Pagiola, 2008). This implies that it is necessary to understand the factors that determine whether landowners choose to participate. In addition, knowledge of who participates, and why, can help to improve program design through minimizing the cost of attracting landowners, and by encouraging those landowners who provide greatest environmental benefits to join (Kosoy et al., 2008).

The importance of the question of farmer participation in agri-environmental schemes[3] (AES) has been widely acknowledged, leading to a considerable amount of research being conducted on the factors that determine participation in schemes such as the Conservation Reserve Program in the US (Ervin and Ervin, 1982; Cooper, 2003), AES in the EU (Wossink and van Wenum, 2003; Vanslembrouck et al., 2002; Bonnieux et al., 1998; Brotherton, 1991), or forest conservation schemes in both locations (Nagubadi et al., 1996; Langpap, 2004). However, there is significantly less quantitative analysis of whether landowners in developing country contexts are affected by similar factors as those in more developed countries. This is in spite of literature showing the relationship between AES and poverty alleviation, in which it is recognized that patterns of participation are a key determinant of the

[3] Carbon afforestation projects are classified as agri-environmental schemes that compensate farmers for voluntary undertaking activities that increase the provision of public environmental goods (Engel et al., 2008; Claassen et al., 2008).

distribution of benefits from AES (Grieg-Gran et al., 2005, Pagiola et al., 2005, Wunder, 2008).

This scarcity of information on AES participation in developing countries is of concern because there are important reasons why landowners might respond differently to AES. These primarily relate to the widespread prevalence of market and institutional imperfections in developing countries. Landowners making decisions about whether or not to join AES in developed countries operate in a setting of broadly well functioning markets and institutions. In contrast, households in developing countries frequently face difficulties in accessing credit, or insecure property rights to land. They may also face an absence of markets for farm outputs, and labor, land or other inputs (Ellis, 1988). Alternatively, where markets do exist, they may not work efficiently. It has been shown in many developing country contexts that the presence of constraints on farming household participation in markets can have significant impacts on how those households make production decisions (Feder, 1985; Carter & Yao, 2002; Sadoulet et al., 1998; Chen et al., 2006).

2.9 Theoretical basis of farmer participation in carbon afforestation contracts

Carbon afforestation contracts are voluntary contractual agreements between individual farmers and carbon offset aggregators in which farmers agree to plant trees on a specified unit of farm land on an agreed upon management practice for a specified duration of time in exchange for an annual cash payment. The payment is conditional on compliance with the contract. Farmers would be eligible to participate, provided that they would not be converting a pre-existing forest area into newly planted tree crops and would be free to choose the tree species as long as they can grow well under the agro-climatic conditions of the area.

Farmer participation in carbon afforestation contracts can be cast within choice theory that assumes that a farmer will choose the contract that maximizes his/her utility (Varian, 1992). The theory conceptualizes individual choice behavior as a function of the characteristics of the decision maker, of the set of available alternatives and their attributes, and a decision rule. Given a fixed set of alternatives and their attributes, individual choice is commonly construed in two steps. First, individuals assess the utility of each alternative and second, derive a choice based on the decision rule of utility maximization. The concept of utility therefore ñassumes commensurability of attributesò. This means that the utility of a decision maker is reducible to a scalar and can be expressed as s single objective function of an alternative in terms of its attributes (Ben-Akiva & Lerman, 1985).

A utility function can either be ordinal or cardinal. The first form is commonly known as a preference ranking of alternatives (respondent *n* prefers for example alternatives *x*>*y*>*z*). Cardinal utility implies the possibility to measure utility as a quantity, thus providing numerical values that express utility for a choice alternative. That is, cardinal utility provides additional information on how much more alternative *x* is preferred over alternative *y*, etc. Empirical studies show that choice is probabilistic rather than deterministic (Quigin, 1982; Fishburn, 1988; Stigler, 1950; Edward, 1954). Probabilistic choice theory has therefore been proposed as more appropriate approximation of individual choice processes. Luce and Suppes (1965) distinguish two probabilistic choice mechanisms: constant utility and random utility.

Constant utility approach assumes that the utility value of the different alternative is fixed. Therefore, a decision maker does not choose the alternative with the highest probability but it is assumed that there is choice probabilities involved. These probabilities are defined by a density function over the different alternative with the utility as parameters. The random utility approach, formalized by Manski (1977), assumes that individuals always select the alternative with the highest utility. Probabilistic choice theory in its random utility form implies that the individualsô reports of their preferences or utilities are not always the same under identical conditions, owing to measurement error or to random variation in the assessment of preference/utility by individuals. Utilities are not known with certainty to the analyst and are treated as random variables. Implied in this formulation is a distinction between latent and manifest utilities, with the latent one represented by the mean of a probability function, and the manifest one by a single observation that can be regarded as a random draw from this distribution. Depending upon oneôs assumptions about these distributions, the latent utilities can be deduced from the relative frequency with which an individual chooses various alternatives under seemingly identical conditions. This study is based on the random utility approach which is in line with choice theory.

Following Brotherton (1989, 1991), farmer participation in carbon afforestation contracts is conceptualized as a function of the characteristics of both the chooser [farmer] and the choice [i.e., the set of carbon afforestation contract alternatives and their attributes], these characteristics constitute both the chooser [farmer] and choice [contract] attributes that need to be taken into consideration when attempting to understand farmer participation in agri-environmental schemes. These factors are discussed below.

(a) Scheme factors

Scheme factors are those that may influence the attractiveness of a particular scheme and include economic incentive, scheme duration and flexibility in contract terms (Wilson, 1997). Several studies have found economic incentives to be key drivers of farmersô participation in AESs (reviewed by Siebert et al., 2006). In a study of participation patterns of over 750 farmers across ten countries in Europe, 79 percent gave financial reasons as their main motive for joining a scheme (Wilson and Hart, 2000). However, as Siebert et al. (2006) point out, it is not unexpected since operating on a market inevitably introduces economic considerations. Scheme duration is a crucial factor in the participation in AES as farmers may not want to be bounded by certain activities for a considerable length of time (Wilson, 1997). Flexibility in terms of the scheme such as whether or not a scheme provides an option of cancelling or flexibility over which areas of farm are entered are important factors that could influence participation (Ruto and Garrod, 2009; Christensen et al. 2011; Broch et al., 2013).

(b) Farmer factors

The influence of farmer factors on participation is varied. Participation may depend on individual farmer and farm characteristics such as age, education, dependency on farms for income, length of residency, farm size, tenure and amount of non-intensively used farmland (e.g., Ilbery, 1978; Kreutzwiser and Pietraszko, 1986; McDowell and Sparks, 1989; Friends of the Earth, 1992; Wilson, 1992). The age and level of education of the farmer seem to be the most important determinants of participation, with younger and more educated farmers being more prone to participate (Wilson 1996, 1997; Vanslembrouck et al., 2002; Mathijs 2003; Jongeneel et al., 2008). However, the importance of age varies between studies (Siebert et al. 2006). Some studies have found that participants in some schemes are older than non-participants (CEAS, 1997), suggesting that the relationship between age and participation is not straightforward. As Ahnström et al. (2009) establish, there are often contradictory results between studies on how different demographic variables relate to the willingness to participate in conservation measures.

A final cluster of factors that may influence participation in the AES relates to attitudes of the farmer toward the environment (McDowell and Sparks, 1989; Wilson, 1992; Morris and

Potter, 1995). Studies on farmer attitudes in relation to AES participation has gained a considerable attention in the past several years and several studies have found that participants have a larger interest in nature and nature conservation than non-participants (Morris and Potter, 1995; MacDonald and Johnson, 2000; Fish and Seymour 2003; Herzon and Mikk, 2007). Interestingly, two studies emphasize that there seem to be no link between knowledge of nature and willingness to participate in conservation measures (Jacobson et al., 2003; Herzon and Mikk, 2007). Wilson (1997) suggested that these effects of attitude, in turn, are likely to be more relevant on farms where scheme participation might be a balance between economic benefit and nature conservation. In contrast, there are potentially larger financial benefits (or lower costs) from participation for larger farms, which might overshadow attitudinal factors. The conceptualization of attitude is however problematic (Burton, 2004). According to theoretical psychology, attitudes are formed by what an individual believes to be true about the attitude object, where the perception may be based on knowledge and/or emotion (Edwards-Jones, 2007), and they relate to different subjectively perceived factors including interest, knowledge, values, norms and self-perception.

2.10 Methods for analyzing farmer willingness to participate in carbon contracts

Carbon trading afforestation contracts are relatively new in Kenya and Africa in general. As such, farmer participation in such contracts cannot be elicited using the revealed preference techniques which involve analysis of *ex post* choice behavior in an actual market. Accordingly, stated preference methods are better in such cases because they elicit farmersô choice behavior before the contract is offered in the market. Such methods therefore reveal farmersô willingness to participate and preferences for carbon contract attributes in a hypothetical market (Alberini and Kahn, 2006; Bateman et al., 2002). Stated preference methods refer to a family of techniques that use individual respondentõs statements about their preferences for a set of options in order to estimate the utility function (Desvousges et al., 1993; Kroes and Sheldon, 1988). By their nature, stated preference methods use surveys for their data collection. The most widely used stated preference methods are contingent valuation and conjoint analysis (Merino-Castello, 2003).

2.10.1 Contingent valuation

The contingent valuation (CV) is a widely used non-market valuation method to estimate economic values for all kinds of ecosystem and environmental services (Mitchell and Carson, 1989). The CV method was originally proposed by Ciriacy-Wantrup (1947) who was of the opinion that the prevention of soil erosion generates some ‘extra market benefits’ that are public goods in nature, so that, one possible way of estimating these benefits is to elicit the individuals’ willingness to pay for these benefits through a survey method (Hanemann, 1994; Portney, 1994). However, Davis (1963) was the first to use the CV method empirically to estimate the benefits of goose hunting through a survey among the goose-hunters. This method gained popularity after two major non-use values, namely, those relating to option and those relating to existence. These values were recognized as important components of the total economic value in environmental economics literature, especially during the 1960s. While the conventional revealed preference methods, such as travel cost method, are not capable of capturing these non-use values (Smith and Walker, 1993), the only method that was identified at that time for estimating these values was the CV method (Desvousges et al., 1993).

Under the simplest and most commonly used CV exercise, respondents are asked to state their minimum willingness to pay (WTP) or their maximum willingness to accept (WTA) for a hypothetical change in an environmental good or service (Hanley et al., 2001; Mitchell and Carson, 1989). Random assignment of cost/price to respondents allows the researcher to trace out the distribution of WTP or WTA for the good. CV has been in use for over 35 years and there are over 2,000 papers and studies dealing with the topic (Carson, 2011). However, the method has been criticized for a number of weaknesses, mainly on the basis of validity and reliability of the results, and the effects of various biases and errors (Diamond et al., 1993; O'Doherty, 1996; Venkatachalam, 2004; Whittington, 2002).

2.10.2 Conjoint analysis

Conjoint analysis (CA) is a family of survey-based methods that are used to measure the trade-offs people make in choosing between goods. It is also used to predict their choices of future products and services. The theoretical underpinning of CA was first espoused by Lancaster in 1966. Based on Lancasterian theory, the utility for a good can be derived from the collective utilities for its attributes (Lancaster, 1966). In CA respondents are presented with various alternative descriptions of a good, differentiated by its attributes and their levels and are asked to choose, rank or rate them. By including price/cost as one of the attributes of the good, both WTP and WTA can be indirectly calculated from those rankings or ratings. The CA allows a more direct route to the valuation of characteristics or attributes of a good and evaluation of marginal changes in these characteristics. CA comprises of three methods,

(i) choice experiments, (ii) contingent ranking and, (iii) contingent rating. These methods differ in the quality of information they generate, in their degree of complexity and also in their ability to produce WTP/WTA estimates that can be shown to be consistent with the usual measures of welfare (Bateman et al., 2002).

2.10.2.1 Choice experiments

Choice experiment (CE), initially proposed by Louviere and Woodworth (1983), is the most applied and widely recognized CA (Adamowicz et al., 1998; Louviere et al., 2000; Hanley et al., 2001). In CE, the respondent is presented with a choice set (or several choice sets) containing two or more alternatives, and, if relevant, also a status quo option, and is asked to choose the most preferred alternative (Louiviere and Woodworth, 1983; Bennett and Adamowicz, 2001). Other things equal, the amount of information extractable from a single CE observation is less than the amount of information that can be extracted from the other CA. However, an advantage of the method is that the task is very simple and the cognitive burden is low. Furthermore, when dealing with goods that are not traded or are yet to be traded in the market, CE bears very close resemblance to the choices that respondents are used to make in the market place (Louviere et al., 2000). Thus, intuitively the task is likely to make sense to respondents.

2.10.2.2 Contingent ranking

In contingent rating (CR), the respondent is presented with a choice set consisting of three or more alternatives, which the respondent is asked to rank from the most preferred to the least preferred alternative (Beggs et al., 1981; Chapman and Staelin, 1982). The CR provides the analyst with much more information on the preference structure of the respondents compared to CE (McFadden, 1986; Hanley et al., 2001; Holmes and Boyle, 2003). However, the task of the respondents in CR is also more cumbersome. It is therefore likely that respondents will find it difficult and strenuous to provide a complete ranking of the alternatives (Hausmann and Ruud, 1987; Ben-Akiva et al., 1991; Foster and Mourato, 2002). This increased task complexity has been shown to affect the reliability of CR data (Louviere et al., 2000). Thus, one potential consequence is that CR data may display inconsistency of preferences across ranks. This inconsistency is suggested to be caused by respondents changing decision protocols across ranks (Hausmann and Ruud, 1987).

2.10.2.3 Contingent rating

In contingent rating (CRT), the respondent is presented with a choice set consisting of a number of alternatives, which he is asked to rate independently from a predefined scale (Louviere, 1988). The rating approach to CA is the one that has the potential to provide the greatest amount of information on respondentsô preferences. The reason is that besides the implicit ranking of the alternatives, the rating approach also provides information on how much one alternative is better than the other alternatives. Also, the method is able to accommodate tied situations where two alternatives are equally preferred (Mackenzie, 1993). In practice though, it is difficult to take advantage of this extra information because the ratings have cardinal properties. Consequently, it cannot be verified if for example, a rating of 10 is twice as good as a rating of 5, or if it four times better. The way individuals use the ratings scale may additionally vary significantly across individuals (Mackenzie, 1993). More specifically, this makes aggregation of ratings across individuals problematic (McFadden, 1986). Consequently it is often advised not to use the CRT (Bateman, 2002; Hanley et al., 2001; Holmes and Adamowicz, 2003).

There are a number of challenges associated with the application of stated preferences methods in low-income countries (Adamowicz and Whittington, 2010; Whittington, 1998). In a recent review of studies on the application of the choice experiment method in developing countries, Bennett and Birol (2010a, 2010b) note that the applications of this method are still scarce in developing countries. While noting the importance of applying the method to inform policy, the review highlighted the need to be careful in the application of the method. The review provided a list of issues to be considered as part of ñbest practiceò in the implementation of the method in developing countries. The list includes the importance of focus group discussions and pre-tests before the main survey for better survey design as well as choice of reliable and realistic payment vehicle in developing countries where there are limited options in terms of types of payment vehicles. Bennett and Birol (2010b) also note that face-to-face interview is most likely the most suitable survey mode in the context of developing countries. They also stress the importance of using visual aids to reduce interviewer bias and circumvent some of the problems associated with language. Keeping task complexity to the minimum and inclusion of follow-up questions in the survey instruments by asking respondents how or why they chose their preferred alternatives were also identiýed for successful implementation of choice experiments in developing countries.

2.11 Previous studies on farmer participation in agri-environmental schemes

There are a number of studies that have analyzed farmer participation in voluntary agri-environmental schemes including carbon trade (Bennett and Birol, 2010b; Christensen et al., 2011; Fletcher et al., 2009; Jiang and Koo, 2011; Yu and Ken, 2011). Fletcher et al. (2009) investigated the willingness of private forest owners in Massachusetts to sell carbon credits in several hypothetical carbon programs. The participants were confronted with six alternative potential carbon credit programs consisting of four attributes, namely eligibility requirement, time commitment, expected payment per acre per year and a penalty for early withdrawal. Each participant was asked to rate six programs using a 10-point rating scale. Tobit and logistic regression models were used to investigate the relationship among program ratings, program attributes and socioeconomic characteristics of participants. The study found that landowners significantly favored higher payments, no withdrawal penalty and, unexpectedly, longer commitment periods. That study provides important methodological lessons for the current study which analyses farmersô willingness to participate in on-farm afforestation for carbon trading.

Jiang and Koo (2011) explored producer preference for land-based carbon sequestration potential on agricultural lands. The study was intended to develop an understanding of producer preference for land-based carbon sequestration in agriculture. A choice experiment approach based on Random Utility Model (RUM) was used to elicit producer choice to provide marketable carbon offsets by participating in different carbon credit programs characterized by varying practices. Using the conditional logit model, the study found that: (a) the market price for carbon offsets could increase producer participation in carbon sequestration; (b) producers perceived differentially different but correlated private costs for adopting carbon sequestering practices, depending on production attributes; and (c) relatively high carbon prices would be needed to stimulate producer provision of carbon offsets by land-based carbon sequestration activities. That study provides lessons on the conduct and application of attribute-based methods in analyzing farmersô preferences for technology attributes and is useful in the current study that analyzes farmer preferences for attributes of carbon trading afforestation projects.

Christensen et al. (2007) used the choice experiment to identify the extent to which Danish farmers were willing to trade off payments for less restrictive subsidy scheme for pesticide-free buffer zones. It also quantified preferences for speciýc scheme features, namely flexibility in contract terms, flexibility in practical management and economic incentive. A random parameter logit model was used to capture heterogeneity among farmers. The results indicated that the vast majority of farmers were willing to trade off the size of the subsidy for less restrictive scheme requirements. The results suggested that the farmers valued flexible contract terms higher than reduced administrative burdens. Regarding payments, the study found that a payment above and beyond direct costs was a necessary condition for showing interest in a subsidy scheme. More interestingly, the choice experiment indicated that the vast majority of farmers (86 percent) were willing to trade off scheme requirements against the size of the subsidy. This study inspired the choice of the methodological approach used in the current study.

Ayuya et al. (2011) investigated the willingness of small-scale farmers to adopt CDM projects in Njoro District, Kenya. The objectives of the study were to assess the level of awareness of carbon trade initiatives and factors that influence the adoption of carbon tree trade. Ordered logit and the double hurdle models were used to estimate factors influencing farmersô adoption decisions. The study found low levels of awareness of 23 percent. Gender, household size, farm debt, attitude towards risk, farm size, land tenure, availability of voluntary CDM and perception of the technology were found to influence farmersô willingness to accept the project. That study provides useful insights on factors likely to influence uptake of carbon projects among smallholder farmers and thus inspired the modeling in the current study.

2.12 Overall assessment

The literature reviewed in this section shows that some work has been done to assess the willingness of farmers to participate in agri-environmental programs for environmental improvement and carbon trade. With the exception of Ayuya et al. (2011), most of the work has been done in the developed countries understandably because carbon trading is a relatively new concept in developing countries in general and Kenya and Africa in particular. The current study sought to assess farmersô willingness to participate in carbon trading afforestation projects. It departs from Ayuyaôs study in two ways. First, the current study applied CE because carbon trading is a new concept and as such farmerôs behavior towards carbon trade is unobservable. Ayuyaôs study applied traditional methods of analyzing farmersô technology adoption behavior. For technologies that have been adopted, an investigator can observe the patterns and intensity of adoption (Adesina and Baidu-Forson, 1995; Adesina et al., 2000; Adesina and Zinnah, 1993). However, for new technologies such as tree planting for carbon trade that are yet to be adopted, such an opportunity does not exist. In such a situation, stated preference methods are needed to elicit farmersô willingness to participate and preferences in hypothetical markets. Secondly, the current study assessed the potential financial benefits from carbon trading. Financial profitability is a crucial factor that could motivate farmer participation in carbon trade.

