Institut für Lebensmittel -und Ressourcenökonomik

Institutional Analysis of Agri-Environmental Externalities

Issues on Collective Action and Technology Diffusion in the Lake Naivasha Basin, Kenya

Inaugural Dissertation

zur

Erlangung des Grades

Doktor der Agrarwissenschaften

(Dr.agr.)

der

Hohen Landwirtschaftlichen Fakultat

der

Rheinische Friedrich-Wilhelms-Universitat

zu Bonn

vorgelegt am

08.07.2013

von

Daniel Kyalo Willy

aus Kenia

Main Supervisor	:	Prof. Dr. Karin Holm-Müller
Second Supervisor	:	Prof. Dr. Thomas Heckelei
Promotionsdatum	:	27. 08. 2013
Erscheinungsjahr	:	2013

Abstract

Institutional Analysis of Agri-Environmental Externalities: Issues on Collective Action and Technology Diffusion in the Lake Naivasha Basin, Kenya

Lake Naivasha is the second largest fresh water lake in Kenya and the only fresh water Lake located in Kenya's Rift Valley. Its basin supports important economic activities such as floriculture, horticulture, food crop production, tourism, fisheries, pastoralism and geothermal electricity generation. Agriculture is the most dominant type of land use in the basin and has substantial direct effects on the Lake Naivasha ecosystem. These effects are manifested through the dependence of the sector on the ecosystem for provisioning, supporting and regulating ecosystem services. As a result of these agri-environmental interactions, the basin has been grappling with three main environmental challenges: siltation, eutrophication and water scarcity. Through these challenges resource users impose unilateral negative externalities on third parties causing a policy challenge.

The goal of this thesis is to identify the institutional challenges encountered while seeking solutions to these environmental problems. It also seeks to analyze the diffusion process of technologies that help to mitigate negative agri-environmental externalities. The thesis is composed of four empirical studies, each addressing a specific objective. All the studies utilized cross-sectional household survey data collected from 308 randomly selected farm households from the Lake Naivasha basin, Kenya. The first empirical chapter identifies co-operators and defectors among the sampled households using two step cluster analysis. Motivated by the theory of collective action, a logistic regression model was used to identify the factors influencing the cooperative behaviour of households. In the next chapter, propensity score matching and exogenous switching regression models were used to assess the effect of implementing multiple soil conservation practices on the value of crop production. The third empirical chapter used a two step regression procedure to assess the influence of participation in collective action and neighbourhood social influence on farm level soil conservation efforts. Finally, a parametric econometric log-logistic duration model was used to analyze the diffusion of rain water harvesting techniques among the sampled households.

The results from the above analyses indicate that the sampled households are predominantly defectors. The tendency to cooperate is influenced by expected benefits, labour endowments, human capital, social sanctions and norms of trust. With regard to private economic benefits of soil conservation practices, the results indicate that multiple soil conservation practices generate higher value of crop production. However, the results indicate that under certain circumstances, these additional positive benefits might not be substantial enough to cover the opportunity costs associated with these practices. Therefore, it was thought important to assess whether there are other factors besides private economic benefits that could motivate farmers to adopt soil conservation practices. It emerged from the results of the third empirical study that participation in collective action is a significant determinant of the soil conservation effort among the sampled households. Secondly, results indicate that social control that emerges from neighbourhood social influence and subjective norms are also key determinants of soil conservation efforts. Therefore, social control can substitute for pure economic incentives as a motivation for engaging in soil conservation. The results from the final empirical study indicate that rainfall variability, access to information and socio-demographic attributes such as age and education level are the key drivers of the process of diffusion of rain water harvesting techniques. It emerged that technology adoption has become more of an endogenous process of social exchange within communities and less driven by external natural predicament and persuasion by external agents. Informal sources of information have emerged as an important medium of technology dissemination.

For each of these results we draw imperative policy implications pointing out areas where policy could focus on so as to enhance mitigation of agri-environmental externalities.

Zusammenfassung

Institutionelle Analyse der Agrar-Umwelt Externalitäten: Aspekte zum kollektiven Handeln und Technologieverbreitung im Becken des Naivasha Sees in Kenia

Der Naivasha See ist der zweitgrößte Süßwassersee in Kenia und der einzige Süßwassersee in Kenias „Rift Valley“. Das Wasser des Sees stellt eine wichtige Grundlage für eine Vielzahl von wirtschaftlichen Aktivitäten rund um den See dar, darunter Blumenzucht, Gemüse und Obstanbau für den Export, Landwirtschaft, Tourismus, Fischerei, Weidewirtschaft und geothermischen Stromerzeugung. Die Landwirtschaft stellt der dominierenden Landnutzungstyp dar und wirkt sich so wesentlich auf das Ökosystem rund um den See aus. Diese Auswirkungen sind bedingt durch die Abhängigkeit der Landwirtschaft von unterstützenden, regulierenden und bereitstellenden Ökosystemdienstleistungen des Sees. Resultierend aus der Wechselwirkung zwischen Umwelt und Agrarwirtschaft im Seebecken ergeben sich drei wesentliche Probleme: Verschlammung, Eutrophierung und Wasserknappheit. Durch diese bürden die Ressourcennutzer Dritten unilateral negative Externalitäten auf, welches eine Herausforderung für die Politik bedeutet. Die durch die wirtschaftliche Nutzung des Sees einseitig verursachten negativen Auswirkungen auf Dritte ziehen agrarpolitische Herausforderungen nach sich.

Ziel dieser Arbeit ist es, die institutionellen Herausforderungen zu identifizieren und Lösungen für die bestehenden ökologischen Probleme zu suchen. Ferner wird der Diffusionsprozessvon Technologien analysiert, welche helfen, die negativen agrarökologischen Auswirkungen zu vermindern. Die Arbeit setzt sich aus vier empirischen Untersuchungen mit jeweils spezifischen Zielsetzungen zusammen. Für alle Untersuchungen wurden Querschnittsdaten auf Haushaltsebene verwendet, die von 308 zufällig ausgewählten landwirtschaftlichen Haushalten im Becken des Naivasha Sees stammen. Mit Hilfe einer zweistufigen Cluster-Analyse wurden im ersten empirischen Kapitel kooperierende und nicht-kooperierende Haushalte in der Stichprobe ermittelt. Angeregt durch die Theorie des kollektiven Handelns wurde ein logistisches Regressionsmodel genutzt, um die Einflussfaktoren für das Kooperationsverhalten in Haushalten festzustellen. Im nächsten Kapitel wurden zur Beurteilung der Auswirkungen verschiedener Bodenschutzmethoden auf den Produktionswert der pflanzlichen Erzeugung das *Propensity Score Matching* und *Exogenous Switching Regression Modelle* verwendet. Für das dritte empirische Kapitel wurde mit einem zweistufigen Regressionsmodell der Einfluss der Beteiligung an gemeinschaftlichen Maßnahmen sowie der soziale Einfluss der Nachbarschaft auf Bodenerhaltungsanstrengungen auf Betriebsebene geschätzt. Abschließend wurde ein parametrisches ökonometrisches log-logistisches Durationsmodell genutzt, um die Verbreitung von Regenwasserspeicherungstechniken in den befragten Haushalten zu untersuchen.

Die Ergebnisse der oben genannten Analysen zeigten, dass sich die befragten Haushalte in erster Linie nicht-kooperativ verhalten. Es wurde festgestellt, dass die Tendenz zu kooperieren von den zu erwartenden Vorteilen, Arbeitsverfügbarkeit, Humankapital, gesellschaftlichen Sanktionen sowie Normen des Vertrauens beeinflusst wird. Im Hinblick auf den privaten wirtschaftlichen Nutzen der Bodenschutzmethoden deuten die Ergebnisse darauf hin, dass integrierte Bodenschutzmethoden einen höheren Produktionswert des Pflanzenanbaus erzeugen. Allerdings zeigen die Ergebnisse auch, dass dieser zusätzliche positive Nutzen unter gewissen Umständen möglicherweise zu gering ist, um die entstehenden Opportunitätskosten zu decken. Deshalb wurde es als wichtig erachtet, neben dem privaten wirtschaftlichen Nutzen mögliche andere Faktoren zu identifizieren, die die Landwirte dazu motivieren könnten, die Bodenschutzmethoden anzuwenden. Die Ergebnisse der dritten empirischen Studie machten deutlich, dass bei den befragten Haushalten die Teilnahme an kollektiven Maßnahmen ein entscheidender Faktor für die Bodenschutzbemühungen ist. Zweitens zeigen die Ergebnisse, dass soziale Kontrolle, die durch den sozialen Einfluss der Nachbarschaft entsteht, und subjektive Normen ebenfalls Schlüsseldeterminanten für Maßnahmen zur Bodenerhaltung sind. Also können soziale Kontrolle und soziale Normen rein ökonomische Anreize zur Implementierung von Bodenschutzmechanismen ersetzen. Die Ergebnisse der letzten empirischen Studie zeigen, dass Niederschlagsschwankungen, der Zugang zu Informationen und soziodemographische Merkmale wie Alter und Bildungsniveau die treibenden Kräfte im Diffusionsprozess der Regenwasserspeicherungstechnologien sind. Es wurde deutlich, dass die Adaption von Technologien mehr ein endogener Prozess eines sozialen Austauschs innerhalb von Gemeinschaften ist und weniger von externen Natureinflüssen oder der Beeinflussung durch externe Vermittler getrieben ist. Informelle Informationsquellen haben sich als ein wichtiges Medium zur Technologieverbreitung herausgestellt.

Für jedes dieser Ergebnisse wurden wichtige Politikimplikationen aufgezeigt, die Politikfelder herausstellen, auf die sich die Politik fokussieren könnte, um die Vermeidung von Agrar-Umwelt Externalitäten der agrarischen Produktion zu fördern.

Table of Contents

List of Tables

List of Figures

List of Acronyms and Abbreviations

ATT	Average Treatment Effect on the Treated
CA	Collective Action
CAC	Command and Control
CAP	Common Agricultural Policy
CBA	Cost Benefit Analysis
CDD	Cumulative Dry Days
CFA	Community Forest Association
CMS	Catchment Management Strategy
CV	Coefficient of Variation
DFG	Deutsche Forschungsgemeinschaft
DTVs	Drought Tolerant Varieties
EIA	Environmental Impact Assessment
EMCA	Environmental Management and Co-ordination Act
EU	European Union
GDP	Gross Domestic Product
GoK	Government of Kenya
IoS	Institutions of Sustainability
IRR	Internal Rate of Return
ITCz	Inter-Tropical Convergence Zone
IWD	Inverse Weighted Distance
KFS	Kenya Forest Service
LNBIMP	Lake Naivasha Basin Integrated Management Plan
LNGG	Lake Naivasha Growers' Group
LNMP	Lake Naivasha Management Plan
MBIs	Market Based Instruments
MSCPs	Multiple Soil Conservation Practices
NEC	National Environmental Committee
NEMA	National Environmental Management Authority
NET	National Environmental Tribunal
NGOs	Non Governmental Organizations
NIE	New Institutional Economics
NMBIs	Non-Market Based Instruments

NPV	Net Present Value
PCA	Principal Components Analysis
PSM	Propensity Score Matching
RAI	Rainfall Anomaly Index
RCR	Resilience Collapse and Reorganization
RWH	Rain Water Harvesting
RWHTs	Rain Water Harvesting Techniques
SCPs	Soil Conservation Practices
SES	Socio-Ecological System
SSA	Sub-Saharan Africa
TRA	Theory of Reasoned Action
WAP	Water Allocation Plan
WRMA	Water Resources Management Authority
WRUAs	Water Resource Users Associations
WWF	World Wide Fund for Nature

Acknowledgements

In the summer of 2007, I came across a disturbing statement while undertaking specialized training at the University of Pretoria, South Africa. The statement, from the then unpublished New Institutional Economics (NIE) text by Dorward et al. (2009:pp 3) read:

> *''Millions of Africans are born, live, and die poor, hungry, and malnourished. Most of these unfortunate people live in rural areas and directly or indirectly depend for a large part of their livelihoods on agriculture.*''

The fact that the statement disturbed me doesn't mean that this was the first time I was made aware of this unfortunate reality. Having been born and brought up in a rural farm household, manual tilling of land was our daily work, and crop failure and famine was not unusual. Therefore, this unfortunate phenomenon was a familiar reality to me. However, this statement was a strong awakening call for me to be involved in finding a solution to the poverty problem in Africa. I was aware that finding solutions to the poverty problem in Africa was an enormous task that needed huge efforts. However, like the Humming bird featured in the story that was narrated by the late Nobel laureate Prof. Wangari Mathai, I made a decision: *to do the best I can*. Given that I was also aware that environmental degradation is both a cause and a consequence of poverty, I chose to be involved in addressing the problem from the environment point of view.

The journey towards fulfilling this mission started on the morning of 20th June, 2010, when I boarded a plane to Germany, leaving behind everything and everyone who was important to me at that time. Departing was not easy, and many small voices kept on convincing me to recede on my decision. However deep inside me was a strong drive that kept on encouraging me to move on, and on and on....That drive was inspired by the dream I had, a dream of bringing hope to someone in a situation just described above. It is at the Institute for Food and Resource Economics at the University of Bonn, Germany, where I have been working towards achieving my dream. Three years of research and several field trips to Kenya have culminated into this thesis.

However, I acknowledge that this achievement has not been as a result of my individual efforts. Many people have contributed to this dream directly and indirectly and to these I will forever be grateful.

My first gratitude goes to the almighty God, my creator the only '*Ngai Mumbi, Ngai Mwatuangi'*. His grace and blessings have been very sufficient in all my situations, both easy and difficult.

To my main supervisor, Prof. Dr. Karin Holm-Müller, thank you for bringing me on-board your team, where I was gladly welcomed into a wonderful team of hardworking ladies and gentlemen of integrity. Thank you for believing in my potential and granting me an opportunity to grow in my career under your direction. Your invaluable support, intellectual mentorship and guidance during my entire PhD study period are highly appreciated. Thank you also for facilitating the relocation of my family to Germany.

To my second supervisor, Prof. Dr. Thomas Heckelei, thank you for your guidance whenever I consulted you especially when I was writing my articles. Thank you also for accepting to be my second supervisor.