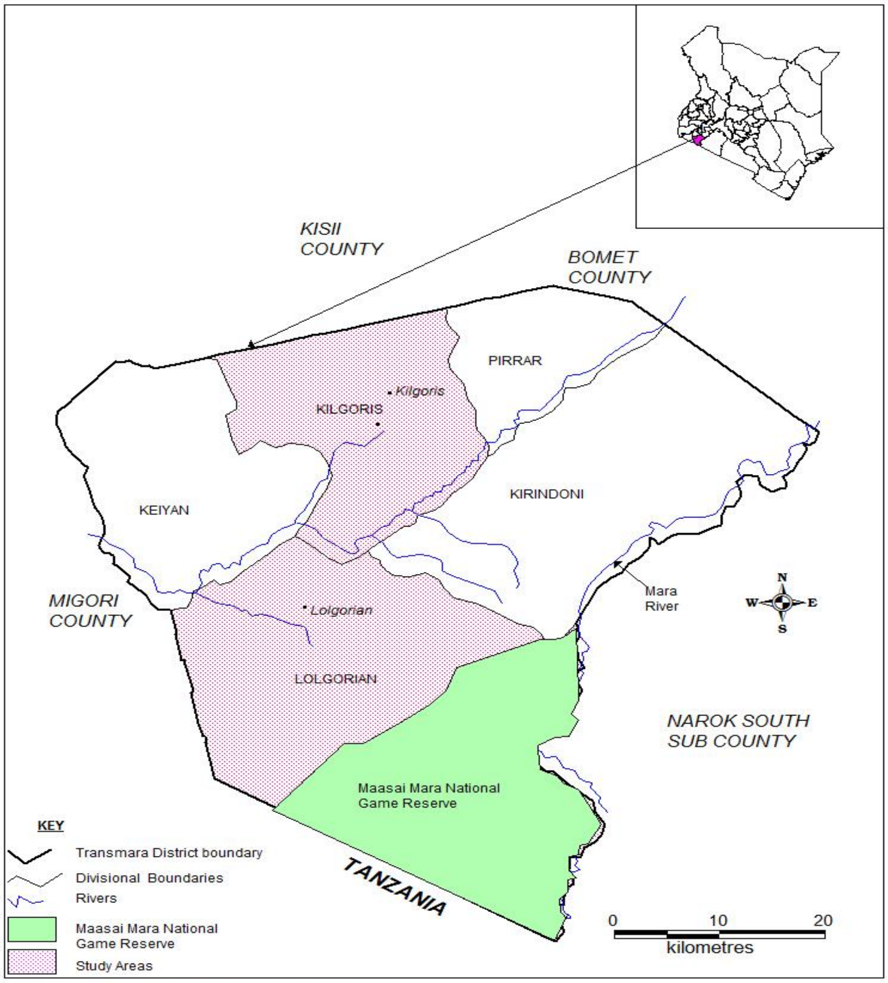
A particular reason for the use of CE in this study was its appropriateness in assessing the multi-attribute carbon trading contracts. Carbon trading contracts may differ in terms of the length of contract, whether or not there is a penalty for early withdrawal, amount of payment among other attributes. It was therefore important to understand farmersô preferences for the attributes of carbon trading contracts as these could influence the level of participation. The CE method also provides for the estimation of how the farmers would trade-off different levels of attributes against per acre payments (Adamowicz et al., 1998). Furthermore, in the case where one attribute may become infeasible, compensating amounts of other goods (rather than the compensating amount based on money) can be calculated. The knowledge of such trade-offs can inform the design of carbon trading afforestation projects and incentives offered to potential participants. Another advantage of using the CE is the minimization of strategic bias that was likely to occur due to the financial payment offer that was made in this study. Strategic bias occurs when a respondent gives an untruthful answer in the hope that she/he will influence the provision of the service in his/her favor (Hanley et al., 1998). The method was preferred because of its simplicity and the low cognitive burden on the respondents.

CHAPTER 3: METHODOLOGY

3.1 Study area

The study was conducted in Trans Mara sub-County, Narok County in Kenya. The sub-County is part of the southern rangelands of Kenya and an extension of the Mara-Serengenti ecosystem. It lies between 0° 50ô and 1°50ô South and 34°35ô and 35°14ôE, and covers about 1,585 km^2 out of which the world-famous Maasai Mara Game Reserve occupies 31 km^2. The topography consists of a plateau rising from 1,500m to 2,200m above the sea level. Annual rainfall lies within the range 800-1,200m and is bimodial with a main dry season from mid June to mid October and a shorter dry season between December and February (TDDP, 2009). The annual mean temperature is 18.9°C. The area falls under eco-climatic zone IV[4] and V. The sub-County has five administrative divisions namely, Kilgoris, Pirrar, Keiyan, Lolgorian and Kirindon (Figure 3.1).

[4] Ecozone IV is classified as a semi-humid area with percentage moisture index of 40 to 50 and an annual rainfall of 600-1100. Ecozone V is semi-arid with percentage moisture index of 25-50 and annual rainfall of 450-900 (Sombroek et al., 1982)



Source:KARI - TRC Environment and land use unit, 2013

Figure 3.1. Map of Trans Mara sub-County showing study areas

3.1.1 Data sources and types

3.1.1.1 Sampling

The sampling frame comprised of resident farmers in Trans Mara sub-County while households were the sampling units. In this study, a farmer is defined as a landowner engaging in agricultural activities (farmer and landowner are used interchangeably in the text). A household was defined as a family unit composed of the household head (usually male), the spouse(s), children and other relatives who reside, eat and work together. Female-headed household were also considered as independent household units.

3.1.1.2 Sample selection

A list of all administrative Divisions in the sub-County was made and two divisions, Kilgoris and Lolgorian, randomly selected to reflect the differences in the modes of agricultural production in the sub-County. Although the agricultural production system in the sub-County is commonly classified as agro-pastoral, most farmers in Kilgoris Division were sedentary and practiced mixed agro-pastoral farming system based on production of annual crops and livestock. In Lolgarian Division, farmers practiced livestock husbandry with subsidiary cropping. Two locations were randomly selected in each of the two divisions from which a further two administrative sub-locations were randomly selected in each location. Figure 3.2 provides a flow chart showing the distribution of administrative units in the sub-County and those that were selected for this study. The sample size was calculated using the Cochran formula (Cochran, 1963):

$$n = \frac{Z^2 pq}{e^2} \tag{3.1}$$

where:

n = sample size

Z^2 = value required for 95 percent confidence interval from standard normal distribution (1.96)

p = *a priori* estimate on expected frequency value on participation in carbon trade in the study area which in this study is postulated be 0.5

q = 1- p

e = desired level of precision (± 8 percent)

This computation gave a sample size of 150 households. A random sample of about forty households in each of the villages was selected using the systematic sampling technique where every fifth household was chosen.

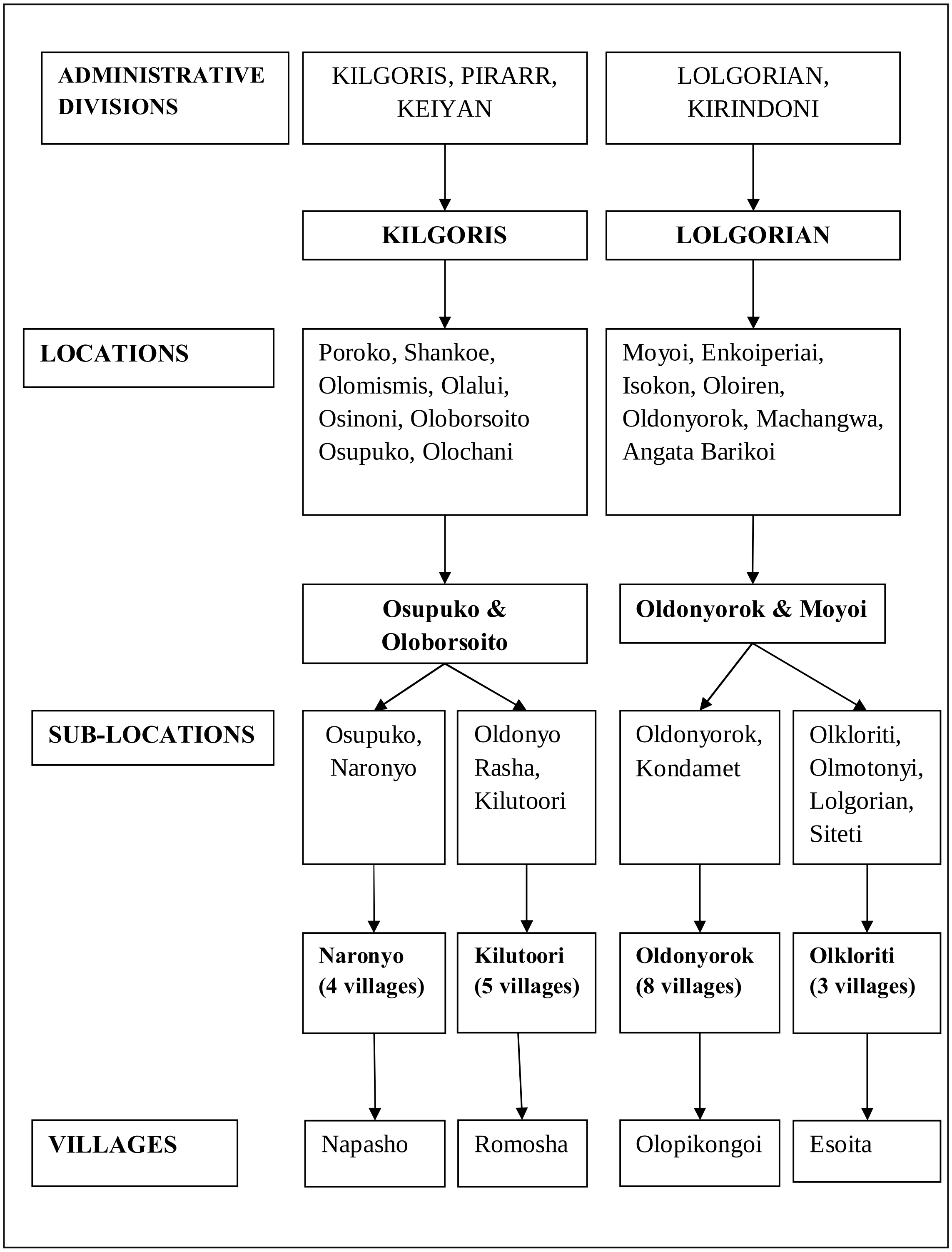


Figure 3.2. Flowchart showing the distribution of administrative units in Trans Mara sub-County and those selected for the study

Source: Trans Mara District Development Plan, 2009

3.1.1.3 Data collection

A number of techniques were used to gather primary data.

(a) Reconnaissance survey

Prior to the commencement of the data collection exercise; a reconnaissance visit was made by the author to Trans Mara sub-County to obtain general knowledge and insight on existing farming and natural resource systems. The visit involved meeting farmers and key informants in the Ministries of Agriculture, Livestock, Environment and Natural Resources; KFS, KEFRI and officials from local NGOs.

(b) Focus group discussions

A total ten focus group discussions (FGDs) were conducted, two in each sub-location (see Figure 3.4), using a checklist of guiding questions (see List 1 in Appendix 3). Each focused group comprised 6-8 resident farmers (household heads who had resided in the sub-County for not less than 20 years). While considering the cultural practices and norms, the groups were carefully selected to ensure that they were as homogenous as possible in terms age and gender balance. This was done with the assistance of local administrators (chief, assistant chiefs and village elders) in selecting farmers who were knowledgeable about agriculture and environmental issues in the sub-location and were known for their ability to share their opinions, and willingness to volunteer information.

(c) Key informant interviews

Key informant interviews were conducted with subject matter specialists in the Ministries of Agriculture, Livestock, Environment and Natural Resources, KFS, KEFRI and local NGOs to collect information on a wide range of issues including agriculture, land use and land tenure systems, climate change and environment, and farmersô coping strategies. A checklist of questions was used (see List 1 in Appendix 3). The findings from the FGDs were also clarified during the key informant interviews.

(d) Household questionnaires

Two structured questionnaires consisting of both closed and open ended questions were used (see questionnaire I and II in Appendix 2). The first questionnaire referred as the ñwillingness to accept carbon trading afforestation contractsò had four sections. Section I, II and III consisted of questions used to elicit the respondentôs socioeconomic characteristics and, perception of, and adaptation to elements of climate variability and change. Section IV consisted of questions to elicit the respondentös attitudes and experiences in tree planting and the CE questions. The second questionnaire referred to as the ñcrop and livestockò questionnaire was used to collect information on crop and livestock enterprises in the sub-County. The questionnaires were pretested in an initial pilot survey. All questionnaires were administered by the author through face-to-face interviews with the farmers. The questionnaires were strictly administered to household head and where a household head was absent, the next homestead was selected. The questionnaires were administered in either Kiswahili or Maasai depending on the language that the respondent was comfortable in. On average the questionnaires took less than an hour to complete. The survey was carried out between August and December 2013.

3.1.1.4 Data storage and analysis

All the data were entered into Microsoft Access spreadsheets where they were cleaned by checking for any missing and incorrect entries before transferring to R software, Microsoft Excel and SPSS for statistical analysis. The data were tested for normality and transformed where necessary before analysis

3.2 Conceptual framework

The conceptual framework for analyzing farmersô willingness to participate in carbon trading afforestation contracts is presented in Figure 3.3. The framework is adapted from Vanslembrouck (2002) and incorporates farmer factors and scheme factors. Farmer factors are of interest as these would explain farmer participation in the contracts while scheme factors are those that may inf3.2uence the economic attractiveness of the contracts thereby increasing the likelihood of participation. Farmer factors are further divided into farm characteristics such as the farm size and tenure, and individual farmer characteristics such as age and education level.

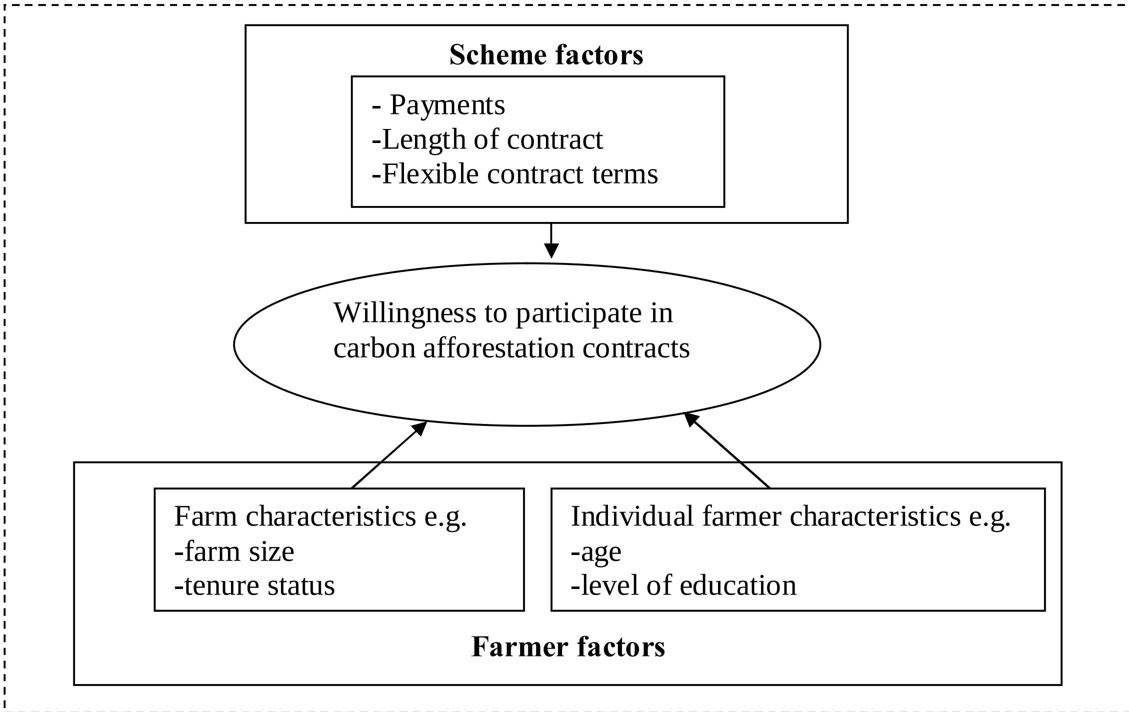


Figure 3.3. Conceptual framework for analyzing farmers' willingness to participate in carbon afforestation contracts

Source: Adapted from Vanslembrouck (2002)

A general order or stages that a farmer goes through in his/her decision to participate in carbon trading afforestation contract is provided in Figure 3.4. The diagram distinguishes between elements that are external to the farmer (and therefore observable) and those that are internal (and therefore unobservable). External, observable elements are those such as the attributes of carbon contract alternatives. Internal, unobservable elements are those such as the perceptions and preferences of the farmer.

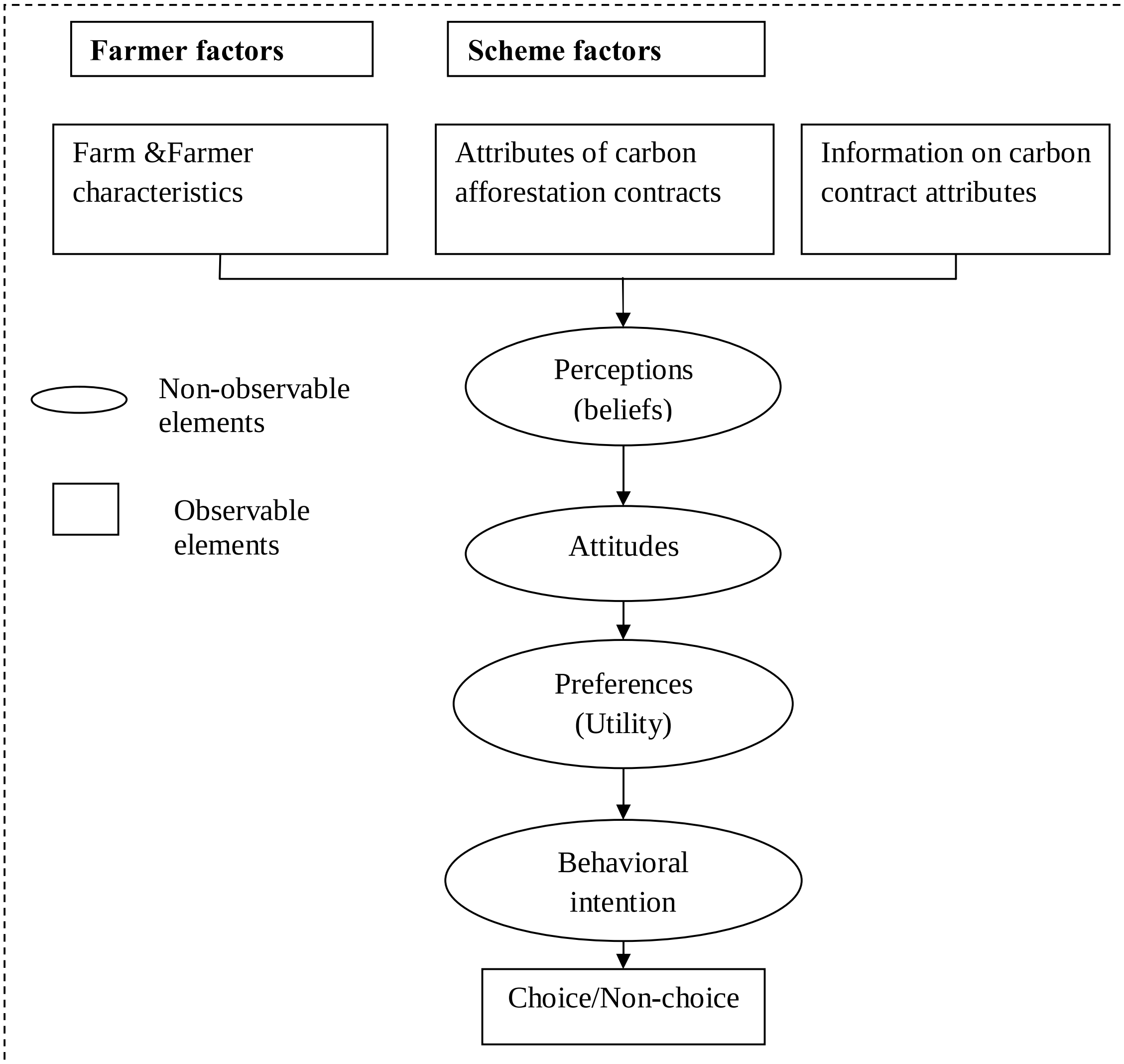


Figure 3.4. Components of farmer's choice process

Source: Adapted from Pearmain et al. (1991)

Following Louviere et al (2000), when a farmer is presented with alternative descriptions of the carbon trading afforestation contract and information about contract attributes he learns about the contract and becomes aware of his needs and or problems to be solved. During the learning process, the farmer forms perceptions and attitudes about which alternatives will satisfy his objectives. Eventually, the farmer becomes sufficiently informed about the contract to form a utility function which involves valuing and trading off contract attributes that matter in the decision. Given a set of beliefs about attributes possessed by carbon contract alternatives, the farmer develops a preference order and makes the decisions about whether to participate in the carbon afforestation contract.