To Dr. Armin Kuhn, words cannot express my gratitude for your support, both within and without the office building and hours. Literally, you made my life here in Germany very easy from the very beginning. After landing in a foreign land, away from my folks and my comfort zone, I had many fears. However, you helped me melt away these fears one by one right from the airport until this very day. Thank you particularly for taking time to read all my drafts that have culminated into this Thesis.

I would like to appreciate the support from my current and former colleagues at the Institute for Food and Resource Economics. Adrian Boos, Bernd Lengers, Sarah Winands, Hugo Storm, Johanna Bunde, Sebastian Rasch, Till Kuhn and all the others, your company and ideas are highly appreciated. Mrs. Alheide von Wehrs, thank you for being available every time I needed your assistance.

To my dear wife Teresiah, and lovely daughter Patience, thank you very much for your support, without which life would have been unbearable during the Thesis write-up process. The smiles you gave me every evening after a hard day at the office was an icon of hope. Thank you for your patience and sacrifice when I had to spend most of my time in the office even during weekends and holidays when I was supposed to be with you.

To all my friends around Bonn and especially the East African community in Bonn, friends at the American Protestant Church and at the Centre for Development Research (ZEF), your moral support and encouragement is highly appreciated, may God bless you.

I would like to appreciate the support from my family in Kenya, My mum, Dad, brother, Sisters, Cousins and Uncles. Your words of encouragement have always given me hope, and your confidence in me has really shaped my future. To my beloved grandmothers, *Susu* Grace Mumbua Nzevela and *Susu* Esther Sukali Ng'ui, your persistent prayers for me have gone a long way to keep me strong and encouraged.

To my field research assistants, Deborah Wambua, Grace Kimenju, Daniel Mbogo and Kelvin Omondi, thank you very much for helping me collect quality data. Your patience and persistence even when sometimes field conditions were working against us was a show of your determination to ensure that my work was a success. My student assistants here in Bonn, Eric Velazquez, Eliza Zhunusova and Vicky Abresch, thank you for your good work.

Thank you Pieter van Oel and your colleagues at ITC-University of Twente. The long discussions we had were always helpful to me. Thank you for your technical support on GIS issues whenever I needed your help.

To the farmers we interviewed, my research work would not have been a success without your cooperation. May God reward your efforts as you continue to genuinely toil your land everyday in support of your livelihoods. The invaluable assistance I received from Mr. Dominic Wambua of WRMA-Naivasha and all WRUA chairmen is highly appreciated.

Finally, I would like to appreciate the Theodore Brinkman Graduate School (TBGS) of the Faculty of Agriculture at the University of Bonn for the scholarship awarded to me to pursue my Doctoral studies. The research funding from the Germany Research Foundation (DFG) that facilitated my field work through the Resilience, Collapse and Reorganisation in of Socio-ecological Systems in African Savannas (RCR) project is highly appreciated.

Thank you and God bless you all.

Daniel Kyalo Willy,
Bonn, 4th July, 2013.

CHAPTER ONE

1 Introduction

1.1 Background

1.1.1 The Agriculture-Environment Nexus

Ecosystems have historically played an important role in supporting terrestrial and aquatic life. Unfortunately, as indicated by the United Nations Environmental Programme (UNEP) in the Millennium Assessment Report, over 60 % of global ecosystem services are being exploited at higher rates than they accrete/regenerate naturally (Millennium Ecosystem Assessment, 2005). The latest Living Planet Report by the World Wide Fund for Nature (WWF) indicates that by 2008, the global ecological foot print had exceeded the earth's biocapacity by 50% (WWF, 2012). The living planet report documents the changes in ecosystems, biodiversity and human demand on natural resources. The figures provided in this report indicate a worrying trend. This is particularly so since most of the negative effects on ecosystems are attributable to human activity. In day to day human activities, there are multiple, nested and coupled interactions between the social, physical and ecological systems, with varied outcomes. To understand these outcomes, it is important to analyze the entire Socio-Ecological System (SES). Anderies et al. (2004) defines a SES as ''....the subset of social systems in which some of the interdependent relationships among humans are mediated through interactions with biophysical and non-human biological units''. From this perspective, a SES can be viewed as a system of interdependent interactions between the units of a social system with those of an ecosystem. These interactions mostly involve complex coupled processes and non linear dynamics involving both physical and social systems (Berkes et al. 2003). Most of the dynamics in ecosystems are usually related to changes in climate factors such as temperature and precipitation causing inevitable transformations in species through ecological succession. However, although ecosystems inevitably undergo changes, human activities have a tendency of altering the natural ecosystem dynamics. Anthropogenic influences on the bio-physical system have particularly led to a multiple environmental challenges such as desertification, biodiversity loss and impacts associated with climate change.

Agriculture is the most dominant type of land use globally and one of the sectors with substantial direct effects on ecosystems (Power 2010). The sector particularly bears a great responsibility of the observed increase in global ecological footprints. The pressure from agriculture to the environment might even increase as the world continues to grapple with the twin challenges of feeding 9 billion people by 2050 in the face of climate change and cyclical financial crises.

Agriculture is highly dependent on ecosystems for provisioning, supporting and regulating ecosystem services. Agricultural production draws most of the major inputs (e.g. water, land) and natural services (e.g. pollination, biological pest control and nutrient cycling) from nature (Power 2010). Other important nature services to agriculture include genetic biodiversity, carbon sequestration and hydrology cycles. Because of this dependence, agriculture is usually associated with processes that impact on the environment negatively such as deforestation, land degradation, greenhouse gas emission, soil erosion and biodiversity loss. Agriculture also contributes to environmental pollution through the use of inputs such as inorganic fertilizers, manure, pesticides and plastics, some of which are non-biodegradable and toxic. Also, soil erosion which is associated with tillage of farm land causes siltation on water bodies while seepage of fertilizer based leachates-mostly Nitrogen and Phosphorous- into water causes eutrophication on surface water and Nitrate pollution on ground water. Irrigation return flows also cause similar effects. However, besides the negative impacts, agriculture can also create positive externalities in the form of ecosystem services such as clean water, landscapes and clean air that emerge from environmentally friendly farming systems such as agro-forestry, crop rotation and other soil conservation practices.

Tisdell (2009) classifies externalities associated with agriculture into three categories: spillovers from non-agricultural sectors into agriculture, spillovers from agriculture to non-agricultural sectors and spillovers within agriculture. The first category is largely exogenous to agricultural decision making and its mitigation can only happen by decisions made outside the sector. These external effects could however influence the stream of costs and benefits within agriculture. The last two categories emanate from agricultural production and marketing decisions. As Tisdell (2009) points out however, not all externalities are Pareto relevant since some externalities do not affect the market equilibrium. Agricultural externalities that are Pareto relevant include ground and surface water depletion, biodiversity loss, nutrient run-off, sedimentation of water ways, pesticide poisoning and greenhouse gas emission. These externalities combined with other factors such as private discount rates could explain agricultural sustainability challenges and therefore are of policy relevance. Policies focusing on designing agricultural strategies for achieving sustainability in the face of growing population and climate change are likely to dominate agri-environmental and development policy agenda in the coming years. In view of the fact that agriculture has many negative impacts on the environment more proactive policies are needed. This thesis seeks to contribute to this debate by providing information on institutional economic aspects of agri-environmental externality mitigation from a low income country perspective. In the next section we assess some of the potential institutional and policy instruments that could be used in addressing agri-environmental externalities to harmonize the interactions between social and ecological systems.

1.1.2 Institutional and Policy Responses to Agri-environmental Externalities

As explained above, agricultural activities impose costs and generate benefits to third parties who don't pay for them (in the case of benefits) or are not compensated (in the case of negative effects). Therefore, this creates a need for policy interventions to help internalize such externalities and yield near social optimality solutions. Addressing externalities generally has been a policy concern in many societies Bruce (2000) uses the examples of the *Refuse Act* of 1899 and the *Air Pollution Control Act* of 1955 to show that the United States of America has had a long history of using regulations to control water and air pollution through regulation.

According to Bruce (2000) the policies that can be used to control externalities can be categorized into either correcting policies or internalization policies. Correcting policies create penalties and rewards such as taxes, fines and subsidies to adjust externality creating activities. Internalization policies on the other hand adjust externality creating activities by changing the institutional arrangements which had created the externalities in the first place. This is usually achieved by making the external costs or benefits internal to those who create them. Creation of property rights and markets for pollution are examples of internalizing policy instruments. Another categorization of policy instruments relevant to natural resources management in agriculture is offered by Orr & Colby (2004). These authors distinguish three principal categories of policy instruments namely, command-and-control (CAC) instruments, incentive-based economic instruments, and cooperative/suasive strategies. These instruments can be delivered through three matching principal institutional arrangements namely: government agencies, markets, and user organizations respectively (Meinzen-Dick 2007).

Command and control instruments on agri-environmental externalities are instruments where an authoritarian government gives directives to regulate economic activities that cause externalities. The government may prohibit an activity that causes negative externalities or make an activity that creates a positive externality mandatory. For example in the European situation, the Common Agricultural Policy (CAP) implemented after the Second World War encouraged agricultural intensification leading to many cases of agri-environmental degradation. To respond to these challenges, the European Union (EU) embarked on agri-environmental policies to regulate nitrate pollution, pesticide pollution and application of animal manure on land through regulatory instruments such as the *EC Drinking Water Directive* of 1980 (ECC 80/778), the *Nitrate Directive* (EEC 91/676) of 1991 and the 1992 *Agri-environmental regulation* (ECC 2078/92) (Latacz-Lohmann & Hodge 2003). Command and control instruments require that the government invests in monitoring and enforcement mechanisms to enhance monitoring and enforcement and ensure compliance. The success of such instruments will therefore depend on the legal and financial muscle of the governments which facilitates implementation, monitoring and enforcement. In both low and high income countries, implementation process of CAC instruments is usually hampered by high transaction costs since it is costly to detect infractions and impose penalties. One of the main sources of such failure is the presence of several monitoring points which make it difficult to identify and quantify the contribution of individual polluters. This is usually the case with non-point agri-environmental pollution (Dinar et al. 1997). CAC instruments fail because they are susceptible to elite capture, rent seeking/corruption, government discretion and low accountability (Acheson 2006).

Market based instruments can be defined as those instruments that regulate behaviour through market signals as opposed to government directives on pollution levels and control methods (Stavins 2000). Instruments such as pollution charges (taxes) and tradable permits which are mostly used in cap-and-trade programmes and credit programmes belong to this category. Market based instruments usually allow flexibility and can be achieved at relatively low social costs since they encourage firms/farms to adopt low cost and more effective pollution control techniques (Stavins 2000). Environmental taxes help to internalize externalities originating from economic activities following the mechanisms identified by Pigou (1920). Some examples of market instruments that can be used to deal with agri-environmental externalities can be found in Lankoski & Ollikainen (2003). The author explores the effect of a fertilizer tax to mitigate nutrient run-off and a subsidy to encourage implementation of conservation riparian buffer strips. However, market based instruments can offer solutions in cases where the cause of the problem is incomplete markets rather than complete market failure (Merlo & Briales 2000). Market instruments will fail to work where there are no well defined property rights, information asymmetries exist and transaction costs are high.

Cooperative/suasive solutions such as voluntary bargaining, education programmes and cooperative agreements among resource user groups often emerge out of informal arrangements among actors in a collective action dilemma. The dilemma makes it necessary for actors to cooperate in establishing mechanisms to deal with a common problem (or share a common resource), drafting of rules to govern their relationships and establishing sanctions to deal with non compliance (Ostrom 1990). Conflicts arising from violations of the established and collectively agreed rules are frequently settled through compromise, social coercion and social exclusion other than through penal punishment. In a cooperative situation, sometimes hybrid forms of coordination such as contracts are used to encourage provision of ecosystem services (North 1990). A high level of trust between participants helps to minimize transaction costs in cooperation situations. However, there are a number of issues that planners must deal with to ensure success of cooperation especially where large spatial areas are involved. Setting up such cooperation would involve substantial transaction costs whereas the benefits from such coordination will be shared among all the actors, regardless of their individual contribution. This creates an incentive for free riding. As observed by Ostrom (1990) the process of providing new institutions "is an equivalent of providing another public good" therefore creating a second-order collective dilemma. This can only be overcome by establishing trust and a sense of community. However, after institutions have been established, appropriators still have to deal with the challenge of creating incentives for actors to commit to the rules and mechanisms for monitoring the adherence to rules. Cooperation solves the monitoring and enforcement challenges since low cost mechanisms such as peer monitoring and social coercion can be used to encourage compliance. Agri-environmental cooperatives belong to this category of instruments. However, examples of successful agri-environmental cooperation in both low and high income countries are not very common in literature. While many studies exist on the use of collective action in management of natural resources, evidence of collective action to address agri-environmental externalities is scanty. Some examples of successful cooperation for environmental management are presented by Ayer (1997) who presents successful cases of grass root collective action initiatives that were initiated to deal with externalities caused by pesticide application and washing of manure, inorganic fertilizers and eroded soils into water courses in the USA. Other successful examples of cooperative arrangements to deal with agri-environmental externalities especially those affecting drinking water quality can be found in Germany, Austria, the United Kingdom and the Netherlands (Brouwer et al. 2002). For example in the Germany case, voluntary agreements between farmers and water companies have resulted to substantial reduction in water pollution by nitrates and pesticides (Brouwer et al. 2002). However, literature on agri-environmental cooperation beyond experimental field laboratories in low income countries is scanty.

The choice of the appropriate instruments to use among the three types of instruments that can be used to address externalities will depend on specific factors related to the type of externality and the nature of actors involved. Command and control instruments have so far been the most widely used instruments to address agricultural pollution. However, the experience with the EU Nitrates directive indicates that achieving water quality targets through CAC instruments is a taxing task (Brouwer et al. 2002). Some researchers, for example Meinzen-Dick (2007) recommend a modest complementary combination of the three instruments. Voluntary cooperative agreements around agri-environmental pollution are currently gaining popularity as a complementary instrument to CAC in dealing with agricultural pollution (Amblard 2012; Brouwer et al. 2002; Polman & Slagen 2002; Slagen & Polman 2002). The literature on agri-environmental cooperation in low income is at emergent stages. This thesis aims at contributing to literature on this area by analyzing agri-environmental interactions in a low income country situation. The study is set in the Lake Naivasha basin, situated in Rural Kenya within Kenya's Rift Valley. In the next section we describe the Lake Naivasha basin and identify agri-environmental externalities experienced in the basin and basin attributes which could be relevant for institutional development to deal with these agri-environmental externalities.

1.2 Description of the Study Area

1.2.1 Location, Physical Features and Climate

Lake Naivasha is the second largest fresh water lake in Kenya and the only fresh water Lake located in Kenya's Rift Valley. Located at $0^o30'$ S - $0^o55'$ S & $36^o09'$ E - $36^o24'$ E, the Lake Naivasha basin is approximately 3400 Km^2 bordered by Mau escarpment (3100 m.a.s.l) to the South -West and the Aberdare ranges (3,990 m.a.s.l) to the North-East (Figure 1.1).

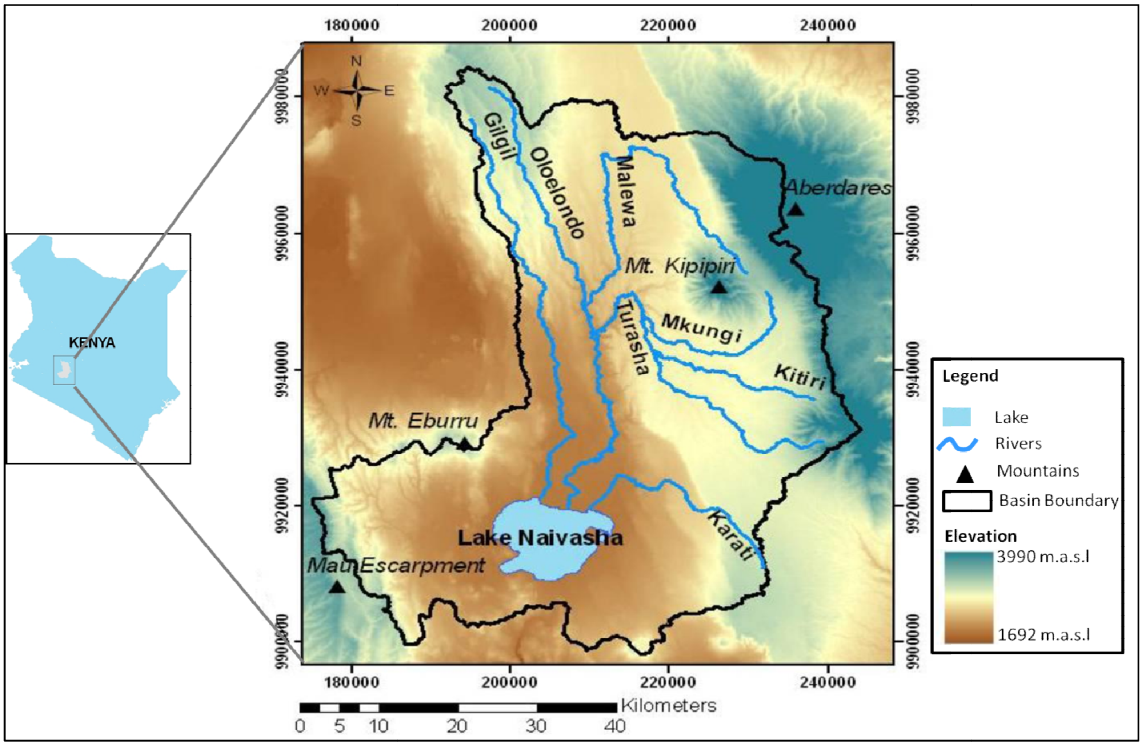


Figure 1.1: Physical features and rivers in Lake Naivasha basin
Source: Adapted from Meins (2013)

Lake Naivasha is an endorheic fresh water Lake Ecosystem, with a main Lake, a semi-separated sodic extension (*Oloiden Lake*) and a separate sodic Crater Lake (*Sonachi*). The inflow of the Lake is contributed by two rivers: Malewa and Gilgil which contribute 80% and 20% of the inflows respectively. The rivers enter the Lake through a riverine floodplain which was initially dominated by papyrus but has undergone substantial degradation in the recent past (Mavuti & Harper 2006; Onywere et al. 2012).

Lake Naivasha basin receives a bimodal rainfall pattern linked to seasonal migration of the Inter-Tropical Convergence Zone (ITCZ) (Stoof-Leichsenring et al. 2011). The long rain season is experienced in March/April while the short rains start in October/November (Figure 1.2).

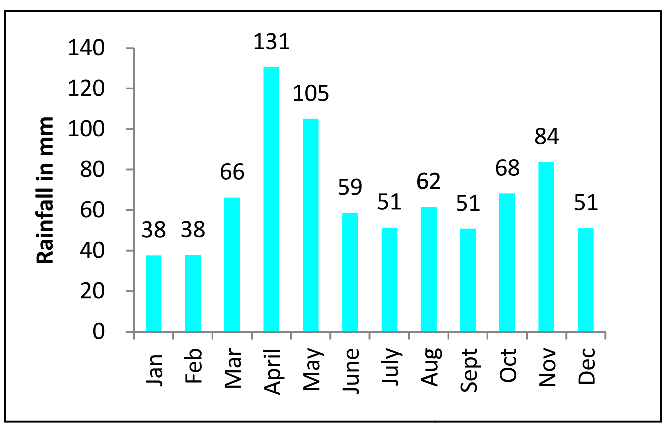


Figure 1.2: Rainfall profile of Lake Naivasha

The wettest month of the year is April while January and February are the driest months. The average annual rainfall around the Lake is approximately 670 mm while in the higher altitude parts of the catchment rainfall averages at 2400 mm (Meins 2013; Stoof-Leichsenring et al. 2011). This huge difference in rainfall can be attributed to the wide altitude variations within the basin which ranges from 1890 meters above sea level (m.a.s.l) around the Lake area to 3,990 m.a.s.l in the Aberdare ranges. Rainfall variability has also been a historical phenomenon in the Lake Naivasha basin as indicated by Verschuren et al., (2000) who also notes that the historical drought and rainfall events had an important influence on cultural, political and agricultural development.

1.2.2 Ecological Description

Lake Naivasha was declared a Ramsar site, designating it as a wetland of international importance in 2005 (RAMSAR convention 2011). This important Lake ecosystem supports many terrestrial, riparian and littoral plants mainly Papyrus (*Cyperus papyrus)* and Potamogeton (*Potamogeton coloratus*). The lake also provides foraging and breeding ground for many resident and migrant bird species. The main Lake is a freshwater wetland with fringing shoreline vegetation dominated by swamp species, *Cyperus papyrus* (Harper & Mavuti 2004) and many other floating wetland plants and submerged species. The river delta vegetation plays an important role in regulating incoming materials such as dissolved and/or suspended nutrients and sediments. The separate sodic Lake is dominated by blue-green algae and soda-tolerant plants. The upper catchment ecosystem is dominated by humid Afro-montane vegetation and bamboo in the Aberdare forest while the Kinangop plateau is dominated by crop land, grassland and scattered fast growing exotic trees (Mavuti & Harper 2006).

Recent trends indicate that some alien invasive species especially water hyacinth (*Eichhornia crassipes*) have emerged in the Lake and colonized some parts.The emergence of these invasive species is attributable to changes in the ecosystem associated with anthropogenic disturbances, especially those linked to agricultural input use and land use change in favour of farming activities. As Kitaka et al. (2002) indicate, the Lake has recently degraded into a eutrophic status, a change that the authors attribute to continuous deposition of nutrients, specifically Nitrogen and Phosphorous leachates into the Lake. These dynamics correspond to the land use changes in the upper catchment where horticultural and irrigated agricultural farms increased by 103% between 1986 and 2007 (Onywere et al. 2012). Besides interfering with the natural lake chemistry, oxygen dynamics and other important biochemical attributes, eeutrophication causes high turbidity which leads to poor light penetration. Anthropogenic impacts on the ecosystem are also associated with a rise in sediment yield in the past 5 decades, from 1.3 tonnes ha^{-1} $year^{-1}$ in 1947 to 8.9 tonnes ha^{-1} $year^{-1}$ in 2006 (Stoof-Leichsenring et al. 2011). Within a 50 year period, approximately 3.4 million tonnes of sediment have been deposited into the Lake. Given the shallow nature of the Lake, it is obvious that although siltation may not cause an alarming impact on the lake depth, it is has significantly affected the turbidity of the lake water with indirect influences on water use for domestic uses, fisheries, tourism and agriculture. Poor light penetration, together with the introduction of alien species such as Cray fish, is also responsible for extinction of benthic flora (Macrophytes) which were an important component of the ecosystem (Becht 2007). A study by Mavuti & Harper (2006) indicated a substantial decline in natural vegetation in the catchment. More recently, Onywere et al. (2012) indicated that papyrus and wetland grassland around the Lake Naivasha had declined by 37.6% between 1986 and 2007.

1.2.3 Socio-Economic Attributes

The Lake Naivasha basin supports multiple economic activities including horticulture, floriculture, commercial vegetable and food crop production, tourism, fisheries, and pastoralism. Subsistence food crop production is also a dominant activity especially in the upper catchment. Two distinct agricultural systems can be identified in the Lake Naivasha basin. In the Upper catchment, we have mainly small-scale farms, engaged in the production of semi-commercial food crops and vegetables. In contrast, agriculture in the Lower catchment is dominated by large scale floriculture and horticulture commercial farms which are highly capital and technology intensive

Figure 1. 3 : Main economic activities in the basin

The history of intensive commercial floriculture and horticulture in the Lake Naivasha region dates back to the early 1980s when a vegetable grower successfully introduced flower growing in the area. Since then, a vibrant commercial horticulture and floriculture industry has thrived along the shores of Lake Naivasha. Irrigated indoor and outdoor floriculture and horticulture around the lake currently occupy approximately 5025 ha (Reta 2011). The industry is favored by the fresh water Lake and underground aquifers providing reliable water for irrigation through-out the year and good all year-round climatic conditions. Proximity to the city of Nairobi also favours the industry by providing access to an international airport linking producers with international vegetable and cut flower markets. The Naivasha floriculture industry is also a key contributor to Kenya's economic growth and livelihood support since it generates about Ksh. 27.8 Billion (or 278 Million Euro) in foreign exchange annually (WWF 2011). The sector also employs approximately 25,000 people directly while supporting over 70,000 indirectly through dependency and employment in service sectors such as agro-chemicals, retail business, transport and other related services. The flower industry is however a major water user and has a great influence on the Lake levels (Becht et al. 2005; Chiramba et al. 2011).

Farming in the upper catchment is dominated by smallholder farm settlements where farm households draw livelihood support by engaging in smallholder semi-subsistence farming. The average farm size in the basin is 2.45 Hectares. In the past 50 years, there has been rapid land use and land cover changes involving conversion of forest land to crop land hence exerting direct pressure on the environment (WWF 2011). Currently, crop land is estimated at 210,000 hectares where small holder farmers grow food and commercial crops such as cereals – maize and wheat; pulses – beans, garden peas and snow peas; vegetables- potatoes, cabbages, kales and carrots. Livestock production, both indigenous and mainly exotic beef and dairy cattle, sheep and goats and poultry also provide a substantial proportion of income to the households. Although crop production in the upper catchment is mainly rain fed, supplementary irrigation is done on approximately 8% of the total crop land. Irrigation water is drawn from multiple water abstraction points on the main rivers (Malewa and Gilgil), their tributaries and underground aquifers. These are also sources of supply of domestic water to over 300,000 people and over 40,000 livestock. The catchment population also depends on public and private forests for biomass fuel -mainly firewood and charcoal- livestock grazing, building materials and other non-wood forest products. Because of the seasonal cropping patterns and continuous land fragmentation caused by population pressure and land inheritance cultural practices, land in the region is subjected to frequent tillage making the soil loose and susceptible to erosion. Soil erosion and accelerated land degradation is also abetted by poor agricultural practices in the upper catchment and has contributed to the siltation of the lake through the increased sediment load (Becht et al., 2005; Stoof-Leichsenring et al. 2011).

The growth of the horticulture industry was accompanied by an average annual population growth of 6.6% from 237,902 people in 1979 (WWF 2011) to 551,245 in 2009 (KNBS 2010). According to a national population census conducted in 2009 by the Kenya National Bureau of Statistics (KNBS), an estimated 490,000 people, approximately 75% of the total basin population were living in the upper catchment (KNBS 2010;WWF 2011). Figure 1.4 presents the population distribution in different sub-catchments of the Lake Naivasha basin as per the 2009 population census.

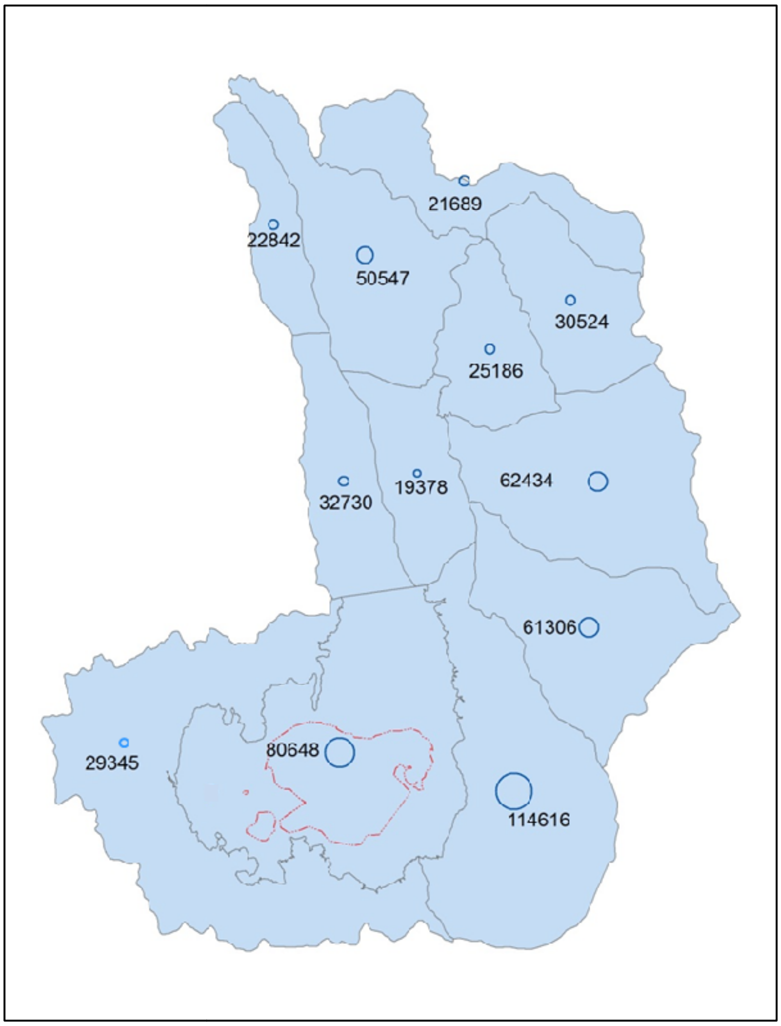


Figure 1.4: Population distribution in the Lake Naivasha Basin

1.2.4 Institutional, Policy and Regulatory Framework in the Lake Naivasha Basin

The legal and regulatory framework governing management of natural resources and other environmental issues in Lake Naivasha basin is mainly composed of national legislations. Further, local organizations composed of resources user groups and other interested stakeholders such as NGOs and lobby groups have designed other institutional arrangements also used in governing resources in the basin. The major legal legislations and institutional arrangements that are relevant for regulating agri-environmental activities in the Lake Naivasha Basin are summarized below.