3.3 Theoretical framework

Following the random utility theory, this study assumes that a farmer is a rational decision-maker that maximizes utility from his choices. Therefore, when a farmer is presented with a choice set containing alternative descriptions of carbon trading afforestation contracts and the status quo, he will choose an alternative that maximizes his utility. This can be expressed econometrically as (Hole, 2007; Revelt and Train, 1998):

$$U_{njt} = \beta'_n x_{njt} + \varepsilon_{njt} \tag{3.2}$$

where U_{njt} is the utility farmer *n* obtains from alternative *j* in choice occasion *t,* x_{njt} is a vector of observed variables that relate to the alternative and the farmer, β'_n is a vector of coefficients of these variables for farmer *n* representing the farmer's tastes and ε_{njt} is a random term that is independent and identically distributed (iid) extreme value, independent of β_n.and x_{njt}. The coefficients vary over farmers' in the population with density $f(\beta)$. This density is a function of parameters θ that represent, for example, the mean and covariance of the β's in the population. The farmer knows the value of his own β_n and ε_{nj} for all *j* and chooses alternative *i* if and only if $U_{ni} > U_{nj}\ \forall\ j \neq i$ The investigator observes the x_{nj}'s but not β_n and ε_{nj}'s. If the investigator observed β_n then the choice probability would be a standard logit since the ε_{nj}'s are iid extreme value. That is, the probability conditional on β_n is

$$L_{njt}(\beta_n) = \frac{e^{\beta'_n x_{njt}}}{\sum_j e^{\beta'_n x_{njt}}} \tag{3.3}$$

Letting i_{nt} denote the farmer's chosen alternative in choice occasion *t* and $y_n = \langle i_{n1}, \ldots\ldots, i_{nT} \rangle$ denote the farmers sequence of choices in the *T* choice occasions, the joint probability of the farmer's sequence of choices conditional on β_n, is the product of the standard logits:

$$L(y_n|\beta_n) = L(i_{n1}, 1|\beta_n) \ldots\ldots L(i_{nT}, T|\beta_n) \tag{3.4}$$

However, the investigator does not know β_n and therefore cannot condition on β. The unconditional choice probability of the farmer's sequence of choices is therefore the integral of $L(y_n|\beta_n)$ over all the possible values of β_n weighted by the population density of β_n, as shown in equation 3.5.

$$P(y_i|\theta) = \int P(y_i|\beta_i)\, f(\beta_i|\theta)\, d\beta_i \qquad (3.5)$$

This expression is the random parameter logit (RPL) model. The log likelihood for the model is given by $LL(\theta) = \sum_{i=1}^{N} \text{In}\, P(y_i)$. This equation cannot be solved analytically, and therefore it is estimated using simulation methods (Train, 2003). The simulated log likelihood (SLL) is given by:

$$SLL(\theta) = \sum_{i=1}^{N} \text{In}\left[\frac{1}{R}\sum P(y_i \mid \beta^{r})\right] \qquad (3.6)$$

where R is the number of replications and β^r is the r^th draw from $f(\beta|\theta)$[5]. Halton[6] intelligent draws are used for the simulation, which have been found to provide far greater accuracy than independent random draws in the estimation of random parameter logit models (Mcfadden and Train, 2000).

The RPL allows heterogeneity in the variances and the means in the distribution of the random parameters. Therefore, moments of the distribution of individual specific parameters can be estimated. Thus, RPL can account for unobserved or unconditional heterogeneity in preferences across respondents (Train, 1998). However, the model does not explain the sources of heterogeneity (Boxall and Adamowicz, 2002). One solution to detecting the sources of heterogeneity while accounting for unobserved heterogeneity is to include interactions of respondent-specific household characteristics with choice specific attributes in the utility function. The model with interactions can detect preference variation in terms of the unconditional heterogeneity of tastes (random heterogeneity) and individual characteristics (conditional heterogeneity), thereby improving the fitness of the model (Revelt and Train, 1998).

[5] Choice probabilities in RPL models take a form of multidimensional integral over a mixing distribution (see e.g. Brownstone and Train, 1999). The integral does not have a closed form in general, and so it must be evaluated numerically. In applications, the integral has been approximated through intelligent draws from the mixing distribution. R is the number of draws of points (replications) taken from the mixing distribution.

[6] Halton sequences are sequences used to generate points in space for numerical methods.

3.4 Design of choice experiment

3.4.1 Identification of contract attributes

The first step in this study was to identify key features or attributes of carbon trading afforestation contracts, which would then be presented to respondents. Attributes and levels of carbon contracts were identified through a thorough review of literature on incentive-based agri-environmental schemes and a series of discussions, consultations and key informant interviews with officials in the ministries of Agriculture, Livestock, Forestry and Environment, Kenya Forest Service (KFS), Kenya Forestry Research Institute (KEFRI), community leaders, farmer representatives and local non-governmental organizations (NGOs). The objective of these discussions and interviews was to identify the most relevant attributes and their levels. The selection of attributes was guided by their significance for the landowners in the region. The final set of carbon trading afforestation contract attributes and their levels are shown in Table 3.1.

Table 3. 1 Carbon trading afforestation contracts attributes and their levels

Attributes	Description	Levels
Length of contract	Period in years that farmers commit their land to carbon afforestation project	5, 10, 15
Payment offer	Annual cash payment in Kenya Shillings to landowner for maintenance of forest plantation on an acre	5,000 7,500 10,000
Option for cancelling contract	Termination of contract by the landowner before expiry of contract period with reimbursement of all payments received	Yes, No

Source: Author (2013)

The justification for use of these carbon afforestation contracts is given below:

Length of contract

Agricultural production is an important source of food and income for inhabitants in Trans Mara sub-County. Any investments in long-term projects such as on-farm forestry for carbon trade would no doubt be a source of concern to most farmers.

Payment offer

Empirical evidence (Wilson and Hart, 2000; Wilson, 1997) suggests that many changes in land use such as conversion of agricultural land to farm forestry are not likely to be adopted without motivating policy measures because they would result in lower benefits in the short run. The payment offer was based on average land rents in the sub-County. Three levels of this attribute were created, Kshs 5,000, 7,500 and 10,000 to reflect heterogeneity in household endowment.

Option for cancelling contract

Given the long-term nature of forestry projects, it may not be unusual to find individuals who may want to withdraw from the project before the expiry of the contract. Provision of a flexible contract that would allow farmers to withdraw may influence their willingness to participate and preferences for carbon trading forestry projects. Two options of this attribute were assessed, the first option which provided for cancellation of the contract with penalty, a reimbursement of all payments at 10 percent interest rate and the second which had no option for cancellation (Broch et al., 2013; Fletcher et al., 2009).

3.4.2 Design of hypothetical contracts for presentation to farmers

A fractional factorial design consisting of possible combinations of each level of the three attributes was created using the rotation design method in R statistical software (R version 3.0.0). The design consisted of 18 paired choice profiles from 3x3x2 contract levels, which were randomly blocked into three sets of six. Each paired choice profile offered the respondents a choice of two alternative carbon trading contracts (Policy A and policy B). An ñopt-outò alternative was included in the CE design to enhance realism and avoid forced choice, as well as enhance theoretical validity of welfare estimates (Batsell and Louviere, 1991; Hanley et al., 2001). It also improved statistical efficiency of estimated choice parameters (Louviere et al., 2000).

The designs were developed into pictures on A4-sized cards and laminated for presentation to potential respondents. Visual aids have been found helpful in communicating information with fewer interviewer biases than text alone particularly among communities with low literacy levels such as the one found in the study area (Bennett and Birol, 2010a). An example of a choice set is provided in Plate 10 in Appendix 3.

3.5 Elicitation of farmer responses to choice experiment

During the CE exercise, each respondent was presented with a series of six choice tasks (one of the three blocks of six contract designs). Before asking the CE questions, the respondents were given a detailed description of each the hypothetical carbon trading contract scenarios. A cheap talk script (see Box 1 in Appendix 3) was used to reduce hypothetical bias, or the discrepancy between preferences expressed in a simulated survey situation and those expressed in a real choice situation following Cummings and Taylor (1999) and List (2001). In a cheap talk script, respondents are explicitly informed of the existence of the hypothetical bias and requested to avoid it by answering as if they were on a real situation. The script was read to the respondents just before the choice experiment questions.

3.6 Empirical model

The CE was designed with assumptions that the observable utility function would follow a strictly additive form. The model was specified so that the probability of selecting a particular policy option was a function of carbon trading contract attributes and alternative specific constant (ASC). The systematic portion of the utility functions to be estimated was specified as:

$$V_{\square} = ASC + \square_{\square}OPTOUT_{\square\square\square} + \square_{\square}CLENGTH_{\square\square\square} + \square_{\square}PAYMENT_{\square\square\square} \quad (3.7)$$

$$V_{\square} = ASC * AGE_{\square} + ASC * HHEDL_{\square} + ASC * LTSYM_{\square} + ASC * LOGAI_{\square} + ASC * TLSZ_{\square} + ASC * TRSB4_{\square} + \square_{\square}OPTOUT_{\square\square\square} + \square_{\square}CLENGTH_{\square\square\square} + \square_{\square}PAYMENT_{\square\square\square} \quad (3.8)$$

Equation 3.7 provides information on farmersô willingness to participate in the carbon afforestation contracts and their preferences for the various features of the contracts. Equation 3.8, with interaction terms, provides information on the influence of farmer-specific socioeconomic characteristics on the likelihood of participation in the carbon contracts. The definition of the explanatory variables in the model, their measurement and expected signs are provided in Tables 3.2 and 3.3.

Table 3.2: Definitions of explanatory contract attributes and socioeconomic variables

Variable	Definition
ASC	Alternative specific constant taking, a value of 1 for policy options A and B in the choice sets, and 0 for option 3, the status quo
OPTOUT	Option for early withdrawal with penalty, a reimbursement of all payment receipts (1= early withdrawal with penalty, 0 otherwise)
CLENGTH	Contract length in years (5, 10 and 15)
PAYMENT	Annual cash payment in Kenya shillings (5,000, 7,500 and 10,000)
AGE	Age of landowner in years
HHEDL	Household education level (1=no formal education, 2=adult education, 3=primary, 4=secondary, 5=college, 6=university)
LTSYM	Land tenure security (1= if farmers had a title deed, 0 otherwise)
LOGAI	Log of agricultural income in Kenya shillings
TLSZ	Household land holding in acres (1 = 0-5, 2 = 5-10, 3 = 10 -20, 4 = 20-50, 5 = 50 ï 100, 6 = over 100)
TRSB4	Experience in tree planting (1=if farmer has planted trees before, 0 otherwise)

Source: Author (2013)

Table 3.3: Measurement of explanatory variables for the empirical model and their expected signs

Variable	Measurement	Expected sign
ASC	Categorical	±
OPTOUT	Categorical	+
CLENGTH	Continuous	-
PAYMENT	Continuous	+
AGE	Continuous	-
HHEDL	Continuous	+
LTSYM	Categorical	+
LOGAI	Continuous	±
TLSZ	Continuous	+
TRSB4	Categorical	+

Source: Author (2013)

The justification for inclusion of the explanatory variables is as follows:

ASC ï This was a categorical variable indicating farmer preference for carbon trading afforestation contract. There is limited information on farmersô participation behavior in carbon trading afforestation contracts in Kenya and Africa in general. As such the direction of the variable was not predetermined as this could either be positive or negative.

OPTOUT ï This was a categorical variable indicating flexibility in contract terms that would allow farmers to cancel the contract before expiry. The variable was hypothesized to be positive as this would provide the farmers with an opportunity to disengage from the contracts to other economically attractive land uses before the expiry of the contract (Broch et al., 2013; Fletcher et al., 2009).

PAYMENT ï This is a continuous variable indicating the amount of payment in Kenya shillings in the carbon afforestation contract. This was hypothesized to be positive as farmers would prefer more cash than less (Wilson and Hart, 2000; Wilson, 1997).

CLENGTH ï This is a continuous variable indicating the contract length in years in the carbon trading afforestation contract. This was hypothesized to be negative as farmers would prefer shorter contracts as these would give them greater flexibility in engaging in any future more economically attractive land uses (Ruto and Garrod, 2009).

AGE ï This was a continuous variable indicating the age of the household head in years. A household headôs age was hypothesized to have a negative effect on the willingness to participate in tree planting for carbon trade. Previous literature suggests that young farmers are more willing to take up new innovations and are therefore more open to change compared to their older counterparts (CEAS, 1997; Maskey et al., 2006). By their nature, tree plantations are long-term investments with the most significant income streams occurring in the distant future. Therefore, an investment in a tree plantation could be a source of concern to older landowners, a hypothesis that is supported by the findings of Wynn et al. (2001) and Bonnieux et al. (1998).

HHEDL ï This was continuous variable indicating the level of education of the household head. It was hypothesized that the level of education of a household head would positively influence participation in carbon afforestation contract. Education enhances oneôs ability to receive, decode and understand information relevant in making decisions about adoption of innovations (Wozniak, 1984). Farmers with more education should be aware of more sources of information and be more efficient in evaluating and interpreting information about new innovations than those with less education.

LTSYM ï This was a categorical variable indicating the possession of a land title deed by a household. A positive relationship was hypothesized between the possession of a land title deed and farmersô willingness to participate in tree planting for carbon trade. A secure land tenure system influences farmersô motivation to participate in tree planting activities because it reinforces individual ownership rights (Otsuka et al., 1999; Besley, 1995). Land tenure security has been shown to have a positive effect on the adoption of improved agricultural management practices (Pattanayak et al., 2003). Kalineza et al. (1999) found that farmers with secure land ownership in Gairo District in Tanzania were more likely to adopt soil conservation practices than those with less secure land tenure. Soule et al. (2000) found that cash-renters were less likely than owner-operators to adopt conservation practices that provide long-term benefits. Simmons et al. (2002) found statistically significant relationship between tree planting and land tenure security in Brazil and Panama.

LOGAI ï This was a continuous variable indicating the householdøs total income from crop and livestock production in Kenya shillings. There is uncertainty about the influence of farm income on farmersô participation decisions in AES in previous literature. In general, decisions to participate in AES have been found to be influenced by the consequences for farm income (Hughes, 1994). Gasson and Potter (1988) found that, for land diversion schemes, only farmers with fewer financial constraints were influenced by the conservation benefit of such schemes. Shaikh et al. (2007) found that farm income was negatively correlated with participation in AES. In this study, the influence of farm income on farmersô willingness to participate was not predetermined as it could either be positive or negative.

TLSZ ï This was a continuous variable indicating the householdøs total land holding in acres. A positive relationship was hypothesized between farm size and willingness to participate. Among the farm structural factors ï e.g. size, type, labor, stocking rates ï many authors consider farm size to be one of the most important determinants of farmersô willingness to participate in AES. Damianos and Giannakopoulos (2002) found that the larger the farm size, the higher the participation rate in agri-environmental programs. Farmers with small land sizes may be discouraged from investing in agri-environmental innovations because of the potential loss of land for other agricultural activities.

TRSB4 ï This was a categorical variable indicating the householdøs head previous experience in tree planting. Previous experience in tree planting was postulated to have positive effect on farmersô willingness to accept carbon trading afforestation projects. Farmers who have previously participated in tree planting are more likely to be aware of the benefits of trees and will more likely accept afforestation contracts for carbon trade.

3.7 Estimation procedure and diagnostic tests

Equations 3.7 and 3.8 were estimated using the ómlogit packageô in R statistical software (R version 3.0.0). All coefficients except that of PAYMENT were specified as random in the RPL. In addition, ASC, OPTOUT, ASC*LTYSM and ASC*TRSB4 were specified as uniformly distributed while CLENGTH, ASC*AGE, ASC*HHEDL, ASC*LOGAI and ASC*TRSB4 was assumed to be normally distributed. This specification was found to have the best fit after estimating several models using different distributional assumptions for the random parameters.

Correlation was allowed between the random parameters so as to account for the inherent correlation between attributes that is characteristic of stated choice data. For example, it may not be unusual to find that households that are generally concerned about contract length might also be concerned about whether or not a contract has an option for cancellation. Indeed, the correlated model was found to have a better fit than the uncorrelated model. The Lagrange multiplier and likelihood tests all rejected the null hypothesis that the random parameters were uncorrelated. Results of these tests are provided in Table A.1 in the Appendix 1. The model fit for equations (3.6) and (3.7) was assessed using rho squared ρ^2 criterion. The ρ^2 value in RPL models is similar to the R^2 in conventional analysis except that significance occurs at lower levels. Henscher et al., (2005) showed that ρ^2 values of between 0.2 and 0.4 are considered good fits.

Additionally, the PAYMENT coefficient was specified as fixed to allow for computation of the distribution of willingness to accept (WTA) for each non-payment attribute. If the payment coefficient is fixed, the distribution of WTA for an attribute has the same distribution as the attribute's coefficient, scaled by the payment coefficient. However, when the payment coefficient is random, the distribution of WTA is the ratio of two distributions, which makes it more challenging to compute (Revelt and Train, 1998). Simulation was performed using Halton sequences at 500 replications (R=500). Two RPL models were estimated, one with contract trading afforestation contract as the only explanatory variable and the other with interaction terms.

3.8 Estimation of willingness to accept

The CE method is congruous with the utility maximization and demand theory (Bateman et al., 2003). Therefore when parameter estimates are obtained from equation 3.7, welfare measures are estimated using the formula:

$$CS = \frac{\ln \sum_i \exp(V_{i1}) - \ln \sum_i \exp(V_{i0})}{\beta_{payment}} \quad (3.9)$$

where CS is the compensating surplus welfare measure, [illegible] is the marginal utility of income, represented by the coefficient of the monetary attribute in the choice experiment, and [illegible] and [illegible] represent indirect utility functions before and after the change under consideration. For the linear utility index, the marginal value of a change in an attribute is given by the ratio of coefficients of the attribute in question and that of the payment attribute, other things being the same. This is the part-worth or implicit price or marginal willingness to accept (MWTA) for the attribute, which can be expressed as:

MWTA = − [illegible] / [illegible] (3.10)

This expression represents an estimate of the minimum payment that an individual would be willing to accept a change, or in this study, to sign up to a particular carbon afforestation contract.

3.9 Assessing the profitability of tree planting for carbon trade

3.9.1 Partial budgeting method

The financial profitability of carbon trading afforestation contracts for carbon trade was evaluated using the partial budgeting approach. Partial budget analysis is a powerful yet simple technique that assesses financial profitability associated with a new management intervention or technology (Pearce and Nash, 1981; Upton, 1987). It focuses only on pre- and post-change scenarios by computing the expected impact on both income and revenues associated with a particular management change. The technique is particularly useful when evaluating management changes that do not require a complete reorganization on the farm as was the case in this study. Partial budgeting is based on the principle that a change in the organization of a farm will have one or more of the following effects: (i) eliminate or reduce some costs; (ii) eliminate or reduce some returns; (iii) cause additional costs to be incurred and (iv) cause additional returns to be received (Roth and Hyde, 2002).

Tree planting for carbon trade is an enterprise that farmers could take up alongside other farming activities and as such it was unlikely that the enterprise would fundamentally reorganize the operations of a farm. Therefore, partial budgeting was found to be an appropriate tool to assess the profitability of tree planting in the study area. An outline of a partial budget for evaluating the costs and benefits of tree planting is shown in Table 3.4.

Table 3.4: Partial budget framework for tree planting for carbon trade project

Revenues	**Costs**
Additional returns Reduced costs	Additional costs Foregone returns
Net benefits	Net costs
Net returns (Net benefits - Net costs)	

Source: Adopted from (Shaw, 2003)

The first column estimates the positive financial effects of the tree planting. Additional returns is revenue received from tree planting while reduced costs are those that are no longer incurred with tree planting. These are the production costs of the enterprise, crop or livestock that will be replaced by tree planting. The second column estimates the costs of shifting land from its current use to planting trees for carbon trade. Additional costs are the production costs associated with planting trees while foregone returns comprise the revenue lost by replacing existing agricultural enterprise (s) with tree planting.

In this study, partial budgeting estimated the financial returns that farmers would gain if land was shifted from a crop/livestock enterprise to a tree enterprise for carbon trade. Most on-farm forestry analyses consider agriculture as the benchmark against which a farm forestry project is to be compared. The analysis was done from a household perspective and was concerned mainly with direct financial costs and benefits only. Land use decisions are made by the households themselves through consideration of their own goals and aspirations, production and consumption possibilities, and constraints.

3.9.2 Estimating revenues and costs of tree, crop and livestock enterprises

3.9.2.1 Trees enterprise

Unlike most agricultural enterprises, on-farm tree planting has a long planning horizon. Therefore, revenues and costs accrue at various intervals throughout the entire production horizon. In addition, there are many direct and indirect benefits associated with trees. Non-market benefits include increased land productivity, fodder production, reduced erosion from runoff and wind, aesthetic appeal, and soil stabilization, among many others (Hines and Eckman, 1993). This study was mainly concerned with direct financial costs and benefits that accrue to households from investing in tree planting for carbon trade. Therefore, the analysis was limited to two main benefits of trees, timber and carbon sequestration services.

The costs and revenues of a tree enterprise depend on the tree species and management techniques used. In this study, a tree plantation for carbon trade was described using the information generated in the household survey and from the Kenya Forest Service office in Kilgoris township, research officers at KEFRI, officials at Maa Habitat Restoration Initiative (MAHARI) and United Multipurpose Project (UMP) and from extensive review of literature. MAHARI and UMP are local NGOs in Trans Mara sub-County that run community-based environmental conservation programmes that include tree planting. The description for carbon trading tree enterprise comprised the tree species, management objective, resources for establishment (materials and labor) and estimated yields for both timber and carbon. Prices of all inputs and outputs were valued at prevailing market prices which were generated during the household survey and from extensive review of literature in the case of carbon.

Because an afforestation program has a long time horizon, the cost and benefit streams were discounted using net present value (NPV) method. The NPV method is one of the most widely used measures to evaluate long term investments in afforestation (Nuru et al., 2014). The formula used for NPV was:

$$NPV = \sum_{t=1}^{n} \frac{B_t}{(1+r)^t} - \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} \qquad (3.11)$$

where B_t is income accruing at time t, r is the discount rate and n is the number of periods during which the project is expected to operate and generate cash inflows. The decision rule was set as: accept tree enterprise if NPV is greater than zero. The internal rate of return (IRR) was computed by setting the NPV value in Equation 3.11 to zero and solving for r, the discount rate. This is the rate at which future incomes will return the initial investment. The formula used for the internal rate of return (IRR) was:

$$0 = \sum_{t=1}^{n} \frac{B_t}{(1+r)^t} - \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} \qquad (3.12)$$

The decision rule was set as: accept tree enterprise if IRR is greater than the minimum acceptable rate of return of return or cost of capital and reject if IRR is less than the minimum acceptable rate of return. The minimum acceptable rate of return in this study was the discount rate used to compute the NPV. The benefit cost ratio (BCR) was calculated using the formula:

$$\square\square\square = \frac{\square_{\square}}{\square_{\square}} \tag{3.13}$$

where $\square_{\square}$ is the total discounted benefits and $\square_{\square}$ is the total discounted costs over the life of the project. A benefit-cost ratio greater than 1 means that tree enterprise has greater benefits than costs; hence they have positive net benefits. In this study, the amount of carbon sequestered was estimated at be 2.8 Mg $Cha^{-1}year^{-1}$, an average of 2.0 ï 3.6 Mg $Cha^{-1}year^{-1}$. This is the estimated net annual carbon sequestration rate for short rotational woodlots in Africa (Kuersten and Burschel, 1993). A carbon price of USD 10 per Mg CO_2 ï equivalent was used. This is the most common estimate of carbon price used literature (Fisher et al., 2011; Luedeling et al., 2011; Nuru et al., 2014; Perez et al., 2007). A 10 percent discount rate was selected for this analysis. This was the prevailing Central Bank of Kenya rate at the time of survey (CBK, 2013).