1.2.4.1 The *Water Act*, 2002

This act provides a legal framework for the management of water resources and regulation of right to use water in Kenya. The Act was established in 2002 to repeal a previously existing law, the *Water Act*, CAP 372 laws of Kenya. A synthesis of the Act by Mumma (2007) reveals that the act introduced comprehensive reforms in the management of the water sector in Kenya. The major reforms introduced by the act were: (i) separation of the management of water resources from the provision of water services; (ii) separation of policy making from day-to-day administration and regulation; (iii) decentralization of functions to lower-level state organs; and (iv) the involvement of non-government entities in both the management of water resources and the provision of water services. The Act set up a formal framework of institutions that govern the management of water resources in Kenya. Section 7 of the Act created the Water Resources Management Authority (WRMA). The authority was mandated to, among others; "develop principles, guidelines and procedures for allocation of water resources, regulate and protect water resources quality from adverse impacts; and to manage and protect water catchments'' (GoK 2002), including development of water allocation plans. The act also introduced non-tradable water permits and block rate water pricing as instruments for regulating water use in Kenya (GoK 2002). The instruments are monitored and enforced by WRMA, a state department established by the same law. Further, section 15 (5) created a provision for development of Catchment Management Strategies (CMS) and mandated WRMA to facilitate the formation of Water Resource User Associations (WRUAs). These are explained briefly in the next section.

1.2.4.2 Water Resources User Associations (WRUAs)

WRUAs are local collective action initiatives with a legal mandate to assist WRMA in catchment water monitoring, rule enforcement and conflict resolution. The WRUAs were created through a provision in the *Water Act*, 2002 which recognized informal institutions through which these community organizations are formed. In the Lake Naivasha basin, 12 such WRUAs were established in 2005, each commanding jurisdiction of a sub-catchment (Figure 1. **5**). Since their introduction, WRUAs have been involved in water management issues and development of sub-catchment management plans.

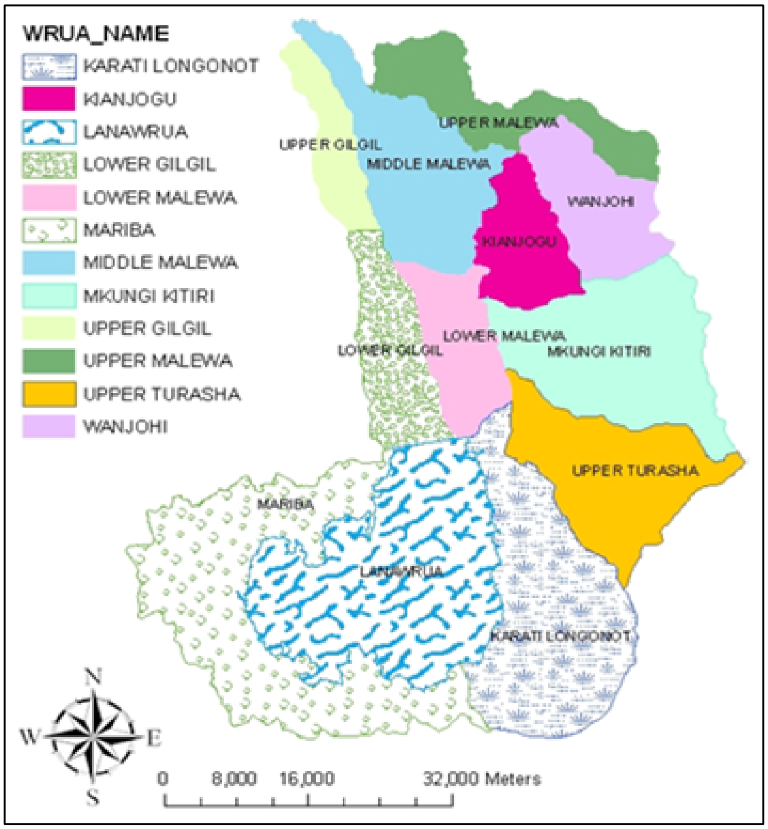


Figure 1. 5: Map of Lake Naivasha Basin showing the 12 WRUAs

1.2.4.3 Lake Naivasha Management Plan

The Lake Naivasha Management Plan was developed as a community based initiative to promote sustainable development, wise use of resources and voluntary adoption of sectoral codes of conduct with a key objective of coordinating human activities around the lake for sustainability (Enniskillen 2002). The plan addressed sustainable management issues of the Lake Naivasha environment and the natural resources within the declared Lake Naivasha Ramsar site and the wider catchment (GoK 2004), taking an approach that allows the local community to benefit from the natural resources as they take care of it. The management plan provided broad guidelines for: (i) Water allocation and abstraction and monitoring of the water balance; (ii) Catchment/riparian rehabilitation and protection, habitat management and nature conservation; (iii) Enhancing sustainability on economic activities around the lake such as tourism, horticulture, floriculture and fisheries; (iv) Minimizing negative externalities on the lake and its environment especially from chemical pollution, solid and sewerage wastes; (v) Research priorities, dissemination of information and monitoring & evaluation of the lake. Implementation of the Lake Naivasha Management Plan was however impended by some concerns raised by stakeholders leading to a legal tussle that halted its implementation. A new plan, the Lake Naivasha Basin Integrated Management Plan (LNBIMP), 2012-2022 was drafted in 2012. The LNBIMP sought to address the shortcomings that were in the earlier plan. However, the draft is still awaiting approval and adoption as a formal document recognized by law.

1.2.4.4 The *Environmental Management and Coordination Act* (EMCA), 1999

This Act came to force in the year 2000 and provides a legal and institutional framework for management of the environment. The Act gives every person in Kenya a right to a clean and healthy environment and confers upon every person the duty to protect and safeguard the environment. EMCA established the National Environmental Management Authority (NEMA) to coordinate and oversee environment management and protection; a Public Complains Committee to investigate complaints against any person or NEMA and to forward recommendations to the National Environmental Council (NEC); a National Environmental Tribunal (NET) for arbitration of allegations and complains. The act also provides for individual citizens to seek redress in courts for violation of environment regulation and to be involved in Environmental Impact Assessment and Audit (EIA) process. Section 42 provides a framework for the protection of rivers, lakes and wetlands and subsection 4 empowers NEMA to issue guidelines for the management of environments for lakes, rivers and wetlands (GoK 1999). The traditional interests of customary communities living around a river, lake, wetland or forest may be incorporated in management plans of such resources, through the provisions in sections 42 (2a), 43 and 48(2).

1.2.4.5 The *Forest Act*, 2005

The *Forest Act* 2005 provides for the establishment, development and sustainable management, including conservation and rational utilization of forest resources for the socio-economic development of the country (GoK 2005). The government supports inter-sectoral development, sustainable use of forestry resources and bio-diversity conservation. Section 27 prohibits variation of state or local authority forest boundaries unless approved by local forest conservation committee and does not impart negatively on the environment after conducting an independent Environmental Impact Assessment (EIA). Part IV provides for community participation in state or local authority forest management through Community Forest Association (CFA) registered under the societies Act. The section also specifies the activities that the CFA members may conduct on the forests, and the products that the community may extract there from. The act is relevant for agri-environmental issues since all the tributaries of the major rivers in the Lake Naivasha basin originate from forests.

1.2.4.6 Participatory Forest Management Plans (PFMPs)

Four PFMPs have been developed within the lake Naivasha basin, covering North Kinangop, South Kinangop, GETA and Eburu forest blocks. These plans were developed through participatory efforts by all key stakeholders involved in management of the covered forest blocks, which are part of the larger Aberdare forest. The management plans are in line with the provisions of the *Forest Act*, 2005, Section 34(1), which stipulates that every state, local authority or provincial forest must be managed in accordance with a management plan (GoK 2005). The forest blocks covered under the management plans are the sources of about 11 tributaries of the Malewa River. The management plans seek to achieve a goal of "enhancing suitable management and utilization of natural resources by all stakeholders including the local communities, with particular focus on environmental conservation and improved livelihoods for the present and future generations" (KFS 2010). The plans, which seek to complement other environmental legislations in the area, give a road map for a comprehensive resource management plan within the forest blocks in the basin. The activities prioritized in the management plans have been categorized into nine programmes: (i) natural forest management; (ii) Plantation forest development; (iii) Water resources development; (iv) wildlife and ecotourism development; (v) community participation and development; (vi) infrastructure and equipment development (vii) human resources development (viii) protection and security and (ix) research and monitoring.

1.2.4.7 The Water Allocation Plan (WAP)

At the turn of the 21st century, it was observed that the then existing water institutions were not explicitly dealing with the volatile nature of water availability in the region and water scarcity situations were becoming very frequent. There were no mechanisms to limit the total water abstractions and therefore perpetual water scarcity was the norm. Diminishing river flows, falling Lake levels and declining ground water levels were common issues in the entire basin. It was clear that water abstractions were beyond the capacity of the resource. This was the major motivation for development of the WAP, which was envisioned to be able to sufficiently deal with the challenge of unregulated water abstraction. The WAP was developed by the Lake Naivasha Growers Group (LNGG) an organization representing the horticultural industry around Lake Naivasha, in consultation with WRMA and other key stakeholders. The WAP had an objective of encouraging sustainable use of water resources in the entire basin. Figure 1.6 demonstrates the basic concept of the WAP, which established thresholds using the traffic light system.

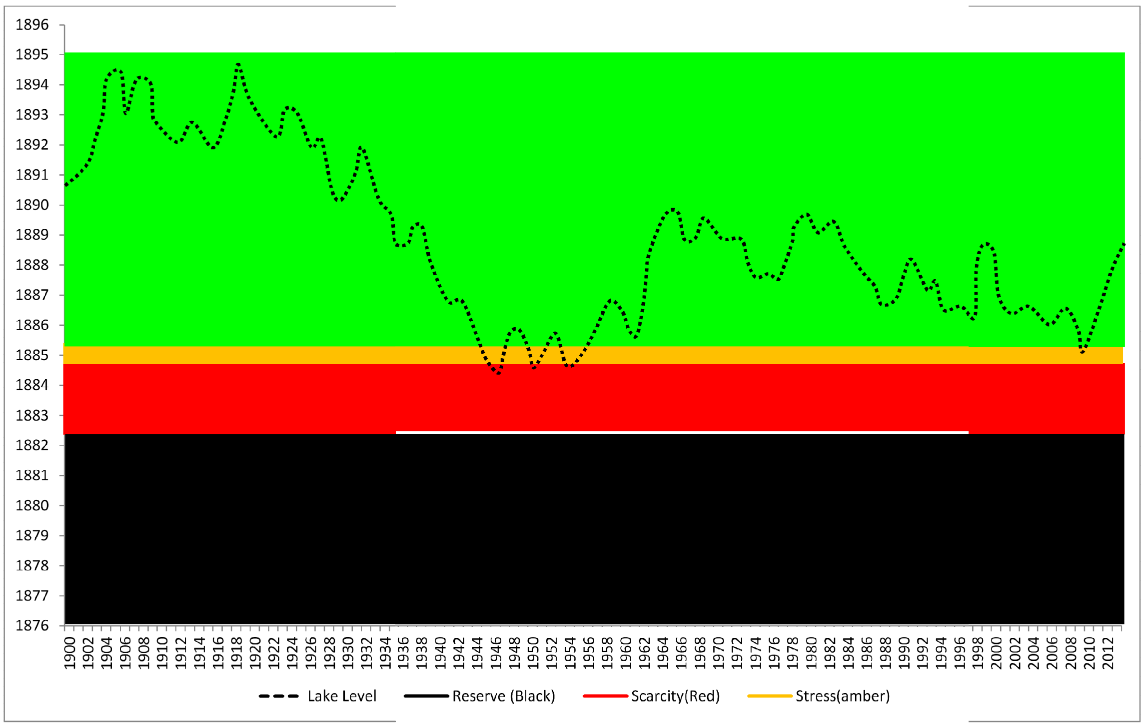


Figure 1.6: Long-term Lake levels and thresholds of the Water Allocation Plan

The black region, lying below 1882 m.a.s.l indicates extreme scarcity, where water should be used for reserve purposes and only basic needs, ruling out surface water use for irrigation. Within the black/reserve region, only water abstraction by domestic users and public water suppliers are is allowed at the rate of 25 liters per person (or per livestock unit) per day. During this period irrigators may however abstract 50 % of their water use from ground water reservoirs. The red region lies between 1882.5 and 1885.5 m.a.s.l and indicates that water resources are at ‘scarce’ status. During this period, severe abstraction limits are imposed where surface and ground water abstraction is allowed only up to 50-75% of normal water requirements as indicated in the permits. At that time pumping water from rivers is completely prohibited. The amber zone (1884.5-1885.3 m.a.s.l) indicates that water resources are at a 'stress' status and therefore slight restrictions are imposed. Domestic water users and public water suppliers are allowed 100% of their requirements while other users can only abstract up to 75% of their permitted quantities. The green zone (>1885.3 m.a.s.l), indicates that water resources are at a satisfactory status. In this zone, water abstraction restrictions are not imposed and all water users are allowed to abstract water up to the maximum daily allowable abstractions as per the water permits.

An informal sanctioning mechanism to identify and punish violators was also established that uses a mix of fines, peer monitoring and social sanctions. Any person in the basin is required to identify and report rule breakers. Once reported, violators are given three warnings by the WRUAs. If they don't change their behavior after the third warning, their names are circulated among all the people in the WRUA and also published in national newspapers. This '*name-and-shame*' process is then followed by the appropriate punishment which could be a fine, revocation of water permits or temporary disconnection of water depending on the nature of the offense.

1.3 Statement of the Problem

The description of Lake Naivasha basin reveals a number of issues that are of institutional and policy relevance. In the wake of increased human activity around the Lake and in the catchment, the Lake Naivasha basin faces several environmental challenges that are a threat to its sustainability and resilience. First, the riparian vegetation along the shores of Lake Naivasha has declined as a result of expanded human activities including establishment of crop land and permanent structures on riparian land. Secondly, unsuitable farming practices in the upper catchment such as rapid conversion of forested land into crop land, farming on steep slopes and fragile ecosystems such as riparian land and poor soil conservation have led to escalated soil erosion and siltation in water bodies. Third, fertilizer run-off originating from farms in the catchment and around the Lake is the major cause of eutrophication in the Lake. This has encouraged emergence of invasive species such as water hyacinth (*Eichhornia crassipes*), algae blooms and other associated issues such as occasional oxygen depletion leading to fish kills, the latest having occurred in 2011. The major cause of eutrophication documented so far is fertilizer run-off from the upper catchment. Finally, water abstraction remains highly unregulated. A water abstraction survey conducted in 2010 by WRMA revealed that illegal water abstraction is ubiquitous, since only 8% of water abstraction points accounting for about 50% of the total water abstracted had acquired updated permits (de Jong 2011; WRMA 2009;WRMA 2010). The low compliance to rules has been attributed to challenges in monitoring of water use and low enforcement of existing rules and legislations by the state organs as a result of logistical and technological challenges and the nature of environmental problems (Willy et al. 2012; Willy et al. 2011).

The presence of these environmental challenges in the Lake Naivasha basin implies that the capacity of the ecosystem to continue supporting the myriad human activities especially the economic activities is at stake. Finding solutions to these challenges is a complex and multi-faceted daunting task that needs a mix of strategies. One of these strategies could be designing institutional innovations that encourage sustainable farming activities and resource use in the Lake Naivasha basin. The current thesis seeks to contribute to this goal. In the next section the overall and specific objectives of the thesis are outlined.

1.4 Research Objectives

The overall objective of this study is to make a contribution to sustainable management of Lake Naivasha basin through analyzing the interactions between social and ecological systems in the basin. The analysis seeks to identify the institutional challenges encountered while seeking solutions to agri-environmental externalities and during the diffusion process of technologies and techniques to mitigate these agri-environmental externalities.

Specifically, the study seeks to achieve the five objectives. The guiding research questions are listed under each objective.

I. To characterize sampled households in the Lake Naivasha basin
   - What are the socio-economic and demographic attributes of sampled households?
   - What are the water use activities and trends among the sampled households?
   - What are the attitudes and perceptions of sampled households on resource management, externalities and rules governing resource use?

II. To assess the potential for cooperative instruments in addressing three agri-environmental externalities: siltation, eutrophication and water over abstraction.

- What are the existing opportunities to cooperate in the upper Lake Naivasha Basin?
- What are the tendencies of sample households to cooperate in the Lake Naivasha basin considering their participation in the existing collective action initiatives?
- What are the determinants of the decision to participate in cooperation or to defect?

III. To estimate the returns to multiple soil conservation practices (MSCPs) in-terms of their effects on the value of crop production among sample small scale farmers in the Lake Naivasha basin.

- To what extent do farmers in the Lake Naivasha basin implement multiple soil conservation practices?
- Does implementation of multiple soil conservation practices generate additional positive benefits in terms of enhanced value of crop productivity?
- What is the value of crop production per ha that can be attributed to multiple soil conservation practices?

IV. To analyze adoption and diffusion of soil conservation practices as a private effort to mitigate siltation and nutrient run-off.

- How does participation in collective action influence farm level soil conservation effort in the Lake Naivasha Basin?
- How does social influence which is manifested through neighbourhood social influences and subjective norms affect farm level soil conservation efforts.
- Does social control that may emerge from social networks within a community substitute for pure economic incentives to undertake individual action on soil conservation?

V. To analyze the effect of rainfall variability and household attributes on the diffusion of rain water harvesting techniques as mechanisms for water conservation and solving household water supply in the Lake Naivasha basin.

- What are the trends in the diffusion of roof-catchment and run-off harvesting techniques in the Lake Naivasha basin between 1960 and 2011?
- How does rainfall variability influence the diffusion path of the two rain water harvesting techniques over the study period? Does this sensitivity of individuals to rainfall variability change over time?

- Does the household water demand influence the household strategies towards securing water supply?
- What are the individual and farm attributes that influence the diffusion of rain water harvesting techniques?

1.5 Sampling and Data Collection Procedures

The studies in this thesis are based on primary cross-sectional data that was collected within the "Resilience, Collapse and Reorganization in socio-ecological systems of African Savannas" (RCR) project funded by the German Research Foundation (DFG). The data was collected through structured interview schedules administered to 308 randomly selected farm households during a household survey.

A stratified random sampling technique was used to select the respondents with Water Resource User's Associations used as the strata. A number of steps were followed in the sampling process. In the first step, eight Water Resources Users associations were selected purposively by the fact that they were located at the Upper Lake Naivasha basin. After selecting the WRUAs, a sampling frame was prepared for each village within the WRUAs with the help of village elders and WRUA officials. In the next step a sample of 308 farm households was drawn from all the WRUAs such that the contribution of each WRUA was proportional to its size. Table 1.1 presents details on the distribution of the sample to individual WRUAs.

Table 1.1 : Contribution of individual WRUAs to total sample size

Name of WRUA	Population	Number of households	Size (Km^2)	Households in WRUA as a % of total	Expected sample size	Actual sample size	Sample adjustment*
Kianjogu	25,186	5,037	143.6	8.5	26	36	+10
Lower Malewa	19,378	3,875	149.4	8.9	27	32	+5
Middle Malewa	50,547	10,109	287.2	17.1	53	58	+5
Upper Malewa	21,689	4,338	146.4	8.7	27	34	+7
Mkungi Kitiri	62,434	12,487	370.3	22.0	68	34	-34
Upper Gilgil	22,842	4,568	106.0	6.3	19	37	+18
Upper Turasha	61,306	12,261	295.8	17.6	54	41	-13
Wanjohi	30,524	6,105	181.5	10.8	33	36	+3
Total	**293,906**	**58,781**	**1680.1**		**308**	**308**	

*the sample size in each WRUA was adjusted for logistical purposes

A pretested interview schedule was then administered to the sample households. The targeted respondents, who were mostly household heads and/or their spouses were interviewed face-to-face by the researcher assisted by trained enumerators. The interview schedule had ten sections under which the following data was gathered: household water use trends; soil and water conservation practices; land use and crop production; Irrigation practices; livestock production; credit access; social capital (trust, membership and participation in groups, social networks); perceptions and awareness on water management and rules; asset ownership; household demographic information and access to main infrastructure. Figure 1. 7 shows the distribution of the sample households in the study area.

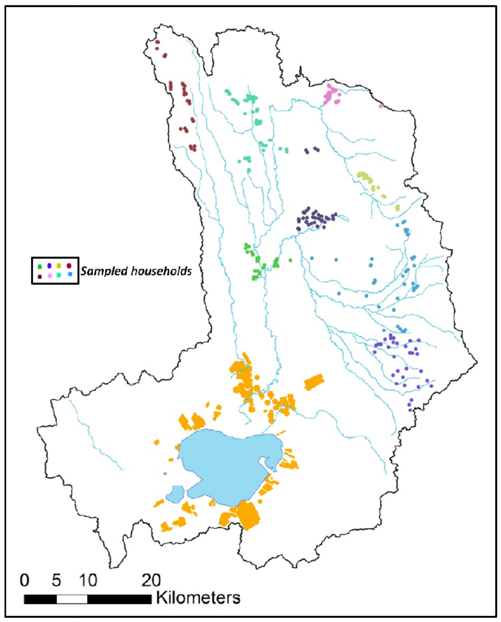


Figure 1. 7: Map of Lake Naivasha Basin showing location of sampled households

1.6 Thesis Organization

The current Chapter has presented background information on the research by discussing the concepts of Socio-Ecological systems and agri-environmental externalities. Further, the typology of policy and institutional instruments that are normally used to address interactions between social and ecological systems and the external effects which emerge from such interactions were discussed. A description of the Lake Naivasha basin, the research area, was offered in detail with an aim of revealing the problematic situation and therefore the research problem. Next, the research objectives were presented accompanied by the research questions that guided the execution of each objective. Finally the sampling and data collection procedures are described in detail. ***Chapter two*** presents a conceptual framework which shows the link between the different ideas tackled in different Chapters. Chapters three - seven take up a single objective each and present comprehensive assessments, complete with a background, literature review, theoretical, conceptual and analytical frameworks, results and discussions and conclusions and policy implications.

Chapter three presents descriptive statics on different aspects of the sampled farmers that are relevant to the issue of agri-environmental externalities. The household attributes presented under the chapter include: socio-economic attributes, demographic characteristics, crop and livestock production aspects, social capital and welfare.

Chapter four addresses the issue of Cooperation as an option for dealing with agri-environmental externalities. The chapter begins by elaborating on the special attributes of agri-environmental externalities which cause monitoring and enforcement difficulties, making some instruments not suitable. Further, a theoretical framework is developed to explain why individuals cooperate or defect. The sampled farmers are then characterized based on the tendencies to participate in collective action initiatives. Finally the factors determining the decision to cooperate or defect are identified.

Since soil erosion is the major cause of siltation externality in the research area, private efforts to engage in soil conservation to control soil erosion are analyzed in Chapters 5 and 6. ***Chapter five*** explores whether implementing a soil conservation package consisting of multiple soil conservation practices (MSCPs) yields private economic benefits. In this chapter, the returns to MSCPs are estimated using Propensity Score Matching (PSM) and exogenous switching regression. These methods were used to identify the effect on value of crop production that could be attributed only to soil conservation eliminating effects from other observable attributes among implementers (treated) and non-implementers (non-treated). ***Chapter six*** further explores motivations of soil conservation beyond private economic benefits. Specifically, the chapter presents findings on the effect of social influence and participation in collective action on individual soil conservation efforts. The chapter begins with a background on previous studies identifying important determinants of adoption of soil conservation practices. A theoretical framework, adapting a modified agricultural household model is used to explain the motivation behind participation in collective action and investment in soil conservation by farmers. An analytical framework which consists of a binary and ordered probit regression models is presented followed by regression analysis results.

Technology adoption and diffusion is not just driven by economic, personal and social factors, but also the natural environment plays a role. Further, the externalities that water users in common pool resources situation inflict on each other could be improved or worsened if households seek alternative household water supply stabilization mechanisms such as rain water harvesting. In ***Chapter seven***, this issue is pursued by exploring the effect of rainfall variability, household attributes and household water demand on the diffusion path of two rain water harvesting techniques: run-off harvesting and Roof catchment rain water harvesting. The chapter also seeks to assess whether the sensitivity of individuals to changes in climatic conditions changes over time.

Finally ***Chapter eight*** offers an overall summary and draws general conclusions of the thesis. The important aspects that are relevant for policy are summarized in a Policy Implication sub-section. The Chapter also highlights areas where we foresee potential for future research focus.

CHAPTER TWO

2 Conceptual Framework

This chapter presents a conceptual framework of the thesis. First, a broad conceptualization of the spatial relationship of farmers within a basin is presented. Then a schematic representation and description of the relationships between dependent and independent variables is offered. The objective of presenting the conceptual framework is to show how the key ideas addressed in this thesis are related and the key determinants of farmers' activities and decisions that relate to crop production and the outputs from this activity. Outputs from cropping activities are either commodity outputs or non-commodity outputs such as negative externality causing pollutants.

2.1 Conceptualizing Spatial Relationships between Farmers in a Lake Basin

Figure 2.1 shows the spatial location of farmers in a Lake basin. The position of each farmer in a basin determines their exposure to agri-environmental externalities and also how they affect others. Some farmers (A1-A4) are located in the upper catchment while others are located in the lower catchment (B1-B4). The *up-streamness* or *down-streamness* of a farmer depends on their location relative to other farmers. All farmers in the lower catchment are downstream to those in the upper catchment. At the same time, some farmers in the upper catchment are downstream to others located in the same region. For example farmer A2 is downstream to A1, A3 to A2 and A4 to A3. Each farmer has jurisdiction over a specific parcel of land (they might have security of tenure or not) and they independently choose the technology to use in their farm. Farms in group A are located adjacent to a river which runs across the basin, feeding into a reservoir at the extreme downstream. Farms in group B are located around the reservoir, and therefore face a real common pool resource dilemma. Each farmer is assumed to have different technology at their disposal and depending on their personal attributes and orientation; they choose the type of cropping enterprises. Besides affecting the production and cost functions, differences in technology and type of crops have implications on a number of other aspects. The type of crop determines the water demand from farming activities. For example, Mekonnen & Hoekstra (2010) estimated that the water footprint[1] for cut-flowers in Lake Naivasha basin was 367 M^3/Tonne while that of vegetables grown in the upper catchment was 222 M^3/Tonne and that of Potatoes another common crop in the upper catchment was 190 M^3/Tonne.