3.9.2.2 Crop and livestock enterprises

Crop enterprises used in the partial budget were maize and beans, the predominant crops grown in Trans Mara sub-County. The maize and beans enterprises were first described based on information generated from the household survey. The description included husbandry practices, inputs and output quantities and prices. Based on this description, revenues and costs for each enterprise were computed on per hectare per year basis. A similar exercise was repeated for the livestock enterprise (cattle, sheep and goats only).

3.4 Partial budget analysis

Using the estimated costs and benefits for each of the four enterprises - tree, maize, beans and livestock - a partial budget was computed using the framework provided in Table 3.4. The analysis was done for two tree enterprise scenarios, timber and carbon and carbon only. In this study, there was uncertainty regarding the actual values of the amounts of sequestered carbon, carbon prices and discount rate. Therefore, a sensitivity analysis was performed to test the robustness of the results of partial budget analysis based on the three variables.

Additionally, threshold analysis was done to determine the minimum and the maximum carbon price at which tree planting for carbon trade would be profitable. This was achieved by setting the net benefit to zero and solving for price of carbon.

3.5 Assessing farmers perceptions of, and adaptation to elements of climate variability and change

An open-ended questionnaire was used to elicit farmersô perceptions to climate variability and change, and their adaptation strategies. The questions focused on the changing farming conditions rather than on climate so that the climate dimension could be identified independently during the interviewing process. Further prodding was done when a farmer mentioned climate related issues during the questioning. Generally, respondents were asked whether they had noticed any long-term changes in farming conditions over the past 20 years, what they thought were the reasons behind the observed changes and any adjustments they had made to cope with the changes. The exact formulation of the questions is captured in the questionnaire (see section III in Questionnaire I in Appendix 2).

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CHAPTER 4: RESULTS AND DISCUSSION

4.1 A general description of farmers' social, economic and demographic characteristics

The frequency distribution of the farmers social and demographic characteristics are reported in Table 4.1.

Table 4. 1. Frequency of farmers' socioeconomic and demographic characteristics in Trans Mara sub-County

Variable	n	percent
Gender		
Male	189	91.7
Female	17	8.3
Education level		
No formal education	47	22.8
Primary	101	49.0
Secondary	37	18.0
College	15	7.3
University	5	2.4
Adult education	1	0.5
Land tenure system		
Title deed	101	49.0
Owned but not titled	96	46.6
Both titled & owned and not titled	9	4.4
Previous experience in tree planting	152	73.8
Households with woodlots	67	32.5
Households with natural forest on farmland	67	32.5
Total	**206**	

Source: Survey data, 2013

The majority (92 percent) of the landowners were male. This was not surprising given the patriarchal orientation of the predominantly Maasai community inhabiting the sub-County and the customary land ownership systems among many Kenyan communities which confers an almost exclusive control of land on men. Contrary to expectation, the literacy rate was high with about 78 percent of the respondents having attended some formal education. This rate compares well with the sub-County literacy rate for adult males (the respondents were predominantly male) which stands at 78 percent but lower than the national average of 82 percent, perhaps a reflection of the generally low literacy level among pastoral and agro-pastoral communities in the country (KNBS, 2010).

About 50 percent of landowners reported having title deeds, the remaining being owners under customary land holding systems. Farmersô experience in tree planting was unexpectedly high, and close to three quarters of the landowners had planted trees for one reason or another with 33 percent having woodlots as enterprises for financial gain. An equal proportion of farmers had natural forest on their land. The main reasons for planting trees were, in order of dominance, provision of fuel and building materials, commercial timber, shade, to prevent soil erosion and make use of idle land. Exotic tree species were most preferred for planting, with *Eucalyptus species* being the most popular species followed by *Grevellia* species, *Cypress* species and *Pine* species in that order.

The means of farmersô social-economic and demographic characteristics is provided in Table 4.2.

Table 4. 2. Means of farmers' socioeconomic and demographic characteristics in Trans Mara sub-County

Variable	n	Mean (Std error)	Range
Age (years)	206	45.10 (0.812)	21 ï 70
Family size	206	8.83 (0.34)	3 ï 30
Farm size (acres)	206	35.52 (6.15)	1 ï 1,000
Farmland (acres) under woodlot	66	1.11 (0.11)	0.10 ï 10
Farmland (acres) under natural forest	44	15.67 (4.72)	0.25 ï 200
Income (half yearly in KShs)			
Livestock sales	178	190,080.16 (94,353.79)	350 - 16,658,000
Crops	172	146,761.98 (29,114.31)	3,000 - 4,480,000
Employment & business	54	82,544.44 (7,774.04)	12,000 - 312,000
Remittances	7	42,685.71 (10,046.26)	6,000 -72,000
Agricultural income	197	299,884.91 (108,099.45)	3,800 - 21,138,000
Total income	200	319,167.64 (107,165.13)	5,050 - 21,258,000
Farmland (in acres) that farmers were willing to set aside for the carbon afforestation project	189	2.26 (0.20)	0.25 ï 20

Source: Survey data, 2013

Farm size compared well with the sub-County average of 5-30 acres but was much larger than the national average of less than ten acres (TDDP, 2009). The most common land holdings were those that were less than 10 acres and those between 20 and 50 acres at 47 percent and 27 percent respectively. On average about 2 percent of total farmland was under woodlots and about sixteen acres under natural forest. Until recently most land in the sub-County including the non-gazetted natural forest was held under communal trust. However, most of the land has since been individualized thereby explaining the presence of natural forest on farmland. Majority of the farmers (59 percent) were willing to commit at least 10 percent of their farmland to the carbon afforestation projects. This is in line with the Agriculture Act (Cap 318) that requires farmers to establish and maintain farm forestry on at least ten percent of every agricultural land holding. The objectives of these rules are to preserve and sustain the environment and combat climate change, among others.

The sale of livestock and livestock products was the major source of income for 53 percent of the respondents. This was anticipated for the predominantly agro-pastoral community in the area as livestock keeping is their main economic activity. However, a closer look at income sources by farm size showed that the livestock to crop income ratio decreased with decrease in land holding. That is, crops were the dominant source of income for household with small land holdings while livestock was the principal income source for large farms. Income from off-farm sources, businesses, employment and remittances constituted 7 percent of total income.

4.2 Choice experiment results

4.2.1 Results of the estimated random parameter logit models

The analysis was based on a sample size of 168 individuals which gave 1008 observations. The frequency of choice for the three policy options A, B and C (status quo) were 44 percent, 39 percent and 17 percent respectively. Since the choice experiment was unlabeled (i.e., where the name of each alternative conveys only the relative order of that alternative in the choice situation; For example, alternative A, alternative B, route A, route B), there was no reason to expect preference for any of the two policy options. This is supported by the data which show an almost even frequency of choice between policy A and B. The estimation results of the two RPL models (also RPL model 1 and RPL model 2) are presented in Table 4.3.

Table 4. 3. Random parameter logit estimates for carbon trading afforestation contract attributes.

Contract attributes	RPL model 1		RPL model 2	
	coeff. (s.e)	Std. dev	coeff. (s.e)	Std. dev
ASC	1.656***	2.679	3.168	1.369
	(0.335)		(2.320)	
OPTOUT	-1.071***	0.728	-1.113***	0.806
	(0.181)		(0.193)	
CLENGTH	-0.322***	0.253	-0.328***	0.252
	(0.026)		(0.027)	
PAYMENT	0.00045***		0.00046***	
	(0.00004)		(0.00004)	
ASC*AGE	-		-0.069**	0.040
			(0.024)	
ASC*HHEDL	-		-0.119	0.723
			(0.241)	
ASC*LTSYM	-		-0.066	0.164
			(0.382)	
ASC*TRSB4	-		-0.755	0.555
			(0.476)	
ASC*LOGAI	-		0.371	0.655
			(0.406)	
ASC*TLSZ	-		0	0.548
Log-Likelihood	-750.54		-732.43	
ρ^2	0.251		0.263	
Adjusted ρ^2	0.243		0.258	
n (respondents)	168		168	
n (choices)	1008		1008	

Note:*** 1% significance level, ** 5% significance level , *10% significance level

Source: Survey data, 2013

The overall fit of the two RPL models as measured by McFadden's ρ^2, is satisfactory. All coefficients are significant at one percent level and have the expected signs. The estimated coefficients and their standard deviations provide information on farmers willingness to participate in carbon afforestation contracts, their preferences for carbon contracts attributes, influence of farmers socioeconomic characteristics on the likelihood of participation in the contracts and WTA.

4.2.2 Farmers willingness to participate in carbon afforestation contracts

The magnitudes of the estimated standard deviations of ASC and contract attributes in the RPL model 1 in Table 4.3 relative to the mean coefficients provide information on preference heterogeneity. This is the proportion of farmers that place a positive value on a particular attribute and the proportion that place a negative value on it. A positive value on ASC shows the proportion of farmers that would be willing to participate in the carbon contracts. Table 4.4 reports the probability distribution of the farmers according to the proportion that places a positive value on a particular attribute and the proportion places a negative value on it.

Table 4. 4. Probability distribution of farmers according to positive and negative values placed on carbon afforestation contract attributes

Contract attribute	Proportion of farmers with a positive value (percent)	Proportion of farmers with a negative value (percent)
ASC	79	21
OPTOUT	14	86
CLENGTH	90	10
PAYMENT	-	-

These figures are given by 100 x Φ(− □□/□□) where Φ is the cumulative standard normal distribution and □□ and □□ are the mean and standard deviation of the coefficient in the RPL model 1 in Table 4.3. No values are provided for the payment because the attribute was fixed.

The results in Table 4.4 indicate that approximately 79 percent of farmers would be willing to participate in carbon trading afforestation contracts.

4.2.3 Farmers preferences for carbon afforestation contracts attributes

The positive and significant coefficient of ASC in the RPL model 1 in Table 4.3 indicates that the land owners preferred carbon trading afforestation contracts to their current situation in which they are without it. The negative coefficients of OPTOUT and CLENGTH indicate that on average, all else being equal, landownersô would prefer shorter contracts and those without an option for cancellation (hereinafter referred to as no opt-out contracts). As hypothesized in the survey design, land owners would prefer contracts with higher payments. The results in Table 4.4 shows that although the general preference among farmers was for shorter no opt-out contracts, approximately 14 percent preferred opt out contracts and 10 percent preferred longer contracts.

4.2.4 Influence of farmer socioeconomic characteristics on likelihood of participation in carbon contracts

To explore possible sources of the unobserved heterogeneity in preferences, household specific variables were interacted with ASC. Such interaction terms reveal which household characteristics affect the likelihood of participation in carbon trading contracts. The estimated results of the RPL with interaction terms (also RPL model 2) are provided in the 3rd and 4th columns in Table 4.3. The RPL model 2 fit improves considerably compared with the RPL model 1 without interactions, as reflected by the increase in log likelihood from -750.54 to -732.43. These results indicate that landownerꞌs age and size of land holding are important predictors of participation in the carbon trading afforestation contracts. The negative and significant ASC*AGE coefficient shows that the probability of participation decreases with increase in landownerꞌs age while the positive ASC*TLSZ coefficient shows that households with larger land holdings were more likely to participate in carbon trading contracts than those with smaller holdings. Coefficients of the other interaction terms, ASC*HHEDL, ASC*LTSYM, ASC*TRSB4 AND ASC*LOGAI were not significant.

4.2.5 Farmers willingness to accept (WTA)

The final set of results that can be derived from the RPL estimates in Table 4.3 is the willingness to accept (also marginal consumer surplus or implicit price) associated with specific changes in each contract attribute. In the present application, WTA for the ASC parameter was hypothesized to be positive as it would reflect the minimum amount that would have to be provided to each household in order to induce them to participate in the carbon trading afforestation projects. For the two contract attributes, OPTOUT and CLENGTH, the direction was not predetermined because the values can be either positive or negative. These values represent the monetary value of farmersꞌ willingness to trade off per acre payments for desired changes in the contract attributes. Table 4.5 presents measures of WTA in Kenya shillings acre $^{-1}$year^{-1}. These values were computed from the coefficients of RPL model 1 in Table 4.3.

Table 4. 5. Estimates of willingness to accept (WTA) for carbon trading contract attributes and their range

Contract attributes	WTA (KShs)	WTA range (KShs)
ASC	3591.19	1720.87 - 5461.51
OPTOUT	2329.64	1452.87 - 3206.41
CLENGTH	705.97	574.51 - 837.44

Source: Survey data, 2013

The minimum average payment required to encourage participation in the carbon trading afforestation projects was KShs 3,591 $acre^{-1}yr^{-1}$. To facilitate the interpretation of WTA values for OPTOUT and CLENGTH, a negative value was interpreted as the maximum amount farmers were willing to pay to have the desired changes in the contract attributes. A positive value was interpreted as the maximum amount of compensation that farmers would demand or were willing to accept in return for a less desirable contractual condition. This interpretation is analogous to that used by Ruto and Garrod (2009). On average, landowners were willing to accept KShs 2,330 $acre^{-1}yr^{-1}$ to have the opt-out attribute (contracts that allow for early withdrawal with penalty) included in the contracts and KShs 706 $acre^{-1}yr^{-1}$ to have the contracts extended by a year.

4.2.6 Discussion

This study set out to assess the landownersô willingness to participate in carbon trading afforestation projects in Trans Mara sub-County, their preferences for contract attributes, the effects of the socioeconomic factors that were likely to influence participation and also determine willingness to accept. The results show substantial interest in carbon trading afforestation contracts in Trans Mara sub-County. The ASC coefficient was positive and significant, indicating that the landowners would prefer carbon contracts to a situation without them, the status quo. Majority, about 79 percent of landowners, had a positive significant preference for carbon trading contracts. This unexpected seemingly high interest could be attributed to a number of factors. First, is the availability of land, and in particular marginal land with minimal agricultural activity that includes large tracts of denuded hills which can easily be committed to tree planting without necessarily compromising food production. Therefore, carbon projects may have been viewed by most farmers as an alternative source of income stream from the otherwise underutilized land. Additionally, the average land holdings in the sub-County are comparatively larger than the national average of less than ten acres, arguably indicating availability of land for diversification of farm enterprises such as carbon trading afforestation projects.

Secondly, and perhaps more interestingly, was what appeared to be a growing and synergistic demand for wood products, mainly fuel wood by tea processing factories in the neighboring Kisii County and electrical posts for rural electrification that was noted and reported during the survey. For the past several years, natural forest was part of Trans Mara sub-Countyös landscape. However, with a steadily growing population and an ensuing demand for food and wood fuel, the natural forests were cleared to create land for agricultural production, thereby causing a shortage of wood and other forest products. This seems to have triggered an interest in tree planting, and in particular in the fast growing exotic *Eucalyptus* species as was reflected by the proportion, about thirty two percent, of landowners with such woodlots. Under these conditions, landowners may have regarded carbon trading afforestation projects as a means of diversifying their production, reducing risk, and building assets to enhance family incomes and security.

As hypothesized by the study, coefficients on contract length and payment were found to be significant and with expected signs, indicating that the landowners would prefer shorter contracts and those that offered higher payments. This is as expected given that shorter contracts may give farmers greater flexibility in terms of dealing with any risk and uncertainties that often characterize any long term investment. It is logical that landownersô willingness to participate in carbon trading afforestation contracts is positively influenced by the amount of payment. This finding is consistent with economic theory that suggests that the farmers will take up farm investments as long as it is profitable to do so, i.e., in this case, as long as the marginal benefit of one acre of additional agri-environmental activity exceeds its marginal costs (Salhofer and Glebe, 2006).

The coefficients on opt-out attribute indicated that the landowners would prefer no opt out contracts compared to opt out contracts. This finding contradicts the earlier expectation that the landowners would prefer flexible contracts that allowed them to leave before the expiry of the contract period. It thus appears that the penalty imposition acted as a disincentive to most farmers who may have considered the potential challenges associated with reimbursement. With high levels of poverty and low income flows that often characterize many rural households in Trans Mara sub-County in particular and the country in general

(KIPPRA, 2013; TDDP, 2009), it would be reasonable to expect that most landowners would face difficulties in paying penalties from the breach of the contracts. Another likely explanation is related to the social desirability bias, a well-known disadvantage of stated preference techniques. This is the tendency of some respondents to answer questions in ways which they believe will receive approval from those conducting the survey (Maguire, 2009) or to answer in ways that reinforce their own moral tendencies (Nunes and Schokkaert, 2003). It is likely that the preference for breach-proof contracts may have been viewed by some landowners as a sign of commitment and honesty on their part, thereby creating an impression that they were trustworthy group.

The estimated coefficients and their standard deviations provide information on preference heterogeneity, this being the proportion of landowners that place either a positive or a negative value on a particular attribute. The results show preference heterogeneity in all contract attributes and the alternative specific constant. Although the majority of landowners had a positive and significant preference for shorter contracts, approximately 10 percent had a preference for longer contracts. Similarly, about 14 percent of the landowners had a positive preference for opt-out contracts. It appears that some landowners may have felt that opt out contracts would give them greater flexibility in shifting to other future economically attractive agricultural programs. In this way, the opt-out contracts could have been viewed as risk management strategy for the uncertain future.

The coefficients of interaction terms provide insight into factors that influence a landownerôs decision to participate in carbon trading contracts. As the results of the study indicate, the landownerôs age and size of landholding were the only significant predictors of participation decisions in carbon trading afforestation contracts. Although the landowners, on the whole, preferred carbon contracts to the situation without them, the status quo, the preference for the status quo situation was higher in older farmers. This is expected given the long-term nature of tree crops and the fact that the most significant income streams from carbon afforestation projects would accrue in the distant future, mainly from the sale of timber at the end of the project. Farm size had a significant influence on the participation decision, that is, the preference for status quo was higher for households with smaller farms. In other words, the landowners owning smaller farms were less likely to participate in carbon trading afforestation. This study corroborates the findings of previous studies on the uptake of AES that have found that the farmers with larger holdings are more likely to participate in such schemes (Ducos et al., 2009; Vanslembrouck et al., 2002).

Previous studies have shown that education can play a significant role in the uptake of AES in many developing countries (Babulo et al., 2008). It is argued that landowners with comparatively low education are less likely to participate in AES schemes or adopt conservation friendly farming practices (Wilson, 1992). In this study however, education was not found to be statistical significant in explaining the participation decision in carbon trading afforestation contracts. This unexpected finding may indicate that the local community is already knowledgeable about the potential economic benefits of tree planting, a fact that is supported by the earlier assertion of a growing demand for wood products in the study area. Therefore, the marginal contribution of formal education would not have resulted in a significant participation decision outcome.

This study hypothesized that a household previous experience in tree planting would positively influence participation in carbon trading afforestation contracts. However, as the results indicate, the coefficient was both negative and insignificant indicating that the more planted trees a farmer already had on his land the less likely he was to accept the opportunity to plant more trees for the carbon trading afforestation contract. With competing land uses and the long-term nature of investment in trees, it may not be unusual to find landowners that would be reluctant to commit more land to trees. Committing more land to trees particularly where land size is limiting this could diminish the ability of landowners to diversify to other agricultural enterprises.

The influence of land tenure status on participation in AES seems to depend on the conditions and characteristics of the scheme (Crabtree et al., 1999; Froud, 1994; Wynn et al., 2001). In this study, tenure security proxied by possession of land title deeds was insignificant in explaining the participation decision. It had been hypothesized that possession of formal individual land title would encourage participation in carbon trading afforestation projects because it eliminates anxiety and uncertainty of expropriation, thereby encouraging land owners to make long term investment decisions. However, the results of this study show that informal land tenure system particularly those conferred through customary systems are not a limitation to farmersô decision to participate in carbon trading afforestation contracts since these systems just like the title deeds, are regarded by the local community as secure and legal entitlements to land. These results are consistent with the findings of (Migot-Adhola et al., 1991) and (Muchena et al., 2005) who reported that land titles per se may be much less important to stimulate investments in land improvement than secure access to land, which can be ensured under different systems of land tenure.

The marginal rate of substitution between the payment attribute and contract attributes reveals the monetary value of farmerôs willingness to trade off per acre payments for desired changes in contract attributes. This is the compensating variation, willingness to accept or implicit price. On the other hand, the marginal rate of substitution between the payment attribute and ASC reveals the minimum amount of money that would have to be provided to each household in order to induce them to participate in carbon trading contracts. The results show that carbon trading afforestation contracts offer a positive welfare gain to landowners. Additionally, land owners are willing to trade off longer contracts and flexible contracts (those that had an option for cancellation) with higher payments. The highest level of payment required by farmers for accepting a less desirable change in carbon trading afforestation contract was observed for the change from a no opt-out to an opt-out arrangement.

4.2.7 Implications

Farmers in Trans Mara sub-County have demonstrated an interest in carbon trading afforestation projects. Policy makers and development agents particularly those at the local level would do well to link these farmers to existing carbon financing mechanisms such as the Clean Development Mechanism (CDM) and the World Bankôs BioCarbon Fund. Entering into carbon sequestration contracts with smallholder farmers requires identifying them, agreeing to a contract, monitoring compliance and paying them. County governments are perhaps better placed to act as offset aggregators because of their local level development obligations, capacity to aggregate farmers so that pools of carbon in tradable amounts are formed and monitor the projects. A policy environment that enables the necessary institutional mechanisms for community participation would be needed for the carbon trading afforestation to work. For them to have a wider appeal, carbon trading contracts should be designed in a manner that accounts for disparities in farmersô resource endowments, size of farm and preferences.

4.3 Potential financial benefits from carbon trading afforestation projects

4.3.1 Crop and livestock enterprises: general description

Summary statistics for the maize and beans enterprises are provided in Tables A.2 to A.12 in Appendix 1. Maize and beans were found to be the predominant crop enterprises, grown as monocrops during the long and short rainy seasons. Other crop enterprises were, in order of dominance, vegetables, bananas, sorghum/millet, tomatoes and sweet potatoes. There were no significant differences in average yields between the long and short rains for both maize ($p = 0.471$) and beans ($p = 0.125$). The average maize yields were found to be much lower than the sub-County average range of between 15 and 18 bags per acre. This was attributed to the poor weather conditions and maize lethal necrosis disease (MLND) as reported by farmers at the time of the survey.

For beans, the average yields compared favorably with the sub-County average of 5 bags per acre. Majority, 82 percent, of farmers planted hybrid maize at an average rate of 10 kilograms per acre. Use of basal fertilizer, diammonium phosphate (DAP) for maize production was reported by over two thirds of the farmers at an average application rate of 38 kg per acre. The mean price of a 50-kg bag of fertilizer was KShs 3,479, purchased largely from the National Cereal and Produce Board (NCPB). The use of organic fertilizer was marginal. Top dressing fertilizer was not applied for beans production; beans harvested from previous cropping season were the main source of seed for planting. Fertilizer use and rates of application were lower than for maize production. The use of agrochemicals for the control of bean diseases and pests seemed rather heavy with more than 60 percent reporting that they used all the three categories of agrochemicals: insecticides, fungicides and foliar fertilizer.

Land preparation for planting was done using oxen and plough owned mainly by farmers or their close relatives although the use of a hired tractor was also reported by 34 percent of the farmers. The cost of hiring a tractor for land preparation was comparable to that of hiring draught animals. On average, land was tilled twice before planting. Labor for planting and post-planting activities was mostly hired, perhaps an indication of the pastoral orientation of the Maasai community who until recently, were traditionally non-cultivators. The average number of persons engaged in various activities for both maize and bean production on per acre land and average wage rates are provided in Tables A.13 to A.15 in the Appendix 1.

Summary statistics on livestock production activities are provided in Tables A.16 to Table A.18 in the Appendix 1. Almost all households, ninety nine percent, kept livestock, thus indicating the importance and role of livestock production as an economic activity within the social system in the sub-County. The dominant livestock species in terms of numbers and amount of income generated were cattle, sheep and goats, poultry and donkey in that order. Even though land was individually owned, livestock were grazed communally. Typically, households allocated land to various activities according to the following order: homestead, cultivation, grazing, leasing and in some cases farm forests. There was no restriction on the use of grazing land because livestock owned by both the household and the neighbors were allowed free access. Direct inputs into the livestock enterprise were labor for herding, acaricides for tick control, salt and mineral licks, anthelmintics and veterinary care costs. Herding was done by family members and/or hired labor. Cattle, sheep and goats were sprayed weekly and given access to salts and mineral supplement. Anthelmintics were given to sheep and goats every quarter, and cattle were seldom dewormed. Direct outputs from livestock production were mainly live animals, milk and eggs.

4.3.2 Description of a maize enterprise for the partial budget

For the partial budget analysis, a maize enterprise, based on survey data was described, as hybrid maize planted on a hectare of land twice a year during both long and short rainy seasons. Ten kilograms of seeds were planted with basal fertilizer (DAP) applied at a rate of 190 kg per hectare. Before planting, the ground was tilled twice using hired oxen and plough. Labor requirements for planting and all post-planting activities, including first and second weeding, harvesting, shelling and drying were hired. The average yields, prices and input costs were assumed to remain constant in both long and short rainy seasons. Maize was bought from the farms by agents. Gross margin calculations for maize enterprise based on survey data are provided in Table 4.6.

Table 4. 6. Gross margin for maize enterprise per hectare per year

	Quantity per hectare per year	Price per unit (KShs)	Total (KShs)
Gross income	40*	2,914	116,560
Input costs			
Materials			
Seed (Kgs)	50	152.5	7,625
Fertilizer (DAP, Kgs)	190	70	13,283
Labor (No. of persons)			
Land preparation	35	141	6,345
Planting	45	166	8,300
First weeding	50	182	18,200
Second weeding	100	176	15,840
Harvesting	90	170	9,350
Shelling and drying	55	150	9,000
Total input cost			87,943
Annual net income			**28,617**

* 1 bag of maize = 90kgs

Source: Survey data, 2013

4.3.3 Description of a beans enterprise for the partial budget

The analysis is based on beans planted on a hectare twice a year during long and short rains using farmerôs own seed harvested during the last cropping season. Basal fertilizer was applied at a rate of 148 Kgs per hectare. Insecticides, fungicides and foliar fertilizer were applied to control pests and diseases, increase yields and improve plant health. Land was ploughed twice using hired oxen and plough. All labor requirements for post-planting activities, including first and second weeding, harvesting, shelling and drying were hired. Gross margin calculations for the beans enterprise based on the survey data are provided in Table 4.7.

Table 4. 7. Gross margin for a bean enterprise per hectare per year

	Quantity per hectare year	Price per unit (KShs)	Total (KShs)
Gross income	20*	4,606	92,120
Input costs (Kshs)			
Materials			
Seeds (kgs)	104	150	15,625
Fertilizer(kgs)	148	70	10,335
Insecticides (100ml bottle)	5	215	1,075
Fungicides (200ml bottle)	5	295	1,485
Foliar fertilizer (1000ml bottle)	2	750	1,500
Labour (No. of persons)			
Land preparation	45	141	6,345
Planting	50	165	8,250
First weeding	90	178	16,020
Harvesting	55	177	9,735
Threshing and drying	60	177	10,620
Total input cost			80,665
Annual net income (Kshs)			**11,455**

* 1 bag of beans = 90kgs

Source: Survey data, 2013

4.3.4 Description of a livestock enterprise for the partial budget

To allow for plausible comparisons of incomes from livestock and carbon trading tree enterprises, a gross margin of the livestock enterprise was calculated on per hectare basis for a typical farm whose description was based on the survey data. The analysis was based on several assumptions: that grazing, although communal was confined to areas designated as grazing areas and natural forest and that, households were homogenous in their livestock husbandry practices. Additionally, it was assumed that there was no differential access to pastures by livestock and finally that herd productivity was comparable across households. This analysis was limited to direct inputs and marketed outputs. Tables A.20 to A.21 in Appendix 1 provide estimates of species-specific stocking rates and input costs on per hectare of land used to compute the gross margins. The stocking rates were calculated using the average grazing land. Table A.19 in Appendix 1 provides details on household allocation of land to various livelihood activities based on the survey data. The average farm size for the livestock partial budget analysis was described as a 32.08 acre farm allocated to different uses as indicated in Table 4.8.

Table 4. 8. Land allocation for a typical farm for the livestock enterprise

Land use	**Acres**
Home compound	0.60
Crop land	3.02
Graze livestock	10.70
Leased out	4.22
Woodlot	0.46
Natural forest	13.08
Total farm size	**32.08**

Source: Survey data, 2013

A livestock enterprise for the partial budget was described as mixed species stocking of cattle, sheep and goats. The flock consisted of 42 cattle, 48 sheep and 18 goats maintained on natural forage. For this analysis it was necessary to assume that grazing was strictly confined to the designated grazing land and natural forest within the farmland. Livestock from outside were not allowed access to the farmǿs grazing land neither were the animals within the farm allowed to graze outside the farm. Animals were allowed free access to salt and mineral lick placed conveniently at watering point and within the livestock enclosure where the animals were kept for overnight rest. The animals were herded by two hired herdsmen, one for sheep and goats and the other for cattle. All livestock were sprayed with acaricides every week, given anthelmintics every three months and vaccinated and/or treated occasionally. Given the dynamic nature of a livestock production system and the associated challenges of quantifying both direct and indirect economic outputs, this analysis was limited to direct inputs and marketable outputs only. The gross margins for the livestock enterprise based on the survey data are provide in Table 4.9.

Table 4. 9. Gross margin of a livestock enterprise for an average farm in Trans Mara

Revenue from sale of livestock & products	Off-take (No.)	Price per unit (KShs)	Total (KShs)
Cattle	14	19,168	268,352
Sheep	26	3,348	87,048
Goats	10	3,425	34,250
Milk (in litres)	3,034	29	87,986
Total revenue			477,636
Variable costs			
Acaricides			109,152
Anthelmintics			15,984
Salts and minerals			4,334
Veterinary care			2,214
Drugs			9,222
Herding			104,470
Repair of livestock shed			6,952
Total variable cost			252,328
Annual net income			**225,308**

Source: Survey data, 2013

Gross margins for the livestock enterprise provided in Table 4.9 do not provide a straight forward means of comparing livestock enterprise to carbon trade tree-planting enterprise because they are not computed on per hectare basis. To compute the per hectare gross margins, it was necessary to make assumptions regarding the herd size and productivity. First is that the herd size was in a steady state, that is, stock density was maintained by altering the level of off-take and productivity was optimal for the available forage resources. Second, that water and forage quality and quantity within the grazing field was self-sufficient. These assumptions made it plausible to compute the stocking density and net income per unit of land.

Within the context of this study, participation in carbon trading tree planting enterprise implies a shift in land use from livestock production to trees. In other words, land will be diverted from livestock production and committed to tree planting for the entire period of the contract, in this case, a hectare of grazing land. The stock density per hectare of land for the typical farm based on the calculations was 4 cattle, 4 sheep and 2 goats. Assuming a stable herd structure and productivity, livestock off take was necessary in order to maintain the steady state. The gross margins for livestock on a hectare land are provided in Table 4.10.

Table 4. 10. Estimated gross margin of livestock enterprise on a hectare land in Trans Mara sub-County

Revenue from sale of livestock and products	Off-take (No.)	Price per unit (KShs)	Total (KShs)
Cattle	4	19,168	76,672
Sheep	4	3,348	13,392
Goats	2	3,425	6,850
Milk* (in liters)	144	29	4,176
Total revenue			**101,090**
Variable costs			
Acaricides (litres)*			4,368
Anthelmintics (litres)*			620
Salts and minerals*			204
Veterinary care*			104
Drugs*			436
Herding*			4934
Repair of livestock shed*			328
Total variable cost			**10,994**
Annual net income			**90,096**

*calculated as a proportion of herd costs using values provided in Table 4.9

Source: Survey data, 2013

4.3.5 Description of tree enterprise

A tree enterprise for the partial budget analysis was described as a *Eucalyptus* species rotational woodlot grown on a hectare of land for a multiple management objective for transmission/construction poles and carbon sequestration on a 10 years plant-harvest cycle from seed to mature tree. It has been demonstrated that a 10 cycle maximizes woody biomass growth and carbon sequestration (Dabas and Bhatia, 1996). After 10 years of maturity, effectiveness for carbon sequestration declines (ibid). Planting holes were dug 30 cm deep and 30 cm wide at an espacement of 3 by 3 meters. In total, 1,250 holes were pitted per hectare. Good quality seedlings were purchased from the Kenya Forestry Service Kilgoris offices. Seedlings were planted during the rainy season and diammonium phosphate fertilizer applied at a rate of 10 grams per hole to improve seedling growth. Replacement of dead seedling (beating up) was done within a month of planting, but not more than six months after. A 10 percent beating up rate was assumed. Complete weeding was done six times in the first two years. At rotation age (10 years), products were sold at farm gate price of KShs 1225 per tree to buyers that undertook to harvest and transport the poles at their cost. Table A.22 to A.24 in the Appendix 1 provides the cash flows for the tree enterprise based on the above assumptions and the survey data.

4.3.6 Financial profitability analysis

The results of the NPV, IRR, BCR and partial budget analysis for the tree and crop enterprises are presented in Tables 4.11 to 4.15. The NPV, IRR, BCR and the net returns based on the partial budget analysis all show that the tree for the multiple objectives of carbon sequestration and timber was financially profitable while the carbon-only tree enterprise was unprofitable. The initial capital outlay for the tree enterprise was comparable to that of the maize and bean enterprises. *Ceteris paribus*, a shift in land use from maize to a rotational *Eucalyptus* species woodlot enterprise on a hectare land would result in a 1,600 percent increase in net returns from KShs 28,617 $ha^{-1}year^{-1}$ to KShs 486,614 $ha^{-1}year^{-1}$. A similar shift from beans to trees would result in a 4,148 percent or KShs 475,159 $ha^{-1}year^{-1}$ increase in net returns. The tree enterprise for a management objective of carbon sequestration only was unprofitable financially at the prevailing carbon price of KShs 860 Mg $Cha^{-1}year^{-1}$ and would result in a 275 percent or KShs 78,696 $ha^{-1}year^{-1}$ loss in net returns, if land was shifted from maize to trees, and 537 percent or KShs 61,534 $ha^{-1}year^{-1}$ loss in net returns if land was shifted from beans to trees. A tree enterprise for the multiple objectives for carbon sequestration and timber remained profitable than both the maize and bean enterprises even at the sub-County average maize yields of between 75 and 90 bags $ha^{-1}year^{-1}$ and the sub-County average beans yields of 25 bags $ha^{-1}year^{-1}$ (see Tables A.25 to A.28 in Appendix 1). The analysis shows that such a shift from maize and bean enterprises at the sub-County average yields to a tree enterprise would result in a 1,040 percent, 179 percent and 1,131 percent increase in net returns respectively. A tree enterprise for the sole objective of timber was more profitable than maize a. nd beans enterprises.

Table 4. 11. NPV, IRR and BCR for carbon trade tree enterprise and decision rule

Type of tree enterprise	NPV	IRR	BCR	Decision rule
Carbon - timber	486,614	37.91	8.5	Accept
Carbon	-50,079	-	-0.23	Reject
Timber	471,819	36.14	8.2	Accept

Source: Survey data, 2013

Table 4. 12. Net returns of maize and tree enterprise for the multiple objectives of carbon sequestration and timber

Revenues	KShs	Costs	KShs
Additional returns	551,490	Additional costs	64,875
Reduced costs	87,943	Foregone returns	116,560
Net benefits	639,433	Net costs	181,435
Net returns	**457,997**		

Source: Survey data, 2013

Table 4. 13. Net returns of bean and tree enterprise for the multiple objectives of carbon sequestration and timber

Revenues	KShs	Costs	KShs
Additional returns	551,490	Additional costs	64,875
Reduced costs	80,665	Foregone returns	92,120
Net benefits	632,155	Net costs	156,995
Net returns	**475,159**		

Source: Survey data, 2013

Table 4. 14. Net returns of maize and tree enterprise for the objective of carbon sequestration

Revenues	KShs	Costs	KShs
Additional returns	14,796	Additional costs	64,875
Reduced costs	87,943	Foregone returns	116,560
Net benefits	102,739	Net costs	181,435
Net returns	**-78,696**		

Source: Survey data, 2013

Table 4. 15. Net returns of bean and tree enterprise for objective of carbon sequestration

Revenues	KShs	Costs	KShs
Additional returns	14,796	Additional costs	64,875
Reduced costs	80,665	Foregone returns	92,120
Net benefits	95,461	Net costs	156,995
Net returns	**-61,534**		

Source: Survey data, 2013

The results of sensitivity analysis are provided in Plates 2 and3 in Appendix 3. The sensitivity analysis was done for the maize and carbon-timber tree enterprise only because the carbon sequestration only tree enterprise was not profitable. The net returns under the maize and carbon-timber scenario were fairly insensitive to changes in per hectare maize and beans yields. For example a 50 percent increase in maize yield would result in a 13 percent or Kshs 58, 250 $ha^{-1}year^{-1}$ reduction in the net returns while a similar increase in beans yield would result in 10 percent or Kshs 46,060 $ha^{-1}year^{-1}$ reduction in net profits.

The sensitivity on discount rates showed that net returns decreased with increase in discount rate. However, rate of decrease was higher at lower discount rates and lower at higher discount rates. For example, a 2.5 percent variation in discount rate from 10 to 12.5 percent for the maize and carbon-timber scenario resulted in Kshs 117,157 $ha^{-1}year^{-1}$ loss in net returns while a similar increase from 17.5 to 20 percent resulted in Kshs 50,445 $ha^{-1}year^{-1}$ loss in net returns. The breakeven price of carbon was Kshs 5,434 Mg $Cha^{-1}year^{-1}$ at maize yields of 40 bags (average yield at the time of survey). The breakeven carbon price at the sub-county average maize yield of 75 $ha^{-1}year^{-1}$ and 90 bags $ha^{-1}year^{-1}$ was Kshs 11,362

Mg $Cha^{-1}year^{-1}$ and 13,903 Mg $Cha^{-1}year^{-1}$ respectively. The results of the partial budget for the livestock enterprise are provided in Tables 4.16 and 4.17.

Table 4. 16. Net returns of livestock and tree enterprise for multiple objectives of carbon sequestration and timber

Revenues	(KShs)	Costs	(KShs)
Additional returns	551,490	Additional costs	64,875
Reduced costs	10,994	Foregone returns	101,090
Net benefits	562,484	Net costs	165,965
Net returns	**396,518**		

Source: Survey data, 2013

Table 4. 17. Net returns of livestock and tree enterprise for objective of carbon sequestration

Revenues	(Kshs)	Costs	(Kshs)
Additional returns	16,407	Additional costs	64,875
Reduced costs	10,994	Foregone returns	101,090
Net benefits	27,401	Net costs	165,965
Net returns	**-138,564**		

Source: Survey data, 2013

The tree enterprise for the multiple objective of timber and carbon sequestration was found to be more profitable financially than the livestock enterprise. A shift in land use from livestock to trees would quadruple the annual net income from about Kshs 90,000 ha^{-1} yr^{-1} to about Kshs 396,518 ha^{-1} yr^{-1}. However the livestock enterprise was more profitable than a tree enterprise whose sole objective was carbon sequestration. If land was shifted from livestock to trees for the objective of carbon sequestration only, it would result in a 54 percent or Kshs 41, 610 $ha^{-1}year^{-1}$ loss in net returns.

4.3.7 Discussion

Carbon trading tree enterprise for the multiple objectives of carbon sequestration and timber was more profitable financially than maize, beans and livestock enterprises. If farmers were entirely profit maximizing it would be plausible to argue that they would shift their land use from crop and livestock to trees for the multiple objectives of carbon sequestration and timber. However, there are several factors that may limit a shift of land use from agricultural production to trees including the fact that crops provide food for home consumption and have a short turnaround time compared to trees. Additionally, the long time lag between plantation establishment (tree planting) and tree product harvesting (even for fast growing species) often denies farmers income to cater for their immediate needs. A tree enterprise for carbon trade would be particularly important to households that are looking for opportunities to diversify their production or those with underutilized or marginal lands. Such an enterprise could provide farmers with income streams that would buffer them against the cyclical downturns in profitability of other farm enterprises.

A tree enterprise for the sole objective of carbon sequestration was found not profitable financially and would result in a loss of income if land was shifted from crop or livestock to trees. It is not reasonable to expect that the farmers would grow trees for the sole objective of carbon sequestration since the payments are often much lower than the income that they would get from other agricultural enterprises. Studies on cost-benefit analysis on tree-based carbon sequestration land use schemes have found that the proportion of income due to carbon payments is relatively small when compared with non-carbon income, such as the income from the sale of timber or fruits (Aune et al., 2005). However, since carbon sequestration is a secondary service from a tree enterprise, the income that the farmers would get from carbon payments should be treated as a secondary revenue source. A tree enterprise even in the absence of carbon payments is expected to be an economically viable enterprise. In addition, tree enterprises provides means through which households accumulate capital which can be liquidated when the household falls short of capital for example, when planting annual crops, for paying school fees and health bills or for other investments. As evidence from Rwanda suggests, trees as natural capital could be used as collateral for loans from financial institutions (FAO, 2011).

Although the analysis in this study was limited to the financial benefits from a carbon trading tree enterprise, there are additional benefits that the farmers derive from trees. These benefits include non-market environmental benefits, such as reduction of soil erosion, stabilization of soil elements and improvement of air quality, among others. Further research could look into both market and non-market benefits of carbon sequestration tree enterprises. This type of research could provide more comprehensive information regarding the benefits of tree enterprises that go beyond profitability.