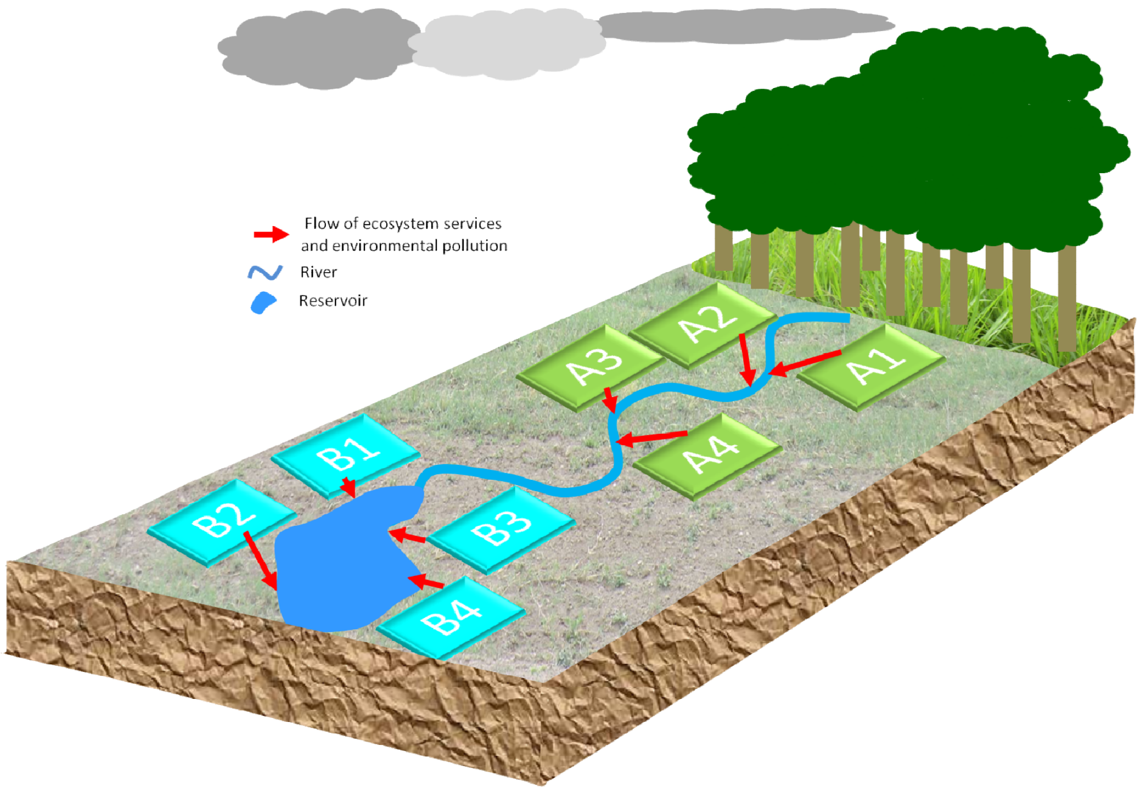


Figure 2.1: Spatial relations between farmers in an Interdependent situation

The type of crop also determines the marginal value of water which may also influence the price that people are willing to pay for water. Further, the irrigation technology used also influences the amount of water used for irrigation and also the quality and quantity of return flows and therefore would also influence the externalities emerging from cropping activities. Given this background, the next section identifies key factors that might influence the quantity of commodity and non commodity outputs that emerge from crop production activity. Further, the section identifies key factors that relate to solutions that farmers might implement to deal with the externalities.

[1] The water foot print concept originated from Hoekstra & Hung (2002) and refers to the amount of water that is required for a person or commodity for a time unit. In the concept, water used in human activities can come from three main sources: blue, green and grey water. Blue water refers to surface of ground water while green water refers to capillary water stored in the soil or in plants, mainly from rain and grey water refers to water that is contaminated and possibly recycled in crop production.

2.2 Relationships Between Variables in Agri-environmental Situations

The conceptual framework used in this study is presented in Figure 2.2. **Crop production activity** is at the centre of decision making. Crop production is an activity that produces two outputs: *Commodity outputs* and *non-commodity outputs*. First the commodity outputs are discussed. Assume farmers are maximizing their agricultural output subject to technology and physical constraints. Technology in this case refers to inputs such as fertilizers, seeds and other output enhancing techniques such as irrigation and soil conservation practices. Physical constraints relate to farm attributes such as slope, altitude and soil type. The level of inputs is further influenced by personal attributes such as age, gender and education level, which determine the farmers' experience, skills and capability. The effect of these factors on output may also be mediated by exogenous factors such as access to extension advisory services, credit and market prices for inputs and outputs. In Chapter four, the influence of soil conservation practices on commodity output is assessed controlling for all the other factors that influence commodity outputs. Based on findings from previous studies, (for example Kassie et al. 2008; Araya & Asafu-Adjaye 1999; Bekele 2005; Otsuki 2010; Nyangena & Köhlin 2009) it was hypothesized that enhanced soil conservation is associated with higher crop productivity.

As mentioned earlier, crop production also generates non-commodity outputs. These include negative externality causing pollutants such as silt and nutrient leachates from farms. The non commodity outputs emerge because of non separability between production of agricultural commodities and non commodity outputs. Once fertilizers are applied on the farms, the farmers have no control of what happens thereafter (Hagedorn 2008). The nutrients from the fertilizers are converted to forms that can easily mix with surface run-off and eventually end up in surface and ground water. Nitrogen is usually converted into soluble forms such as nitrate (NO_3^-) and nitrite (NO_2^-) while phosphorous is usually transported imbibed in soil particles or dissolved in run-off water. These processes could however be mitigated through environmental friendly soil conservation practices such as soil conservation. It was therefore important in the current study to assess the determinants of soil conservation effort at farm level as a way of mitigating agri-environmental externalities. The process of adoption of soil conservation practices is a complex process and is hypothesized to be influenced by several factors. Some of the important hypothesized determinants of soil conservation include personal characteristics such as age, gender and education level (Napier et al. 1984 ; Doss and Morris, 2001), economic factors such as income, farm size and household asset ownership (Ervin & Ervin, 1982; Kabubo-Mariara et al., 2006; Marenya & Barrett, 2007 and Nkonya et al., 2008); physical factors such as slope, altitude, and soil quality (Kabubo-Mariara, 2012); social and institutional factors such as credit, access to extension services, land tenure and perceptions on existence of soil erosion problem and the perceived and actualized benefits of engaging in soil conservation (Ervin & Ervin, 1982; Kabubo-Mariara, 2012; 2007; Meinzen-Dick & Di Gregorio, 2004 ; Migot-Adholla et al., 1991; Place & Swallow 2000; Rogers, 1995 and Shiferaw & Holden, 1998). Further, social factors such as subjective norms and social capital may also determine the soil conservation effort by individuals. Therefore, other than economic and personal attributes, whether individuals engage in soil conservation and the effort of soil conservation may depend on the level of social control from peers and engagement in collective action.

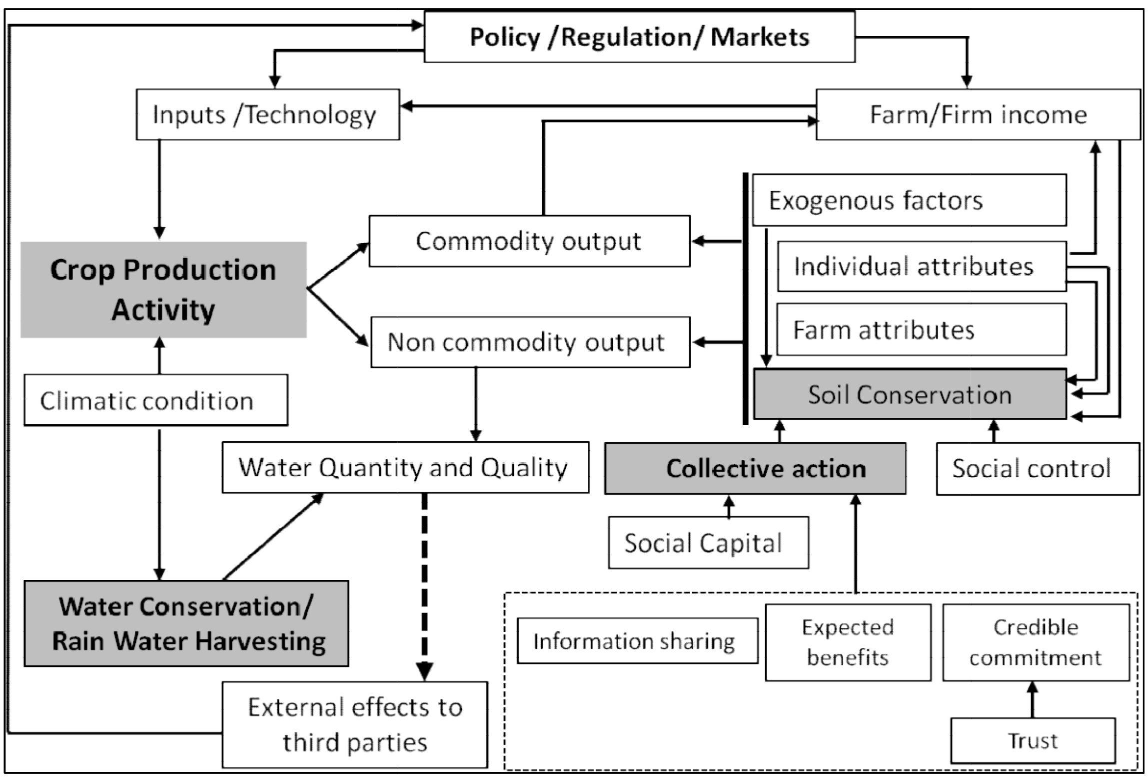


Figure 2.2: Agri-environmental externalities: A conceptual framework
Source: Author's conceptualization

Besides regulatory and market instruments[2], collective action/cooperation is one of the instruments that can be used to address agri-environmental externalities   Collective action is relevant for agri-environmental externalities because most environmental bads (externalities) such as silt and nutrient runoff are usually 'non-point' and therefore are hard to monitor and link to a particular farm/individual. Due to the difficulty in monitoring and detecting individual liability, there is an incentive to over produce agri-environmental externalities and avoid abatement. Further, ecosystem services are usually produced privately by individuals but their benefits are enjoyed beyond their production localities. As such, individual farmers who produce environmental benefits cannot individually determine who else will use them and therefore they have no incentives to generate such benefits. Due to the public good nature of these agri-environmental externalities they would be better managed through collective action to help bring their production closer to Pareto optimum levels. Ostrom (1990) proves that resource users in a common pool resource situation can come up with self organized mechanisms to deal with the problem and avoid the tragedy of the commons that was predicted by Hardin (1968).

The other reason why collective action in necessary is that by the virtue of the spatial location of farmers in the basin (see illustration on Figure 2.1), we have a unidirectional upstream-downstream externality since only those upstream can impose an externality to those downstream. The externalities result from upstream crop production activities and end up affecting the crop production activities for the downstream farmers. Therefore since the externalities create interdependence between farmers located in different spatial areas, collective action would be ideal. However, collective action will be more attractive if done not just to solve downstream problems but rather to solve the problems of those upstream as well. Creating such collective action will however depend on the incentives for cooperation that exist for the upstream farmers. For example, it could be at the interest of upstream farmers to improve their farms in order to avoid the loss of long term crop productivity associated with soil erosion and land degradation. However, such a collective solution might require the upstream farmers to forego their current benefits for the sake of creating both private and social benefits. There must therefore be some sort of incentives to compensate them for the loss in income associated with this sacrifice. Such incentives might come from direct benefits associated the activities which farmers engage in to mitigate their negative

[2] The regulatory instruments and market based instruments are beyond the scope of this Thesis. However, an overview of the instruments is offered in Chapter one.

effects or other selective benefits offered by the group. Selective incentives are benefits that are accessible only to members of a certain group and therefore might motivate individuals into participation. Such benefits include training opportunities and exclusive access to advice or credit that may boost farming activities. Participation in cooperation is hypothesized to be influenced by norms of trust and reciprocity which help to form credible commitments and cement relationships. Also mechanisms for information sharing are very important since communication helps to solve prisoners' dilemma. Finally, farmers must perceive that such cooperation is beneficial and that the costs of cooperating are lower than the benefits. Since cooperation needs governance structures and mechanisms for monitoring and enforcement of rules, the presence of social sanctioning and peer monitoring might also be important determinants of cooperation.

Finally, in situations where farmers are abstracting water from a common source, individual extraction behaviour may exert external effects on other users. An example is when water over abstraction drives the ground water levels very low such that marginal pumping costs also increase. This may also be the case in the situation where some of the water users have asymmetric access[3] to water like in a watershed or Lake Basin. The flows of water into the shared reservoir can be greatly affected by the water abstraction behaviour by the upstream farmers. The amount of water used by each farm depends on factors such as the nature of farm enterprises (e.g. the type of crops produced), production and irrigation technologies used and weather conditions among other factors. Whether the amount of water abstracted leads to externalities will further depend on the conservation status of the farm/firm (e.g. whether there are water saving technologies) and the degree of dependence on common versus individual water supply system[4]. This aspect if addressed in chapter seven where it is hypothesized that rain water harvesting and storage at household level is influenced by both exogenous natural factors such as rainfall variability and endogenous factors such as household socio-economic/demographic attributes.

[3] Asymmetry in water access occurs because of the vertical nature of the river, where upstream water users are privileged to decide on how much water to abstract before their downstream counterparts. Consequently, water use by each upstream water user contributes to externalities for the downstream water users and the entire system. However, at the reservoir (lake), all users have equal access to water.
[4] This would include run-off and roof catchment rain water harvesting.

CHAPTER THREE

3 Attributes of Sample Farmers and their Activities in Upper Lake Naivasha Basin

This chapter presents descriptive statistics on the sampled households in the upper Lake Naivasha basin. Particularly, the chapter presents descriptive statistics on attributes of the sampled households and activities that they engage in that may have implications on their interactions with natural resources.

3.1 Socio-Demographic characteristics

Table 3.1 summarizes the socio-demographic attributes of the sampled households. Out of the 308 households interviewed, 13.3% were female headed while the average age of the household heads was 54.8 (SD=14.1) years. The average household education level was 7 years. The average education level for each household was computed by summing up the years of schooling completed for all household members and dividing the sum by the total number of household members who had attained school going age. The education level of the household head was also captured. Majority of the household heads (46%) had attained primary level of education, followed by secondary level of education[5]. The average household size for the sample was 5.0 members of whom 61.2% were adults over 18 years of age. The average household size in terms of adult equivalents[6] was 4.4.