There are a number of limitations in the analytical methods used to arrive at the gross margins of the livestock enterprise. The partial budget analysis for the tree planting and livestock enterprises required that gross margins be computed on per unit area of land. Within the context of this study, this required that the computation of the livestock enterprise gross margins be done on a hectare land. This situation presented challenges, given the characteristics of livestock production system in study area as well as the nature of data that was collected. A cursory review of available literature on livestock gross margins showed that calculations in most studies are commonly based on whole farm analysis. Therefore, it became necessary to describe a hypothetical farm, based on available data and make several assumptions regarding livestock production and productivity. Limitations notwithstanding, the partial budget results on livestock provide useful insights into the potential benefits of carbon trading tree enterprises that would accrue to farmers if a shift in land use was made from livestock to trees.

4.3.8 Implications

Greater efforts are required to encourage uptake of carbon trading tree enterprises in Trans Mara sub-County particularly among households with underutilized or marginal agricultural land or those seeking for opportunities to diversify their farming activities. However, such efforts should be sensitive to the specific needs and constraints of farmers and also provide mechanisms through which farmers can participate in decision making.

Further research is required on the costs and benefits of carbon trading tree enterprise in order to provide more comprehensive information. The research should include both market and non-market benefits of the enterprise.

4.4.1 Farmers' perceptions of climate variability and change

The analysis of the farmersô perceptions of, and adaptation to climate variability and change was based on 136 responses from respondents aged 40 years and above. The age restriction was considered reasonable given that the study was based on a recall time of 20 years. Majority of the farmers (87 percent) believed that the study area had progressively become less productive to crop farming and/or livestock production over the past twenty years. Seven percent of the farmers believed that the area had become more productive to agricultural activities while the remaining 6 percent believed the conditions had not changed. Table 4.18 gives details on the farmersô views of what they perceived to be the reasons for the unfavorable farming conditions.

The results show that unpredictable rainfall pattern (53 percent), inadequate rainfall (56 percent) and delayed onset of rains (40 percent) were the major weather-related elements that the farmers thought had shown the greatest variability over time thereby affecting crop and livestock production and productivity. The general view by most farmers was that twenty years ago rains were more regular and would begin when they were expected to and fell in sufficient quantities throughout the growing season. Although there were a few occasions when this regularity would be disrupted, such events were few and wide apart. However, with the passage of time, rainfall had become increasingly unpredictable, either coming too early or too late in the season. It was also reported that, unlike in the past, rainfall was heavy but not well distributed through the growing season. The heavy rainfall caused flooding and soil erosion. Other rainfall related causes of unfavorable farming conditions that were reported by the farmers in the in the study area were poor distribution of rainfall (27 percent) and extended dry periods (13 percent).

Table 4. 18. Farmers perceptions of causes of unfavorable farming conditions in Trans Mara sub-County

Reasons for unfavorable farming conditions	n	Percent
Inadequate rainfall	76	55.9
Unpredictable rainfall pattern	72	52.9
Delayed onset of rains	64	39.7
Crop diseases and pests	47	34.6
Declining soil fertility	39	28.7
Poor distribution of rainfall through planting season	37	27.2
Destruction of natural vegetation	23	16.9
Extended dry periods	17	12.5
Increased subdivision of land	15	11.0
High temperatures	1	0.7

Source: Survey data 2013

Indirectly related to rainfall was the reported destruction of natural vegetation mainly forests, that had occurred over the years. About seventeen percent of farmers associated the changed rainfall pattern to destruction of forest resources in the sub-County. According to the farmers, forests used to attract rainfall. However, after most of what was there as forests in the past was cleared to create land for agricultural production, the pattern of rainfall got somewhat affected. Another interesting perspective related to forest clearing was the role of forests in protection of water sources. It was reported that before the forests were cleared, the area had many all year round water streams and seasonal rivers that provided easily accessible water for livestock and domestic use. However, because of forest destruction, most of these water sources have disappeared. It was reported that the duration between the rainy seasons had now become progressively longer than it than it was twenty years ago. This factor is closely related to inadequate rainfall, as it led to extended dry periods.

An elevated environmental temperature is one of the key elements of weather that is frequently associated with climate change. In this study, hardly any famers attributed the deteriorating farming conditions to an increase in environmental temperature. Other factors that affected farming conditions, though not directly related to weather conditions, were declining soil fertility (29 percent), increasing crop pests and diseases (35 percent) and increased subdivision of land (11 percent).

4.4.2 Farmers' adaptation strategies to climate variability and change

Farmers made a number of adjustments to their farming practices in order to cope with the long-term shifts in weather pattern and unfavorable farming conditions in general. Table 4.19 provides a list of adaptation strategies used by farmers in Trans Mara sub-County in order of the frequency. Change in crop variety (61 percent) and livestock breed (60 percent), reduction in herd size (51 percent) and diversification of farm enterprise (41 percent) were the predominant means by which the farmers adapted to long-term changes in climate. In general, farmers indicated that they had changed crops varieties and adopted more drought tolerant and disease resistant varieties. For example, some farmers reported that they had shifted from the 600 series of maize hybrids (613, 614, 615) to the fast growing and generally more drought resistant *Katumani* or the unimproved local variety which was believed to have similar characteristics. Another strategy that was reported by about 8 percent of the farmers was to plant different crop varieties on different plots (crop rotation) to minimize the risk of crop failure since different crops are affected differently by climatic events. A small proportion (about 2 percent), reported that they prepared land early, during the dry spell that precedes the rainy season so as to allow for the decomposition of crop residues and weeds. Planting was then done as soon as the rains fell.

Table 4. 19. Farmers' adaptation strategies to climate variability and change in Trans Mara sub-County

Adaptation strategy	n	Percent
Change crop variety	83	61.0
Change livestock breed	81	59.6
Reduce number of livestock	59	50.7
Diversification of farm enterprise	56	41.2
Use fertilizer and agrochemicals	20	14.7
Change from crop to livestock	18	13.2
Crop rotation	11	8.1
Find off-farm job	8	5.9
Water harvesting	7	5.1
Lease land	7	5.1
Change from livestock to crops	6	4.4
Timely land preparation and planting	2	1.5
Crop/livestock insurance	1	0.7

Source: Survey data 2013

Reduction in herd sizes (50.7 percent) and change of local breeds (59.7 percent) were the main livestock-specific farmer responses to unpredictable weather conditions and unfavorable farming conditions. Erratic and insufficient rainfall had reduced the quantity of pastures, thereby compelling most farmers to reduce their herd sizes and improve their local breeds to ensure that production was not adversely affected. The sahiwal breed was found to be the most preferred for beef production although a few farmers reported having tried out crosses of some dairy breeds.

Diversification of farm enterprises (41.2 percent) was yet another adaptation strategy used to spread the risk of climate change variability on agricultural production. The study found that the farmers diversified from the traditional maize and bean enterprises to other crops, such as millet, sorghum, potatoes, bananas, tomatoes, onions, vegetables and trees. An unexpected finding was the existence of aquaculture enterprises. Some farmers, about 4 percent also reported having diversified from a livestock only enterprise to a mixed crop-livestock enterprise. Thirteen percent reported they had diversified from a crop only enterprise to a mixed crop-livestock enterprise.

Finding off-farm jobs (6 percent) mainly in the informal sector was another adaptation strategy that the farmers used in response to the declining income from agricultural activities caused by poor weather and farming conditions. Examples of the off-farm jobs included for example the motorcycle business popularly referred to as *bodaboda,* selling of food and clothing items at local markets and the cattle sale business mainly as brokers. Land leasing (4 percent) and water harvesting (5 percent) were other adaptation strategies to climate change and variability. Land was commonly leased for a single cropping season while rain water was harvested mainly for domestic use, livestock and for small-scale irrigation activities.

4.4.3 Constraints to adaptation to climate variability and change

Farmers faced several challenges in adjusting their farming practices to cope with the changing climate. Table 4.19 lists the constraints to adaptation to climate change.

Table 4. 20. Constraints to adaptation of farming practices to climate variability and change in Trans Mara sub-County

Constraint	n	Percent
Lack of money	83	61.0
Lack of information	64	47.0
Insufficient labor	15	11.0
Insufficient sahiwal bulls	6	4.4
Cattle rustling	2	1.5
Insufficient land	1	0.7
Livestock diseases	1	0.7

Source: Survey data 2013

The results in Table 4.19 show that lack of money (61 percent), information (47 percent) and labor (11 percent) were the main constraints that the farmers in the study area faced in their endeavor to adjust their farming practices to cope with the changing climate. In general, farmers indicated that they needed financial resources and information to make the right and optimal adjustments to their farming practices. For example, they did not quite know the profitable enterprises to take up given their circumstances and available opportunities. In most cases farmers reported having tried out different enterprises, mostly based on what they thought was profitable or what they saw their neighbors doing. A case in point was the horticultural enterprises where some farmers reported that they had taken up the enterprise only to abandon it later when they failed to get markets for their produce. Another notable example was the aquaculture enterprise which was introduced by the national government through the economic stimulus package. Whereas some farmers took up the enterprise as a strategy to diversify their farming activities, the requisite market information and infrastructure were not set up to ensure that the produce was disposed off profitably. This led some of them to abandon the enterprise. A number of fish ponds were found in a disused state during the survey.

4.4.4 Discussion

The results of this study show that the farmers in Trans Mara sub-County had reasonable perceptions to the effects of climate variability and change and had taken steps to adjust their farming activities. These findings are largely consistent with the findings from similar studies that have reported generally high levels of perceptions to climate change among smallholder farmers (Silvestri et al., 2012; Speranza et al., 2010). Changes in rainfall pattern and intensity were the key ways in which farmersô perceived these changes, expectedly so because rainfall is one of the significant climatic parameters affecting agricultural production. Most of agricultural production in the sub-County is dependent on rainfall. Therefore, any variations in the pattern and intensity of rainfall are expected to be easily observable. Farmersô knowledge and understanding of the phenomena of rainfall variability, intra-seasonal factors including the timing of the onset of the rainy seasons and the distribution, and periodicity of rains within the growing seasons appeared to be relatively broad. It was no surprise therefore, that the farmers were able to perceive the long-term elements of uncertainty and unpredictability within this phenomenon. This was perhaps well illustrated by the diverse but often related perspectives on rainfall variability.

The effects of climate change on agricultural production in Trans Mara are confounded by other production and environmental challenges. Increased prevalence of crops diseases and pests, declining soil fertility, destruction of natural vegetation and increased subdivision of land, appeared to exacerbate the effects of climate variability on agricultural production. Coincidentally, the maize crop in the sub-County was under attack by the maize lethal necrosis disease at the time of the survey. These findings highlight the need for a multi-pronged approach when dealing with climate related challenges in agriculture which must inevitably go beyond the climate variability to include other constraints to agricultural production and productivity.

The results of this study show that the farmers made adjustments to their farming practices in response to climate variability. Diversification of farm enterprises, changing crop varieties, reducing flock sizes and changing livestock breed were the most common adaptation strategies. Most of these strategies would not require huge financial outlays to implement and possibly explain their popularity among farmers. Some interesting inclusions in the list of adaptation strategies, though not too common, were water harvesting and crop/livestock insurance. Insurance and water harvesting can effectively cushion farmers against the effects of climate variability as well as support increased investment in agricultural production. Alternative income generating activities such as land leasing and off-farm jobs were other strategies that farmers used to cushion themselves against the cyclical downturns on profitability of farm enterprises caused by climate variability and change and other production challenges.

Although the farmers reported using various adaptation measures in response to changes in climate, it is noted that these actions transcend the climate dimension and are clearly played out within the context of other pressures and disturbances on livelihoods. For example, the reduction in herd size may be correlated to subdivision of the previously communal land or breed improvement may be profit- driven rather than a response to the changing weather pattern. The entwined nature of disturbances and change-inducing factors in livelihoods cannot be ignored and is widely recognized in the literature (Campbell, 1999), including in attempts to disaggregate the effects and show their linkages (Blaikie and Brookfield, 1987). For adaptation to climate change to occur, it is not necessary for households and communities to ignore other livelihood disturbances. Indeed, to be successful, adaptation arguably needs to be embedded in the full milieu of life-affecting processes. However, it is important for climate change to be recognized as a significant factor, and for the subtle dimensions of climate parameter change, which are the experienced realities, to be understood and reacted to.

Farmers faced considerable challenges as they endeavored to adjust their farming practices to climate variability. Lack of financial resources, insufficient labor and limited access to information were the major constraints that impeded adaptation. Resource constraints limits farmersô ability to take up adaptation measures in response to changes in climatic conditions as they are often unable to meet the transaction costs necessary to acquire new adaptation measures (Kandlinkar and Risbey, 2000). Labor availability is considered an important input constraint. The expectation is that farm households with more labor are better able to take on various adaptation management practices in response to changes in climatic conditions compared to those with limited labor.

Information concerning adaptation options and other agricultural production activities remains an important factor affecting use of various adaptation measures for most farmers. Lack of, and or limitations in information increase high downside risks from failure associated with uptake of new technologies and adaptation measures (Jones, 2003; Kandlinkar and Risbey, 2000). Availability of better climate and agricultural information helps farmers make comparative decisions among alternative crop management practices and this allows them to better choose strategies that make them cope well with changes in climatic conditions (Baethgen et al., 2003).

4.4.5 Implications

Policymakers, development agencies and other stakeholders would do well to facilitate the availability of credit, provide climate, agricultural and market information, invest in new technologies, encourage uptake of agricultural insurance, invest in irrigation, carry out more research on the use of new crop varieties and livestock species that are more suited to the changing climatic conditions in the area and create additional opportunities for off-farm employment. Such measures would help the farmers in the Trans Mara sub-County and the southern rangelands in general, to moderate the adverse consequences of climate variability change, while maintaining their livelihoods and food security.

CHAPTER 5: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

There are many opportunities associated with climate change mitigation that can benefit farmers and the country in general. Carbon trading afforestation contracts represents one such opportunity that could increase farmersô incomes while ameliorating the negative effects of climate change and environmental degradation. Currently, though, considerable gaps in knowledge exist on whether farmers would be willing to participate in such contracts. This study set out to explore the feasibility of carbon trading afforestation contracts among farmers in Trans Mara sub-County. The study had six objectives.

The first three objectives assessed farmersô willingness to participate in carbon trading afforestation contracts, their preferences for contract attributes, the influence of farmers socioeconomic characteristics on the likelihood of participation and WTA. The choice experiment method was applied and data was analyzed using two random parameter logit models. The results show substantial interest in carbon trading afforestation among farmers in Trans Mara sub-County with about seventy nine percent indicating that they would participate in the contracts. Farmers preferred shorter contracts and those without an option for cancellation. With respect to ñfarmers factorsò the farmersô age and farm size were found to be the most the important predictors of participation decision in carbon trading contracts. The probability of participation was found to decrease with an increase in age and a decrease in land holding size. The minimum average payment required to encourage participation was found to be KShs 3,591 acre^{-1}yr^{-1}. On average, the landowners were willing to accept KShs 2,329 acre^{-1}yr^{-1} to have the opt-out attribute (contracts that allow for early withdrawal with penalty) included in the contracts and KShs 705 acre^{-1}yr^{-1} to have the contracts extended by a year.

The fourth objective sought to determine the financial benefits of carbon trading afforestation projects. A comparative analysis was done between the carbon trading afforestation enterprise (for the multiple objective of timber production and carbon sequestration) and the following three enterprises: (i) maize enterprise, (ii) beans and (iii) livestock to evaluate the financial benefits or losses that farmers would incur if land use was shifted from agriculture to trees for carbon trade. A similar comparative analysis was done between the carbon trading afforestation enterprise (for the sole objective of carbon sequestration) and the three enterprises. The partial budgeting approach was employed. Descriptions of each of the enterprises for the partial budget were provided and used to estimate gross margins on per hectare per year basis. The results of the NPV, IRR, BCR and partial budget revealed that a carbon trading afforestation enterprise for the multiple objectives for carbon sequestration and timber production was more profitable financially than all other enterprises: maize, beans and livestock. The tree enterprise whose sole objective was carbon sequestration was found to be unprofitable.

The last two objectives assessed farmersô perceptions of and adaptation strategies to climate variability and change. The analysis was based on farmersô recall and observations of climatic events over a period of the last 20 years at the time of the survey. The farmersô responses were elicited indirectly through a series of questions focused on changes in general farming conditions. The results showed a general trend of declining and more variable rainfall. The farmers observed some changes in the rainfall quantities and patterns that were variously described as unpredictable, delayed onset of rain, brief and intense rainfall and insufficient rainfall. Farmers made several adjustments to their farming practices in response to these long-term changes in climate. Changing of crop varieties and livestock breeds, reducing the herd size and diversifying their farm enterprises were some of the adaptation strategies used. Inadequate financial resources, information and labor were cited as the main constraints to the adoption of adaptation strategies to climate change.

5.2 Conclusions

From a policy perspective, the most significant implication of the results on carbon trading tree enterprise is the fact that there was some evidence of substantial interest in carbon trading afforestation projects in the Trans Mara sub-county. Carbon trading provides a new way through which the farmers can earn extra income from planting trees. As the results of this study indicate, the farmers in the region are increasingly turning to tree planting as a means of diversifying their production activities, mainly to generate commodities for home consumption and also enhance their income through market sales of tree products. Hence farmers would not find it difficult to accept carbon trading afforestation contracts at mutually agreeable contract terms. Farmers would have to agree to adopt specific forest management practices that enhance carbon storage through tree plantations to qualify to receive carbon payments. However, they would not directly participate in carbon markets because their tree plantations would be of limited size that would store small amounts of carbon. Therefore, the farmers would need to work with agents who may include group of farmersô organizations or local institutions. Among the local institutions, the County governments would probably be well placed to act as offset aggregators to facilitate aggregation, monitoring and verification. Mechanisms similar to those of contract farming or good agricultural practice certification would have to be set in place to enlist farmers, to maintain or enhance stock volume and quality, and to enforce appropriate use of management practices that enhance carbon sequestration. To design projects that maximize returns on investment for farmers, the local institutions would need to pay attention to the development of institutional framework that would ensure representation of all the stakeholders in contractual negotiations and decisions and also promote transparency in the computation and distribution of payments to those involved in carbon trading contracts.

There was a considerable degree of preference heterogeneity in the contract attributes. Among the farmer factors, farm size and household head age were found to be the most significant predicators of the participation decision. This insight provides useful information about the types of landowners that could be targeted for the carbon trading afforestation projects. The results on welfare estimates based on the evaluation of the willingness to accept showed that carbon projects would offer considerable welfare benefits to landowners in Trans Mara sub-county. In other words, maintaining land use in its current status would be less preferred, and shifting it to tree plantation for carbon trading improves the average household welfare. Another important finding was that landowners would be willing to trade-off less desirable contract attributes against per acre payment. Such information is important when designing optimal contracts that would appeal to wider groups of farmers, thereby encouraging wider participation in carbon trading afforestation projects.

The results of this study augment a growing body of knowledge that confirms climate variability and change as a threat to the livelihoods of smallholder farmers in Africa. Farmers in Trans Mara sub-County are aware of the deteriorating farming conditions that they largely attribute to a changing climate. To cope with the changes the farmers have diversified production by, for example, changing and using different crop varieties and livestock breeds and diversifying farm enterprises. The farmersô ability to adapt to the effects of climate change was found to be limited by inadequate finances and information concerning appropriate adaptation strategies. Supporting farmers, for example by providing the necessary resources such as credit, information and training can significantly help them to adopt climate change adaptation strategies and thus be able to improve and sustain farm productivity levels even under changing climatic conditions. This study demonstrates that it is important to record local perceptions of climate change and to identify how people are responding because it identifies more precisely the kind of support that could be provided and provides a baseline to evaluate future shifts in them

Ideally, participation in carbon sequestration and trading schemes would be voluntary. Households should be able to participate in ways that take into account their different levels of resource endowments, risk tolerance and opportunity costs. Even though this study found that carbon trading afforestation projects for the multiple objectives for carbon sequestration and timber would be more financially profitable that maize, beans and livestock enterprises, agriculture still provides food for home consumption and short run cash flows that are important for livelihood needs. Therefore, carbon projects could be particularly attractive to the households with underutilized pieces of land or to those seeking opportunities to diversify their farming activities.

5.3 Recommendations

This study found considerable interest in carbon trading afforestation contracts in Trans Mara sub-County and identifies recommendations for different stakeholders.

Policy makers and development agents particularly those at the local level should;

- Link farmers in Trans Mara sub-County to existing carbon financing mechanisms such as the World Bankôs BioCarbon Fund. The County government of Narok which is, by law, mandated to spearhead local development could play an important role in this regard through its role as coordinator and promoter of the carbon projects in the County.
- Set up an institutional framework for carbon afforestation projects that are transparent and would ensure representation of all stakeholders in contractual negotiations and decisions.

- Facilitate the provision of credit, climate, agricultural and market information; invest in new technologies, encourage uptake of agricultural insurance, invest in irrigation and create additional opportunities for off-farm employment

Academia and researchers should;

- Carry out more research on the use of new crop varieties and livestock species that are more suited to the changing climatic conditions in Trans Mara sub-County
- Carry out further research to look into both market and non-market benefits of carbon sequestration tree enterprises. This type of research could provide more comprehensive information regarding the benefits of tree enterprises that go beyond profitability.
- Conduct longitudinal research and systematic reviews on local knowledge and perceptions of climate variability and change by contextualizing them in deeper historical and wider structural setting
- Conduct comparative analysis of carbon afforestation projects with other agricultural land-based carbon offset projects, the other economic tools to reduce carbon emissions that could benefit smallholder farmers as well.

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APPENDIX 1

Table A.1: Results of Lagrange multiplier and Likelihood ratio tests

Likelihood ratio tests

Model 1: RES ~ ASC + OPTOUT + CLENGTH + PAYMENT + ASCAGE + ASCHHEDL + ASCLTSYM + ASCTRSB4 + ASCLOGGMA + ASCTLSZ

Model 2: RES ~ ASC + OPTOUT + CLENGTH + PAYMENT + ASCAGE + ASCHHEDL + ASCLTSYM + ASCTRSB4 + ASCLOGGMA + ASCTLSZ | 0

#Df LogLik Df Chisq Pr(>Chisq)

1 55 -732.96

2 2 19 -762.70 -36 59.488 0.00819 **

Signif. codes: 0 ǿ***ô0.001 ǿ**ô0.01 ǿ*ô0.05 ά.ô0.1 óô1

Lagrange multiplier test

chisq = 117.5938, df = 36, p-value = 1.371e-10

Table A.2: Crop enterprises in Trans Mara Sub-County

Enterprise	Number of households (n=61)	Percent
Maize	61	100
Beans	56	91.8
Sorghum/millet	19	31.2
Bananas	26	42.6
Vegetables	32	52.5
Tomatoes	4	6.6
Sweet potatoes	1	1.6

Table A.3: Characteristics of maize and bean enterprises (intercropping and cropping calendar)

Characteristics of enterprise			Number of observations (n=61)	Percent
Intercropping maize and beans	Intercrop		6	9.8
	do not intercrop		55	90.2
Number of times maize/beans planted in cropping calendar	Maize	once	5	8.2
		twice	56	91.8
	Beans	once	33	44.1
		twice	23	37.7

Table A.4: Yields (in 90-kilogram bags) per acre

Yields per acre	Maize		Beans	
	short rains (n=53)	long rains (n=55)	short rains (n=32)	long rains (n=37)
Range	24.67	24.25	17	14.5
Mean (std error)	7.08 (0.79)	7.90 (0.80)	3.62 (0.56)	4.83 (0.55)
Standard deviation	5.72	5.94	3.14	3.32

Table A.5: Price (in KShs) per ninety-kilogram bag of maize and beans

Price of maize and beans	Maize (n=29)	Beans (n=41)
Range	5200	4000
Mean (std error)	2913.79 (230.05)	4606.10 (204.46)
Standard deviation	1238.87	1309.21

Table A.6: Type of seeds for maize and bean production (percent)

Type of seed	Maize (n =61)	Beans (n=54)
Hybrid	85.2	-
Local	14.8	-
Certified seeds	-	18.5
Own seeds	-	74.1
Other sources (market, neighbors)	-	7.4

Table A.7: Price of maize and bean seeds and quantity planted per acre

Statistic	Maize (hybrid)		Beans	
	Price per 2kg packet	Quantity planted per acre (Kgs)	Price per 2 kg	Quantity planted per acre (Kgs)
Number of observations	51	49	15	43
Range	210	8	300	80
Mean	304.9 (5.53)	10.65 (0.28)	195.33(23.03)	32 (3.21)
Std deviation	39.47	1.93	89.19	21.08

Table A.8: Types of fertilizers

Type of fertilizer	Maize (n=61)	Beans (n=56)
Organic	3 (4.9)	3 (5.4)
Inorganic	47 (77)	32 (57.1)
Both organic and inorganic	2 (3.3)	2 (3.6)
Non-users	9 (14.8)	19 (33.9)

Table A.9: Rate of fertilizer application (kilograms/acre)

	Maize (n=48)	Beans (n=33)
Range	40	40
Mean (std error)	38.18 (2.0)	29.70 (2.53)
Std deviation	13.79	14.52

Table A.10: Source of fertilizer (percent)

Source of fertilizer	No of observations (percent)
Market	15 (24.6)
NCPB	18 (29.5)
Both market and NCBP	1 (1.6)

Table A.11: Price of fertilizer and agrochemicals

Statistic	Fertilizer (50-kg DAP) (n=48)	Insecticides (n=42)	Fungicides (n=32)	Foliar fertilizer (n=39)
Range	2750	400	350	445
Mean (std error)	3478.75 (111.23)	215 (16.05)	296.87 (19.56)	234.87 (17.72)
Std deviation	770.52	104	110.67	110.64

Table A.12: Cost of fertilizer transport and tractor hire

Statistic	Fertilizer transport cost per 50kg bag	Tractor hire (Maize)	Tractor hire (Beans)
No of observations	27	20	17
Range	450	1000	1000
Mean (std error)	169.96	2695	2717.65
Std deviation	23.99	62.19	294.18

Table A.13: Labor requirements for maize production

	Land preparation	**Planting**	**First weeding**	**Second weeding**	**Harvesting**	**Shelling**	**Hauling and drying**
No of times activity was undertaken No of observations Once Twice Thrice	 61 3 (4.9) 51 (83.6) 7 (11.5)	-	-	-	-	-	-
Type of labor No of observations 1 = man 2 = man-animal 3 = man ï tractor	 61 - 41 (67.2) 20 (32.8)	 61 6 (9.8) 54 (88.5) 1 (1.6)	 61 61 (100) - -	 45 42 (93.3) 3 (6.7) -	 61 61 (100) - -	 61 61 (100) - -	 61 61 (100) - -
Number of persons that worked on the activity Type of labor No of observations Range Mean (std error) Std deviation	 Man-animal 38 2 2.74 (0.12) 0.97 Man - tractor 20 3 2 (0.22) 0.97	 Man 6 9 9.17 (1.38) 3.37 Man-animal 52 6 4.54(0.14) 1.0	 Man 61 18 9.74 (0.51) 3.97	 Man 42 19 8.9 (0.55) 3.58 Man-animal 3 1 2.33 (0.33) 0.58	 Man 60 16 11.28 (0.48) 3.69	 Man 50 13 5.62 (0.4) 2.81	 Man 55 7 3.05 (0.20) 3.69
Number of working days Type of labor No of observations Range Mean (std error) Std deviation	 Man-animal 39 2 2.77 (0.11) 0.67 Man - tractor 20 1 1.05 (0.05) 0.22	 Man 6 2 1.67 (0.33) 0.82 Man-animal 52 4 2.27 (0.11) 0.82	 Man 61 3 1.61 (0.10) 0.78	 Man 42 3 1.69 (0.13) 0.87 Man-animal 3 2 1.67 (0.67) 1.16	 Man 60 2 1.2 (0.07) 0.514	 Man 50 6 1.74 (0.16) 1.14	 Man 55 6 2.53 (0.14) 1.05

Table A.14: Labor requirements for beans production

	Land preparation	Planting	First weeding	Second weeding	Harvesting	Threshing	Hauling and drying
No of times activity was undertaken							
No of observations	55	-	-	-	-	-	-
Once	4 (7.3)						
Twice	44 (80.0)						
Thrice	7 (12.7)						
Type of labor							
No of observations	55	55	54	5	55	43	50
1 = man	-	3(5.5)	54 (100)	5 (100)	55 (100)	43 (100)	50 (100)
2 = man-animal	38(69.1)	51 (92.7)	-	-	-	-	-
3 = man ï tractor	17 (30.9)	1 (1.8)	-	-	-	-	-
Number of persons that worked on the activity							
Type of labor	Man-animal	Man	Man	Man	Man	Man	Man
No of observations	36	3	54	5	55	43	50
Range	2	9	18	7	21	8	5
Mean (std error)	2.69 (0.12)	9.0 (3)	9.37 (0.55)	7.8 (1.36)	10.60 (0.63)	5.60 (0.41)	2.98 (0.20)
Std deviation	0.71	5.20	4.03	3.03	4.66	2.66	1.38
	Man - tractor	Man-animal					
	17	49					
	3	6					
	2 (0.21)	4.53 (0.15)					
	0.87	1.04					
Number of working days							
Type of labor	Man-animal	Man	Man	Man	Man	Man	Man
No of observations	36	3	54	5	55	43	50
Range	2	2	4	3	2	6	6
Mean (std error)	2.69(0.10)	2.0 (0.58)	1.70 (0.11)	1.60 (0.60)	1.33 (0.08)	1.74 (0.18)	2.66 (0.16)
Std deviation	0.62	1	0.84	1.34	0.61	1.20	1.12
	Man - tractor	Man-animal					
	17	49					
	1	4					
	1.06 (0.06)	2.22 (0.12)					
	0.24	0.82					

Table A.15: Wage rates per person

Wage rate	Number of observations	Range	Mean	Std. Error	Std. Deviation
Planting	31	230	166.13	10.961	61.029
1st weed	50	300	182.20	9.799	69.291
2nd weed	38	300	176.32	11.286	69.571
Land Prep	20	830	199.50	43.234	193.349
Harvest	47	230	170.21	7.992	54.792
Threshing	42	230	149.52	8.235	53.372
Postharvest	40	350	172.75	11.723	74.144

Table A.16: Livestock population by species in Trans Mara Sub-County

Livestock species	No of households	Statistic	Statistic	Mean	Std. Error	Std. Deviation
Cattle	199	1299	6897	34.66	7.002	98.772
Sheep	123	749	4309	35.03	7.006	77.706
Goats	104	129	1374	13.21	1.707	17.403
Donkey	130	7	258	1.98	.114	1.300
Poultry	155	58	2247	14.50	.954	11.876
Household with all category livestock species	34					

Table A.17: Household bi-annual income from sale of live animals, milk and eggs

Variable	No. of households	Range	Sum	Mean	Std. Error	Std. Deviation
Cattle sold	99	299	732	7.39	3.087	30.718
Cattle total income from sale	99	15544000	24531300	247790.91	157851.169	1570599.298
Price per cattle	99	45833	1897642	19168.10	797.329	7933.328
Sheep sold	54	249	680	12.59	5.094	37.432
Sheep total income from sale	54	998300	2885300	53431.48	22459.118	165040.140
Price per sheep	54	23767	180799	3348.13	425.561	3127.221
Goats sold	44	19	199	4.52	.649	4.305
Goats total income from sale	44	73000	704200	16004.55	2552.686	16932.602
Price per goat	44	5600	150688	3424.73	163.947	1087.500
Donkey sold	7		7	1.00		
Donkey total income from sale	7	2000	35000	5000.00	288.675	763.763
Poultry sold	74	39	465	6.28	.827	7.118
Price per unit	74	800	31149	420.93	17.535	150.844
Poultry total income from sale	74	31200	228880	3092.97	554.134	4766.841
Milk quantity sold	91	39	767	8.43	.847	8.083
Milk quantity sold in 6 months	91	7020	138060	1517.14	152.346	1453.287
Milk price per unit	91	30	2629	28.89	.573	5.464
Milk total income (daily)	91	1575	22981	252.54	29.302	279.523
Milk total income	91	283500	4136625	45457.42	5274.429	50314.844
Eggs quantity sold (weekly)	35	29	267	7.63	1.170	6.920
Eggs price per unit	35	10	331	9.46	.353	2.091
Eggs total income (weekly)	35	365	2712	77.49	13.925	82.381
Eggs total income	35	8760	65088	1859.66	334.198	1977.141

Table A.18: Livestock health care costs

Variable	No of households	Range	Sum	Mean	Std. Error	Std. Deviation
Weekly acaricide cost	53	2920	30745	580.09	95.477	695.082
Acaricide cost per animal	53	121	1607	30.32	4.480	32.614
Quarterly Anthelmintic cost	54	6900	59760	1106.67	175.701	1291.135
Anthelmintic cost per animal	54	194	2877	53.28	5.900	43.354
Amount salt	53	1370	19140	361.13	46.828	340.913
Veterinary care cost	37	5430	31085	840.14	184.491	1122.217
Cost of drugs	42	4400	32280	768.57	164.117	1063.599
Herding costs	17	15000	74000	4352.94	1217.039	5017.982
Commission on sale of animals	9	400	1400	155.56	44.444	133.333
Cess amount	17	180	1620	95.29	11.508	47.450
Repair of livestock shed	31	14750	107770	3476.45	810.050	4510.165
Compensation for crop damaged	4	6500	15500	3875.00	1419.727	2839.454

Table A.19: Household land use

Land use	No. of households	Range	Sum	Mean	Std. Error	Std. Deviation
Home compound	191	7.90	282.60	1.48	0.08	1.11
Crop land	1.81	129.75	1351.80	7.47	1.01	13.64
Graze livestock	190	499.50	3396.85	17.88	3.34	46.05
Fallow/un-cropped	14	33.00	119.75	8.55	2.80	10.49
Leased out	51	59.00	531.50	10.42	2.09	14.91
Woodlot	66	9.90	74.93	1.14	0.20	1.66
Grazing & home compound	3	10.13	16.88	5.63	3.20	5.55
Workers/church	4	10.50	23.50	5.88	2.29	4.59
Natural forest	47	439.00	1520.00	32.34	10.05	68.93

Table A.20: Estimated livestock density on per hectare grazing land

Livestock species	Population	Stocking density per hectare
Cattle	6897	3.37
Sheep	4309	2.11
Goats	1374	0.67
Donkey	258	0.13
Total	12838	6.28

Total grazing area = 2045.07 hectares, an aggregate of grazing land, fallow land and natural forest

Population includes number that was reported and those that were sold off in the past 6 months

Table A.21: Estimated livestock income on per hectare land

Livestock species	Total income	Income per hectare land
Cattle	24531300	11995.34
Sheep	2885300	1410.86
Goats	704200	344.34
Milk	4136625	2022.73
Total	32257425	15773.26

Table A.22: Cash flow for a carbon trading tree enterprise for multiple objectives of timber and carbon sequestration

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Total
Revenue												
Carbon	2,408	2,408	2,408	2,408	2,408	2,408	2,408	2,408	2,408	2,408	0	
Discounted carbon	2,189	1,990	1,809	1,645	1,495	1,359	1,236	1,123	1,021	928	0	
Timber	0	0	0	0	0	0	0	0	0	0	1,531,250	
Discounted timber	0	0	0	0	0	0	0	0	0	0	536,694	
Total revenues	2,408	2,408	2,408	2,408	2,408	2,408	2,408	2,408	2,408	2,408	1,531,250	
Total revenues (discounted)	2,189.09	1,990.08	1,809.17	1,644.70	1,495.18	1,359.25	1,235.68	1,123.35	1,021.23	928.39	536,693.8	**551,489.90**
Input costs												
Seedlings	13,750	0	0	0	0	0	0	0	0	0	0	
Land preparation	3,813	0	0	0	0	0	0	0	0	0	0	
Pitting	25,000	0	0	0	0	0	0	0	0	0	0	
Planting	6,250	0	0	0	0	0	0	0	0	0	0	
Fertilizer	6,250	0	0	0	0	0	0	0	0	0	0	
Weeding	9,100	7,920	0	0	0	0	0	0	0	0	0	
Total variable costs	64,163	7,920	0	0	0	0	0	0	0	0	0	
10% discount rate	1.10	1.21	1.33	1.46	1.61	1.77	1.95	2.14	2.36	2.59	2.85	
Discounted input costs	58,330	6,545										**64,875**
NPV	**486,614**											

Table A.23: Cash flow for a carbon trading tree enterprise for the objective of carbon sequestration

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Total
Revenue												
Carbon	2,408	2,408	2,408	2,408	2,408	2,408	2,408	2,408	2,408	2,408	0	
Discounted carbon	2,189	1,990	1,809	1,645	1,495	1,359	1,236	1,123	1,021	928	0	**14,796**
Input costs												
Seedlings	13,750	0	0	0	0	0	0	0	0	0	0	
Land preparation	3,813	0	0	0	0	0	0	0	0	0	0	
Pitting	25,000	0	0	0	0	0	0	0	0	0	0	
Planting	6,250	0	0	0	0	0	0	0	0	0	0	
Fertilizer	6,250	0	0	0	0	0	0	0	0	0	0	
Weeding	9,100	7,920	0	0	0	0	0	0	0	0	0	
Total variable costs	64,163	7,920	0	0	0	0	0	0	0	0	0	
10% discount rate	1.10	1.21	1.33	1.46	1.61	1.77	1.95	2.14	2.36	2.59	2.85	
Discounted input costs	58,330	6,545										**64,875**
NPV	**-50,079**											

Table A.24: Cash flow for a tree enterprise

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Total
Revenue												
Timber	0	0	0	0	0	0	0	0	0	0	1,531,250	
Discounted timber	0	0	0	0	0	0	0	0	0	0	536,694	**536,694**
Input costs												
Seedlings	13,750	0	0	0	0	0	0	0	0	0	0	
Land preparation	3,813	0	0	0	0	0	0	0	0	0	0	
Pitting	25,000	0	0	0	0	0	0	0	0	0	0	
Planting	6,250	0	0	0	0	0	0	0	0	0	0	
Fertilizer	6,250	0	0	0	0	0	0	0	0	0	0	
Weeding	9,100	7,920	0	0	0	0	0	0	0	0	0	
Total variable costs	64,163	7,920	0	0	0	0	0	0	0	0	0	
10% discount rate	1.10	1.21	1.33	1.46	1.61	1.77	1.95	2.14	2.36	2.59	2.85	
Discounted input costs	58,330	6,545										**64,875**
NPV	**471,819**											

Table A.25: Net returns of maize and tree enterprise for the multiple objectives of carbon sequestration and timber (at sub-County maize yields of 75 bags ha^{-1} year^{-1})

Revenues	(KShs)	Costs	(KShs)
Additional returns	551,490	Additional costs	64,875
Reduced costs	87,943	Foregone returns	130,607
Net benefits	639,433	Net costs	195,482
Net returns	**443,950**		

Table A.26: Net returns of maize and tree enterprise for the multiple objectives of carbon sequestration and timber (at sub-County maize yields of 90 bags ha-1 year-1)

Revenues	(KShs)	Costs	(KShs)
Additional returns	551,490	Additional costs	64,875
Reduced costs	87,943	Foregone returns	262,260
Net benefits	639,433	Net costs	327,135
Net returns	**312,297**		

Table A.27: Net returns of beans and tree enterprise for the multiple objectives of carbon sequestration and timber (at sub-County beans yields of 25 bags ha^{-1} year^{-1})

Revenues	(KShs)	Costs	(KShs)
Additional returns	551,490	Additional costs	64,875
Reduced costs	80,665	Foregone returns	115,150
Net benefits	632,155	Net costs	180,025
Net returns	**452,129**		

Table A.28: Net returns of maize and tree enterprise for the objectives of timber only (at sub-County maize yields of 40 bags ha^{-1} year^{-1})

Revenues	**(KShs)**	**Costs**	**(KShs)**
Additional returns	536,694	Additional costs	64,875
Reduced costs	80,665	Foregone returns	92,120
Net benefits	617,359	Net costs	156,995
Net returns	**460,363**		

APPENDIX 2: Questionnaires

Questionnaire 1: Willingness to accept carbon trading afforestation contracts

SECTION I: HOUSEHOLD CHARACTERISTICS

1. Name:
2. Division: Location: Sub-location/village:
3. Age:
4. Gender: 1 = Male 2 = Female
5. Education level *1 = Not gone to school* *2 = Attended adult education* *3 = Primary* *4 = Secondary* *5 = College* *6= University*
6. Education level of household member (living in the home) with the highest formal education **(use codes as above)**
7. Composition of the household members (household members are defined as family members living together, including those who are away at the time of survey) No of wives: é é é é é é é é . Children above 18 years:é é é é é é é é é é é . Children below 18 years:é é é é é é é é é é é .
8. Do you work off your farm (including any business venture)? 1 = Yes 2= No
IF YES, what do you do?
9. How much income to you earn monthly from off farm work?
10. Do you receive any financial support from elsewhere? 1 = Yes 2 = No
If YES, how much do you receive per month?

SECTION II: DESCRIPTION OF THE FARM ENTERPRISE

1. How large is your farm (in acres)?
2. What is your land tenure system? **Tenure System** *1= Title deed* *2= Owned but not titled* *3= Public land* *4= Rented-in/ sharecropped* *5= Other (specify)*
3. Do you **RENT OUT** your land to others? 1 = Yes 2 = No
4. **If YES**, how much of your land do you **RENT OUT** and for how long? é é é é é é é é .. acres é é é é é é é .. months
5. IF LAND IS RENTED OUT, how much are you paid per acre?
6. Do you **LEASE** land to from others? 1 = Yes 2 = No
7. IF YES, how much land do you **LEASE** and for how long? é é é é é é é é .. acres é é é é é é é .. months
8. IF LEASED, how much do you pay per acre?
9. What do you use leased land for? 1. Cropland 2. Grazing area/grass 3. Trees/woodlot Other (specify) é é é é é é é é é é é é é .
10. Are there any restrictions of how you use leased land? 1 = Yes 2 = No
IF YES, what are the restrictions?

11. How do you use your farmland?

Land usage	Size in acres
1.Home compound	
2.Crop land	
3.Graze livestock	
4.Fallow/un-cropped	
5.Rented out	
6.Others specify	
Activity 1.	
Activity 2.	
Activity3.	