Table 3.1: Household socio-demographic characteristics

	Mean	Std. Deviation
Age of household head (years)	54.8	14.1
Household size (adult equivalents)	4.4	2.0
Household size (numbers)	5.0	2.0
Average household education level (years)	7.3	3.4
Farming experience (years)	24.27	13.9

[5] In the Kenyan education system primary level of education takes eight years while the secondary level takes four years.
[6] This is an aggregate indicator of household sizes that is computed taking into consideration the attributes of household members such as age and gender to derive a figure that is comparable across households.

Table 3.1 Continued

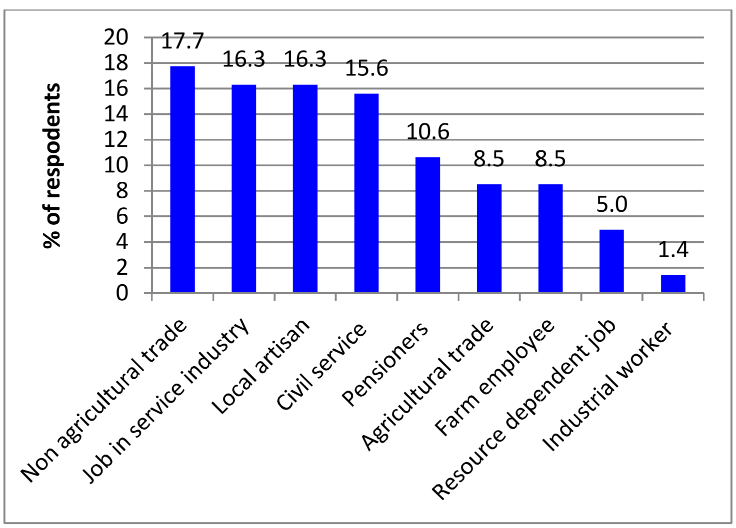
		Frequency	Percentage
Gender			
	Male	267	86.7
	Female	41	13.3
Household head education level			
	None	61	19.9
	Adult literacy education	4	1.3
	Primary	142	46.3
	Secondary	83	27.0
	Tertiary college	15	4.9
	University	2	0.7

Source: Author's household survey data, 2011

3.2 Socio Economic Characteristics

The sampled households were generating their income from two main sources: farming activities (crops and livestock) and off farm activities (employment and non-employment sources). Minor income sources included remittances and rental income (Table 3. **2**). On average, off farm sources provided significantly higher incomes (mean = Kshs. 227, 619/year) compared to agricultural activities (mean= Kshs. 154, 956/year; $t_{(307)} = -2.33$; p= 0.02, r[7] = 0.13).

The main off-farm income generating activities among the sampled households were non agricultural trade (17%), employment in the service industry (16%) and engagement in local artisan jobs (tailoring, carpentry and masonry) (16%) and employment in the service sectors (17%) (Figure 3.1).



[7] Where r is the effect size showing the importance of the effect, computed using the following formula (Field 2009): $r = \sqrt{\frac{t^2}{t^2+df}}$

Figure 3.1: Off-farm income generating activities

About 10% were earning their off-farm income from pension while 5 % were generating their income directly from natural resources (Figure 3.1). The direct resource dependent activities include lumbering, charcoal burning and selling of wooden poles.

Table 3. 2: Annual household income by source

Income source	Mean	SD
Net return from agricultural activities(Kshs)	154, 956	153,770
Mean annual income from off-farm activities (Kshs)	227,619	118,283
Average total annual household income [a]	241,226	259,375
Average total annual household income [b]	205,608	242,909
Remittances	17,760	58,389
Rental Income (buildings)	8,538	55,124
Rental Income (Land)	1,836	10,242

a. Including value of own produced commodities consumed at home
b. Excluding value of own produced commodities consumed at home
Source: Household survey data

3.3 Cropping Activities, Land Ownership and Use

Farming activities among the sampled farmers included crop and animal production. On average, households own 2.67 ha of land, ranging from 0.2 ha to 38.5 ha. The land is mainly used for growing crops (38%), pastures/grassland (39%), woodlots/farm forests (2.3%), homesteads (8.1%) and unusable/degraded land (2.3%). About 62.3% of the respondents reported that they had secure rights to land (have title deeds to land). Table 3. **3** summarizes the crops produced in the upper catchment of the Lake Naivasha basin. Roots and tubers, mainly Irish potatoes and carrots are the major crops grown in the area. Maize and pulses take second and third positions respectively. Pulses included those produced for home consumption and local markets such as beans and green peas and those produced for the export market such as French beans, sugar snaps and snow peas.

Table 3. 3 : Crops produced by sampled households in the catchment

Crop	Acreage (Ha)	% of crop land occupied by the crop
Roots and Tubers	145.3	37.4
Maize	89.4	23.0
Pulses (Long Season)	35.4	9.1
Fodder (perennial)	33.5	8.6
Vegetables (Rainfed)	27.6	7.1
Pulses (Short season)	19.8	5.1
Fodder(Long Season)	18.5	4.8
Vegetables(Irrigated)	9.3	2.4
Fodder (Short season)	6.6	1.7
Other cereals	3.3	0.9
Other crops	1.4	0.4
Total	390.1	

About 23.4% of the sampled farmers indicated that they were engaged in irrigation within the reference year. The irrigated area was about 7.2% of the total crop land. On average, irrigators had significantly higher incomes from cropping activities with a mean income of Kshs. 95,508 annually compared to the Ksh. 30, 696, generated by non-irrigators ($t_{(233)}$ = -3.627; p= .000, r = 0.23). A commercialization index was computed to assess the degree of market orientation of the sampled households. The index was computed for each household following the formula:

$$\text{Commercialization index} = \frac{\text{Value of agricultural output sold}}{\text{Value of total output produced in the household}} \qquad (3.1)$$

The average commercialization index was 0.46, indicating that most of the households were engaged in production for own consumption. As expected, farmers involved in irrigation had a higher commercialization index ($\bar{X}$=0.64 SE= 0.026) compared to those who were not engaged in irrigation ($\bar{X}$=0.40 SE= 0.019); $t_{(305)}$ = -6.336, p = 0.000; r = 0.34).

To estimate the profitability of different crop enterprises, the gross margins of selected crops were computed. As indicated in Table 3. 4, vegetables (cabbages and carrots) had the highest gross margins as a percentage of gross revenues followed by cereals (Maize and beans). Other vegetables-Kales, Green peas- and Potatoes ranked last.

Table 3. 4: Gross margins of major crop enterprises

		Crop Enterprises						
		Maize	**Beans**	**Potato**	**Green peas**	**Carrots**	**Cabbages**	**Kales**
Output								
	Output (Kg/ha)	2973	874	7547	943	11733	11329	4394
	Selling price (Ksh/Kg)	18	48.36	13	57.67	8.92	14.95	14.79
	Sales (Kshs/ha)	**53514**	**42267**	**98111**	**54383**	**104658**	**169369**	**64987**
Variable costs								
Seeds	Quantity Kg/ha	30	60	1592	42	7	0,75	7,5
	Price (Ksh/ Kg)	132	86	22	265	3000	24000	2300
	Seed cost	**3960**	**5160**	**35024**	**11130**	**21000**	**18000**	**17250**
Basal Fertilizer (BF)	Quantity Kg/ha	173	30	156	48	41	102	49
	Price (Ksh/ Kg)	67	67	67	67	67	67	67
	BF cost	**11591**	**2010**	**10452**	**3216**	**2747**	**6834**	**3283**
Top dressing Fertilizer (TDF)	Quantity Kg/ha	16	4	5	14	5	10	10
	Price (Ksh/ Kg)	50	50	50	50	50	50	50
	TDF cost	**800**	**200**	**250**	**700**	**250**	**500**	**500**
Farm yard manure	FYM (Kg/ha)	2209	449	956	547	1229	1527	1263
	Price per Kg[a]	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Manure cost	**1104.5**	**224.5**	**478**	**273.5**	**614.5**	**763.5**	**631.5**
Labour	Persondays/ha	127	106	154	120	180	150	150
	Wage rate	150	150	150	150	150	150	150
	Labour cost	**19050**	**15900**	**23100**	**18000**	**27000**	**22500**	**22500**
Pestcides	**Pestcide costs/ha**	**0**	**0**	**1500**	**4500**	**1500**	**3000**	**2000**
Other variable costs	**Land preparation**	**4000**	**4000**	**4000**	**4000**	**4000**	**4000**	**4000**
Total Variable cost (Kshs/ha)		**40505**	**27494**	**74804**	**41819**	**57111**	**55597**	**50164**
Gross margin (Kshs/ha)		**13009**	**14772**	**23307**	**12563**	**47547**	**113771**	**14823**
GM as a % of revenue		0.243	0.349	0.238	0.231	0.454	0.672	0.228

a. Since there is no proper market for manure in the research area, this was an imputed price

Since the amount of fertilizers used in farms have a direct relationship with the concentrations of nitrates (NO_3^-), nitrites (NO_2^-) and phosphates in the soil, a follow-up was made on the types and amount of fertilizer used by the sampled households. Di-Ammonium Phosphate (DAP) and livestock manure were the main fertilizers applied on the farms. Manure is easily accessible because 92.8% of the households own livestock. The average manure production per household was 10 tonnes (wet-weight) per year. Table 3. 5 presents the amount of nutrients (Nitrogen, Phosphorus and Potassium) that were applied per hectare depending on the fertilizers applied.

Table 3. 5: Fertilizer use among sample farmers

Type of fertilizer	Average amount Applied-I[a] (Kgs/ha)	Average amount Applied-II[b] (Kgs/ha	Amount of Nutrients Applied (Kg/Ha)[c]		
			Nitrogen	Phosphorous	Potassium
Calcium Ammonium Nitrate (CAN)	7.37	36.9	9.28	0	0
Di-Ammonium Phosphate (DAP)	99.0	117.4	21.13	23.48	0
NPK(20:20:0)	6.1	50.8	10.16	10.16	0
NPK (17:17:0)	1.3	26.5	4.505	4.505	0
Urea	1.4	28.5	13.11	0	0
Farm Yard Manure (FYM)	2541	3940	9.85	2.36	7.88

a. Average for entire sample
b. Average for only those who applied the fertilizer
c. The manure conversions are based on Pimentel (1997) where the nutrient content is given as: N(0.25%), P(0.06%) and K(0.2%).

3.4 Water Use Trends

Households used water mainly for domestic purposes (washing, cooking and bathing), livestock watering and irrigation. The average domestic water use was 47.5 M^3 per household (or 13 M^3 per adult equivalent) per year. Irrigation water averaged at 300 M^3 per household per year while livestock watering consumed an average of 67 M^3 per household annually.

Table 3. 6 presents statistics on the proportion of water obtained from the different sources. Majority of the household source their water from rivers either directly or conveyed to their homes through piping system. Ground water is mainly used for domestic but only a small percentage of households use ground water for irrigation. The limited use of ground water for irrigation can be attributed to technology constraints since most households do not have water pumps but use improvised mechanisms to draw ground water by hand.

Table 3. 6 : Proportions of household water use from different sources

	River	Roof catchment	Borehole	Well	Spring	Wetland	Piped water	Pond
Domestic	.10	.15	.05	.16	.04	.03	.49	.02
Irrigation	.02	.03	0	.06	.03	.01	.77	.07
Livestock	.14	.08	.013	.14	.03	0	.47	.13

Livestock production, mainly dairy cattle, is a key farm enterprise in the catchment, and just like many rural areas in Kenya, it plays an important role in easing household's cash inflow constraints. The average livestock holding was 6.5 (SD=4.7) Tropical Livestock Units per household. Livestock income is generated mainly from sale of milk, eggs and live animals. Livestock watering used on average 67.2 M^3/household/ year, which considering that approximately 90% of the households keep some sort of livestock, could have substantial impacts on water resources at basin level.

3.5 Irrigation Practices among the Sampled Households

About 23.4% of the households interviewed reported having practiced irrigation within the year 2010. Three WRUAs in the upper catchment accounted for over 80 % of all the total irrigation: Upper Malewa (40.2%), Wanjohi (29.3%) and Lower Malewa (13.0%). Irrigated land was about 7.2 % of the total crop land cultivated by the sampled households in the upper catchment. Irrigation water use averaged at around 45.5 $M^3Ha^{-1}day^{-1}$. However, the amount of water used for irrigation per hectare per day did not differ significantly between the three WRUAs, $F_{(2,133)} = 1.307$; MSE=1.23 , $p > .05$.

The respondents were asked to indicate the months when they irrigated intensively and when irrigation was moderate. These responses were plotted together with the monthly rainfall recordings to assess whether there was a correlation between the intensity of irrigation and the amount of rainfall. Figure 3. **2** indicates that intensive irrigation is normally done between the months of January and March, which also happen to be the driest months of the year. On the other hand, moderate irrigation, which is mainly done for supplementary purposes, is done through-out the year depending on the precipitation, but mainly between September and December. The number of months during which the crops were irrigated differed significantly between the January-March irrigation season ($\bar{X}$=2.8; SE=.08) and the September-December irrigation season ($\bar{X}$=2.1; SE= 0.19); t (182) = 3.107; p< 0.01; r = .22).