12. IF FARMER GROWS CROPS, what crops have you been growing in the past three years?

1 = Maize 2 = Beans 3 = Vegetables 4 = Sweet potatoes 5 = Sorghum/finger millet

6 = Others (specify)

13. How much income did you get from crop farming during the last cropping season?

Crop	Quantity sold	Price/bag/kilogram	Total income
1 = Maize			
2 = Beans			
3 = Vegetables			
4 = Sweet potatoes			
5 = Sorghum/finger millet			
6 = Others (specify)			

14. If farmer keeps livestock, specify the types

Type	How many do you have now?	No sold in the last 6 months	Income from sale
1 = Cattle			
2 = Sheep			

3 = Goats			
4 = Donkeys			
5 = Poultry			
6 = Others (specify)			

15. How much income did you get from the sale of the following livestock products in the past 6 months?

Products	**Quantity sold per day**	**Price per unit**	**Total income per day**	**Total for 6 months**
Milk				
Eggs				
Manure				
Skin				

16. If farmer has other activities specified in **Q11 (6)** how much income did you get in the past 6 months?

Income from activity 1
Income from activity 2
Income from activity 3

17. Do you graze any of your livestock off farm?

If YES, where do you graze them?

SECTION III: PERCEPTION TO AND ADAPTATION TO ELEMENTS OF CLIMATE VARIABILITY

1. Is this area becoming more productive or less productive to farming for crop and/or livestock compared to how it was twenty years ago? 1 = More productive 2 = Less productive 3 = Has not changed
2. In your view what do you think is making farming conditions less favorable/more favorable to crop and or livestock farming? Please explain
3. IF LESS FAVOURABLE, what adjustments have you made in your farming to these long-term shifts in farming conditions? Please list them
4. Check the answers for **Q3** then ask for the ones not yet listed there
1 = change crop variety
2 = build a water-harvesting scheme
3 = buy insurance ï for crops or livestock or for both?
4 = change from crop to livestock
5 = reduce number of livestock
6 = change livestock breed
7 = find off-farm job

8 = lease land
9= others (specify)
5. What were the main constraints/difficulties in changing your farming ways?
1 = Lack of money
2 = Lack of information
3 = Shortage of labor
4 = Others (please specify)

SECTION IV: WILLINGNESS TO ACCEPT

Trees play an important role in mitigating climate by removing ñbad airò from the environment. Farmers can play an important role in mitigating climate by planting trees on their land which removes ñbad airò and brings ñmore rainò. As trees grow they remove ñbad airò from the environment. There is a possibility that farmers could receive payment for planting trees on their farm. I am interested to know whether you would be interested to participate in such a project

1. Do you have natural forest on your farm? 1 = Yes 2 = No
2. IF YES, how many acres of your land is currently under natural forest?
3. Do you harvest any products from the forest? 1 = Yes 2 = No
4. If NO, why not?
5. IF YES, what products do you harvest?
6. Would you enroll the natural forest on your farm to the carbon tree trading project? 1 = Yes 2 = No
7. If NO, why not?

8. Have you ever planted trees on your farm? 1 = Yes 2 = No
9. If NO, why not? then go to **Q17**
10. IF YES, why did you plant trees? Please start with the most important

1 = to prevent soil erosion	
2 = to provide shade	
3 = to provide fuel wood and building materials	
4 = to grow commercial timber	
5 = to diversify production	
6 = to make use of idle land	
7 = Other (please specify)	

11. Do you have a woodlot on your farm? 1 = Yes 2 = No
If NO go to Q 17
12. IF YES, when did you plant the trees?
13. How many acres of woodlot do you currently have?
14. Have you ever harvested the trees for sale? 1 = Yes 2 = No
15. IF NO, why not?
16. **IF YES**, when did you last harvest, who or where did you sell to and how much income did you get? When sold: Who/where sold to: Income:
17. Would you set aside part of your land to plant trees for the carbon tree planting project? 1 = Yes 2 = No
IF YES, go to **Q 19**
18. If NO, why not? Would you enroll your woodlot for the carbon trading tree project? 1 = Yes 2 = No

IF YES, SHOW FARMER CARDS
19. How much land (in acres) are you willing to set aside to plant trees?
20. What are you currently doing on the on land that you will plant the trees?
1 = Grow crops (farmers to specify crop/s) 2 = Graze livestock 3 = Leased to others
4 = Others (farmer to specify activity)
21. If FARMER **WILLING** TO PLANT TREES, what tree species would you prefer? (show farmers pictures of five commonly planted trees in the sub-County including an option for others where a farmers will specify any other tree species)
22. Suppose you were to enter a contract that permits someone to plant trees on some portion of your land. The agent determines the number of trees planted but you are free to choose the species as long as the trees can grow well. All direct costs of tree planting such as establishment, monitoring, management and maintenance are covered and you are provided with an annual compensation on per acre basis. The contracts differ in terms of contract length, payment offered and an option for early withdrawal. I will show you the 6 cards each consisting of two versions of the contract (provide a description of these attributes). Each card has an option of not choosing either contract. You are free to choose this option if you do not prefer any of the two (farmers were presented with pictorial cards of the six choice sets from which they will be asked to pick one option in each choice set)

Questionnaire 2: Crop and livestock enterprise questionnaire

1. Name:		
2. Division: Location: Sub-location/village:		
3. Gender: **1** = Male **2** = Female		
4. Do you grow crops on your farm? **1** = Yes **2** = No		
5. Which crops do you grow? **1** = Maize **2** = Beans **3** = Vegetables (specify) **4** = Sorghum/finger millet **5** = Bananas **6** = Others (specify)		
6. Do you intercrop maize and beans? **1** = Yes **2**= No		
7. When do you intercrop? 1 = During long rains only 2 = During short rains only 3 = during both long & short rains		
8. How many times do you plant maize in a year? **1** = Once **2** = Twice		
9. How many times do you plant beans in a year? **1** = Once **2** = Twice		
10. What variety of beans do you plant? **1** = Rose coco **2** = Wairimu **3** = Nyayo **4** = Surambaya **5** = other (specify)		
	Maize	**Beans**
11. How many acres of maize & beans did you plant during the last season and what quantities did you harvest?		
Acreage under crop in long rains		
Quantity harvested in long rains (bags/kilograms)		
Acreage under crop in short rains		
Quantity harvested in short rains (bags/kilograms)		
12. Was your maize crop affected by the maize necrosis disease during the last season? **1** = Yes **2** = No		

13. Did you sell any of the maize & beans that you produced during the last season? **1** = Yes **2** = No		
Where sold (**1** = Local market **2** = Middlemen/Local traders **3**= School **4** = NCPB **5** = Others (specify)		
Quantity sold		
Price per (bags/kilos)		
SEEDS		
14. What type of seed did you use? (Maize: 1 = Hybrid 2 = Local Beans: 1 = Certified 2 = My own)		
15. Where did you obtain the seeds? **1** = Purchased **2** = Used my own **3** = Others (specify)		
16. How much did you pay for the seeds (price per 2 kilogram)?		
17. What quantity did you plant per acre during the last cropping season?		
FERTILIZER		
18. Did you apply fertilizer to your crop? **1** = Yes **2** = No		
19. What type did you use? 1 = Inorganic 2 = Organic 3= Both organic & inorganic		
20. IF FARMER USES **INORGANIC** FERTILIZER, where did you obtain the fertilizer? 1= From local market **2** = From NCBP/KGGCU/KFA **3** = Others (specify)		
21. How much did you pay for the fertilizer (price per kilogram)? [ ]		
22. What quantity of fertilizer did you apply on your crop (quantity per acre)?		
23. How much did you spend to transport fertilizer to your farm (price per bag)?		
24. IF FARMER USES **ORGANIC** FERTILIZER, what type do you use? **1** = Animal manure **2** = Compost **3** = Others, specify		
25. Where did you obtain the **ORGANIC FERTILIZER**? **1** = Used my own **2** = Got from neighbor **3** = Others (specify)		

26. How much did you spend in cash or kind to obtain fertilizer? [ ]			
27. Did you apply any agrochemicals to your bean crop? **1** = Yes **2** = No			
	Type	Quantity /acre	Cost
28. If YES, specify type, quantity used and cost of agrochemicals based on function **1** = to control of bean fly **2** = to control of fungal diseases (Baridi) **3** = as foliar fertilizer **4** = other (specify)			

	Maize	**Beans**
29. Did you use a tractor for your maize/bean production? **1** = Yes **2** = No		
30. If yes, where did you get the tractor? **1** = Hired **2** = Used my own **3** = Others (specify)		
31. Did you pay per acre or per day? **1**= Per day **2**= Per acre		
32. How much did you pay?		
33. How many times did you use the tractor during the last cropping season?		
34. Did you use draught animals for your maize/bean production? **1** = Yes **2** = No		
35. If yes, where did you get the animals? **1** = Hired **2** = Used my own **3** = Others (specify)		
36. What were the animals used for? **1**= Land preparation **2** = Planting **3** = Both land preparation & planting		
37. How many times did you use the animals during the last cropping season? 1 = Once 2 = Twice 3 = Thrice		
38. Did you pay per acre or per day? **1**= Per day **2**= Per acre		
39. How much did you pay?		

LABOUR

Activity	Land preparation		Planting/ replanting		First weeding		Second weeding		Third weeding		Harvesting		Shelling/ Threshing		Post harvest activities (hauling& drying)	
	M	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**	**B**	**M**	**B**
1. No of times activity was carried out																
2. Type of labour (1=man, 2=man-animal, 3=man-tractor)																
3. How many persons worked on the farm for (activity)																
4. On average, how many days did they work																
5. On average, how many hours per day were normally spent for (activity)																
6. What as the prevailing wage rate per person per day for each activity performed																
7. Total amount paid to hired workers																

1. Do you keep livestock? 1 = Yes 2 = No			
If farmer keeps livestock, specify types?			
Type	**How many do you have now**	**No sold in the last 6 months**	**Income from sale**
1 = Cattle Local			
Exotic			
2 = Sheep			
3 = Goat			
4 = Donkeys			
5 = Poultry Local			
Exotic			
6 = Others (specify)			

2. How much income did you get from the sale of livestock products in the past 6 months

Products	Quantity sold per day	Price per unit	Total income per day	Total for 6 months
Milk				
Eggs				
Manure				
Skin				

3.Total income from livestock and livestock product for 6 months [ ]

Acaricides

4. Do you use acaricides on your animals?**1** = Yes **2** = No

5. How often do you spray your animals? Cattle [ ] Sheep & goats [ ]

1.Weekly

2.Fortinightly

3.Monthly

4.Quaterly 5.Yearly 6.Others specify
6. What type of acaricide do you use commonly?
7. How much did you spend (averagely) on acaricides every time you spray your animals? Cattle Sheep & goats
Dewormers
8. Do you use dewormers on your animals? **1** = Yes **2** = No
9. How often do you deworm your animals? Cattle [ ] Sheep & goats [ ] 1.Monthly 2.Quaterly 3.Yearly 4.Others specify-
10. What dewormers do you use commonly?
11. How much do you spend (averagely) on dewormers every time you deworm your animals? Cattle [ ] Sheep & goats [ ]
Animal feeds
12. Do you buy any feeds for your animals? 1 = Yes 2 = No
How often do you buy feeds for your animals? 1.Weekly 2.Monthly 3.Quaterly 4.Yearly 5.Others specify-
13. How much do you spend (averagely) on animals every time you buy animal feeds?
14. Do you buy salt for your animals? **1** = Yes **2** = No
15. How often do you give salt to your animals? 1.Weekly 2.Monthly 3.Quaterly

4.Yearly 5.Others specify-	
16. How much do you spend on salt every time you buy? [ ]	
Veterinary fees	
17. Have you used veterinary services (treatment & vaccinations) for the past 6 months? 1 = Yes 2 = No	
18. How much did you pay for the service? [ ]	
19. Have you bought any drugs for your animals in the past 6 months? **1** = Yes **2** = No	
20. How much did you spend on the drugs? [ ]	
21. Who herds your animals? 1= Self 2 = Family member 3 = Hired hand 4 = others (specify)	
22. If farmer hires labor, how much do you pay the hired worker per month? For cattle [ ] for sheep & goats [ ]	
23. **IF FARMER HAS SOLD ANIMALS IN PAST 6 MONTHS**, how much did you spend on the following items:	
24. Transport of animals to market: Drover	
Truck	
25. Commission on sale of animals	
26. County council cess	
27. Feed and water at the market	
28. Night guard [IF NECESSARY] at the market	
29. Construction and major repairs of livestock boma	
30. Have you paid for any damages caused by animals (crop raiding) in the past 6 month? 1 = Yes 2 = No	
32. How much did you pay	

THANK YOU FOR YOUR TIME

APPENDIX 3: List of plates

Block 1

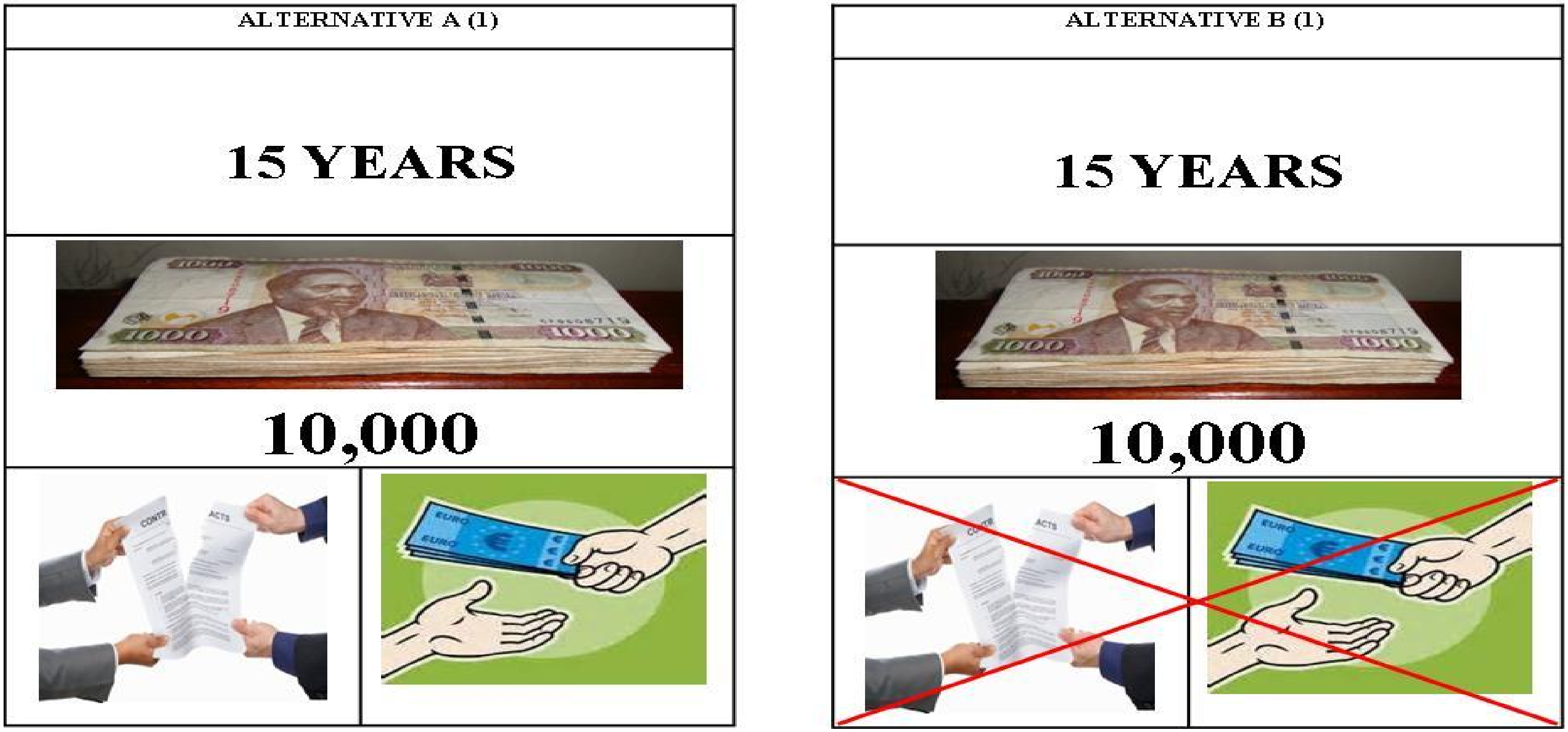

Plate 1. An example of a choice experiment card

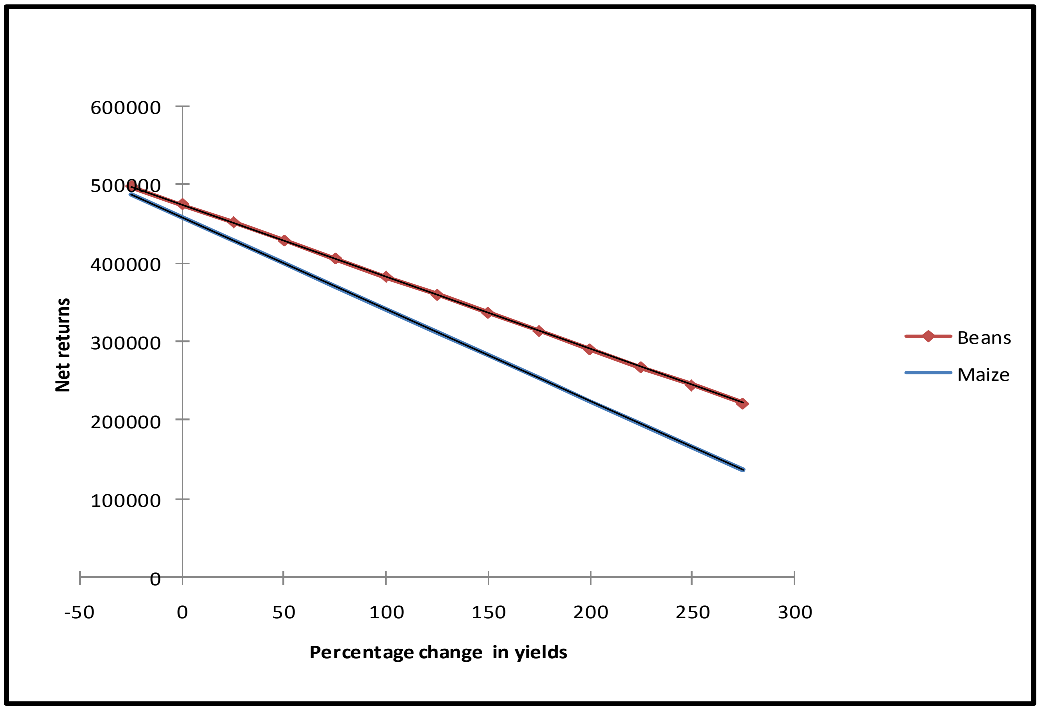

Plate 2. Sensitivity analysis of net returns to maize and bean yields

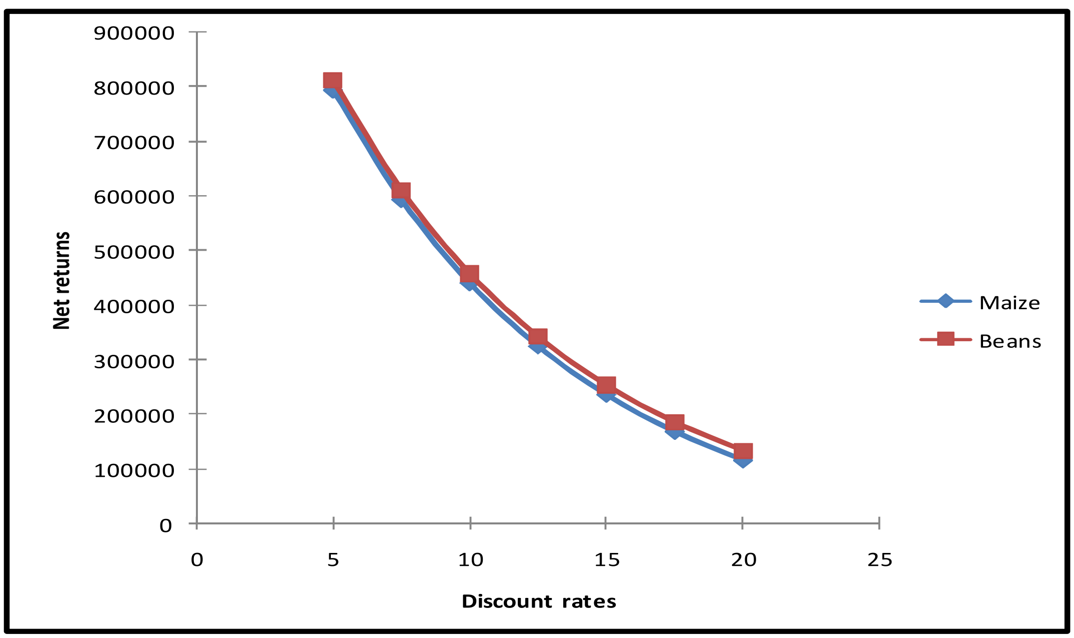

Plate 3: Sensitivity analysis of the net returns to discount rates

Box 1: A cheap talk script

Even though the set of conditions described to you are not real and do not commit you to any actions, itôs really important that you answer as if this was a real choice with real consequences. Sometimes people say one thing in a survey but when they face the same situation for real, they do something else. Please think really carefully about whether you really would do what you say.

List 1: Check list of issues for focused group discussions in Trans Mara sub-County

1. State and trends of environmental change
2. Main drivers of environmental change in Trans Mara sub-County in the past 20 years
3. Land and land-use changes
4. Climate variability and change
5. State and trends in agricultural production and productivity
6. Developmental challenges in the sub-county
7. Ways to tackle environmental and development challenges
8. Forestry and tree planting activities