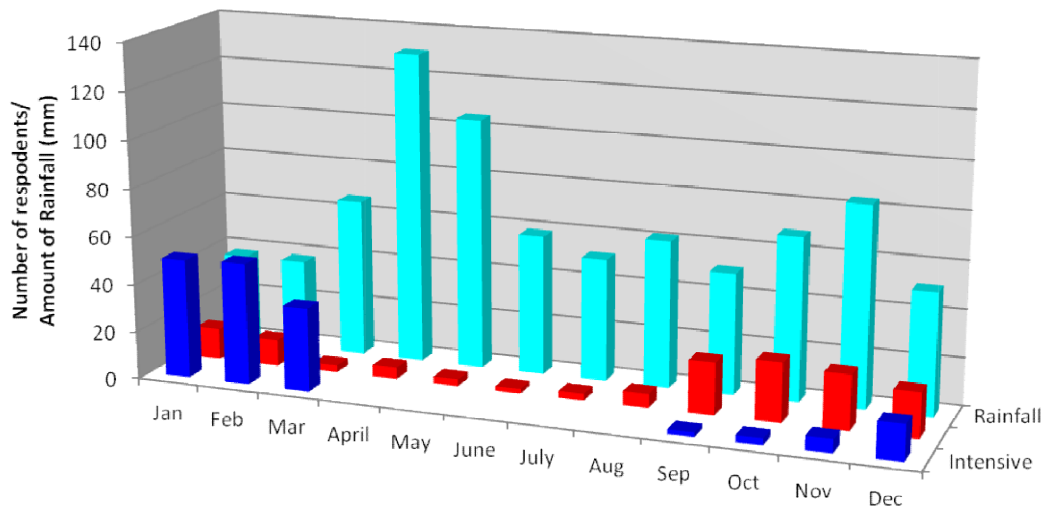
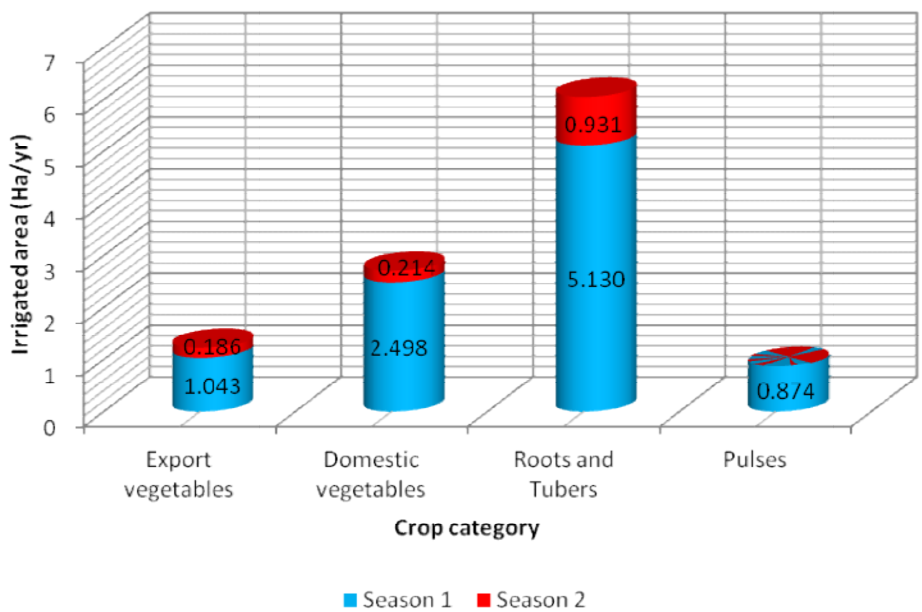


Figure 3. 2 : Figure: Intensity of irrigation in different months of the year

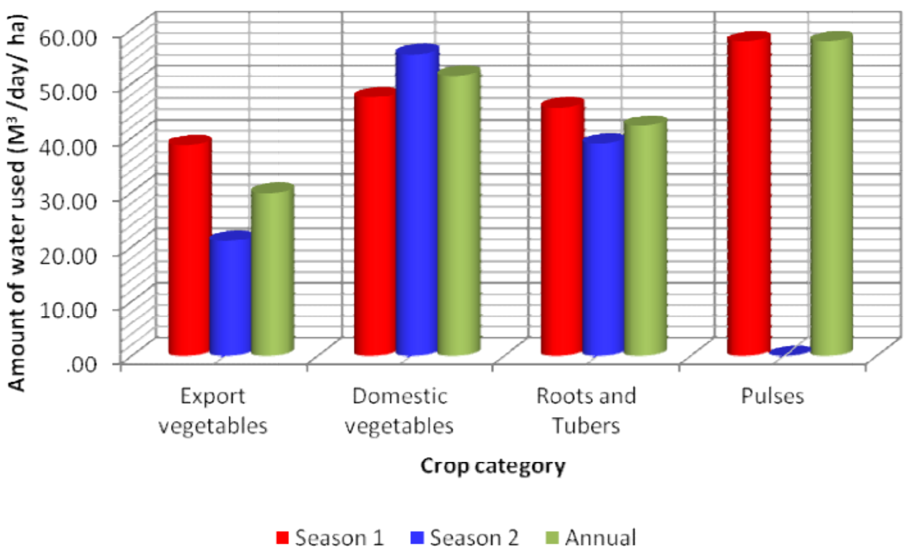
As indicated in Figure 3. 3, export and domestic vegetables and roots/tubers are irrigated in both seasons, while pulses are irrigated only during the January-March irrigation season. Further, roots and tubers occupy the largest irrigated land followed by domestic vegetables and export vegetables in that order.



*Season 1 is the January-March irrigation season while season 2 is the September-December irrigation season.

Figure 3. 3 : Area irrigated by crop and season.

Figure 3. 4 reveals that domestic vegetables (Kales, Spinach and cabbages) use relatively more water per hectare per day compared to the other crops. They also require more supplementary irrigation than all other crops, as indicated by the increase in amount of water between season 1 and season 2. Although pulses (mainly green peas) seem to have used more irrigation water per hectare per day, the crop still used least water cumulatively. This is because they are irrigated for the least number of months (2.77) per year.



*Season 1 is the January-March irrigation season while season 2 is the September-December irrigation season.

Figure 3. 4: Amount of water used for irrigation by crop and season

3.6 Household Asset Ownership, Welfare and Poverty

The physical capital endowment for each household was estimated using asset indices for five categories of assets: crop related assets, livestock related assets, farm structures, and water/irrigation related assets and transport assets. An overall asset index was also computed. The asset indices were computed following the principle components analysis (PCA) approach suggested by Filmer & Pritchett (2001). The PCA approach aggregates several binary asset ownership variables into a single dimension. The variables representing the single dimensions were then normalized to a 0-1 scale using the formula:

$$Normalized\ value = \frac{x - x_{min}}{x_{max} - x_{min}} \qquad (3.2)$$

where x is the initial value of observation, $x_{\min}$ is the minimum observation and $x_{\max}$ is the maximum observation. Normalization generates values ranging from 0 to 1 and therefore comparisons can be made across all the assets and across individuals. Using the total household annual income, a poverty indicator was developed by computing the daily per capita income. Based on the per capita income, 57.1% of the households were living on less than US$ 1.25/person/day[8]. There was a high correlation between household income /poverty level and asset ownership. As indicated in Figure 3. 5, households living below the poverty line had generally lower asset indices compared to those living above the poverty line (total asset index mean difference = 0.073, $t_{(305)} = 5.47$, $p<0.01$). Only the index for crop assets which are composed of farm tools and implements was almost equal for both groups. This can be attributed to the fact that the poor households are mostly engaged in agricultural activities and therefore are likely to have many farm implements.

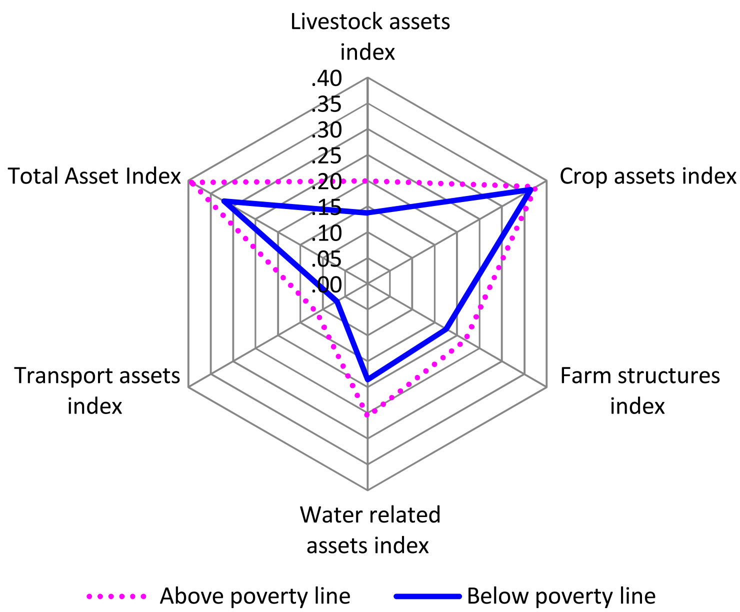


Figure 3. 5 : Household asset ownership indices

Wealth and income inequality among the sampled households was assessed using the Lorenz curves and the Gini coefficient. The Lorenz curve is used to assess the proportion of income or assets that is controlled by different sections of the population, while the Gini coefficient is an index that ranges between 0 and 1, and measures the extent to which the distribution of income is unequal. A Gini coefficient of 0 implies perfect equality while that

[8] This corresponds to the current world bank poverty line for Kenya (http://data.worldbank.org/topic/poverty)

of 1 implies perfect inequality. Generally, income and assets were moderately distributed. Three variables were used in constructing the Lorenz curves (Figure 3.6). First the total annual household income including the value of home produced commodities that are consumed at home (Inclusive income) was used. Using this variable, the Gini coefficient was estimated at 47.8% and the poorest 10%, 20% and 30% of the households commanded approximately 2%, 3% and 5% of the income respectively. When the value of home consumption of own produced commodities was excluded (exclusive income), the inequality widened slightly with the Gini coefficient increasing to 51.5%. The other variable used in constructing the Lorenz curves was the total assets owned by each household in the sample. This variable displayed a huge inequality with a Gini coefficient of 82.0% with 10% of the richest households in the sample controlling over 60% of the assets.

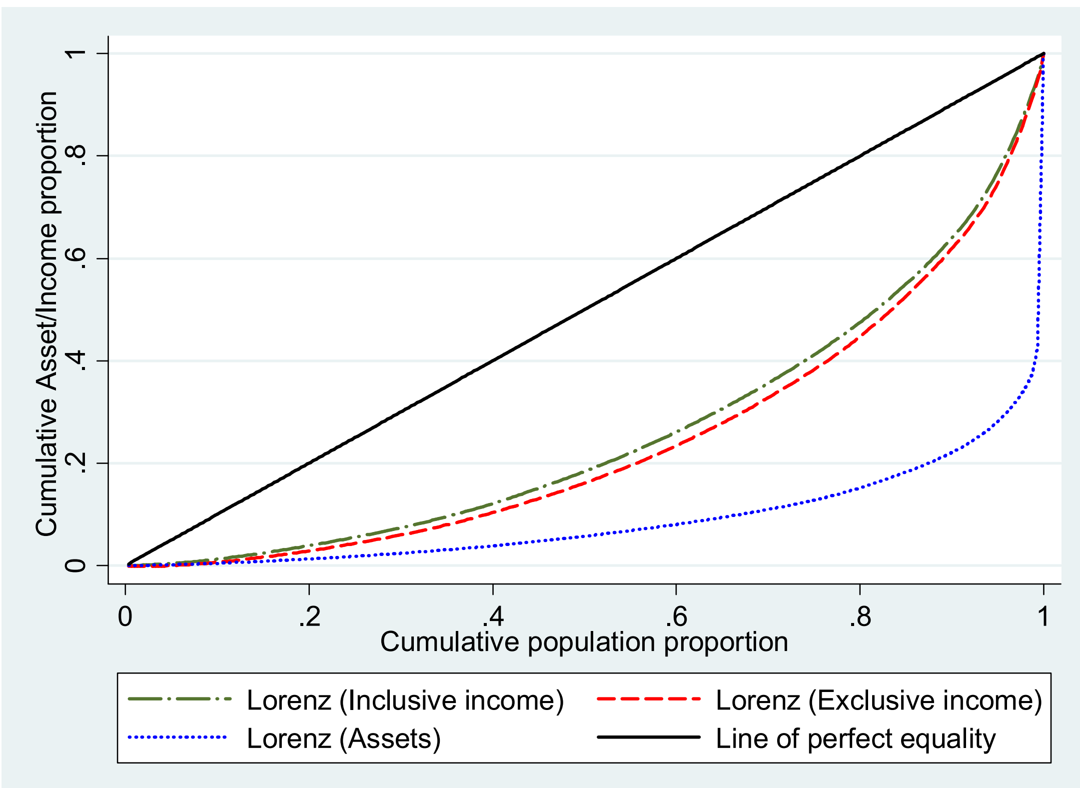


Figure 3.6 : Distribution of income and assets among sampled households: Lorenz curve

3.7 Social Capital Endowments

The concept of social capital is used repeatedly in different chapters of this thesis. In the respective chapters, contextual explanations are offered on the relationship between social capital and different issues tackled in the chapters. This section offers a detailed discussion on how the level of social capital for each household and for different Water Resource User Associations was estimated. The section further presents descriptive statistics on the estimated social capital at household level and at WRUA level. Social capital is a concept that has become widely used in many disciplines such as education (Coleman 1988); civic participation (Putnam 2000), natural resources management (Pretty & Ward 2001) and agricultural innovations (van Rijn et al. 2012). Although there is no a generally agreed definition of the concept, what is unanimously agreed is that social capital is all about social networks, the horizontal bonds that exist between relatively homogenous people (bonding social capital) and the vertical bridges that link diverse people (bridging social capital) (Putnam 2000). Uphoff (1999) further breaks social capital down into cognitive and structural components. According to this categorization, social capital can be viewed to be established based on shared norms of trust, norms of reciprocity and is facilitated by shared values. Further, Social capital can be viewed to be a composite of networks, relationships and institutional structures which link individuals. Therefore, social capital is an important asset in any community because it is the lubricant that oils social relationships in a community hence facilitating collective action (Ostrom & Ahn 2009). Social capital also enhances the capacity of a household to access other forms of capital, access information and also avoid opportunistic behavior.

Social capital can be looked at as a composite concept that can be disaggregated into many components. In the current study five components of social capital were estimated namely: *social participation, social networks, social support, reciprocity and trustworthiness.* Indices were developed for each of these components using principal components analysis (PCA) approach. PCA was conducted in three steps: First, respondents were asked specific questions that were used as indicators of each of the 5 components of social capital. Second, PCA with orthogonal rotation was carried out on these items. Sampling adequacy for the analysis was verified using Kaiser-Meyer-Oklin (KMO)[9] statistic while Bartlett's test of sphericity[10] was used to test whether correlations between items were large enough for PCA. Third, the components obtained from step 2 with Eigenvalues greater than 1 were selected for further analysis. The factor scores in each PCA component were summed up for each social capital component to obtain a single score and normalized on a 0-1 scale. The higher the score

[9] This statistic is used to compare the observed correlation coefficients in relation to the partial correlation coefficients. Large KMO values are preferred because they indicate that potential factors can be explained by the other variables.

[10] This statistic is used to test the null hypothesis that the correlation matrix is an identity matrix. The variables should be highly correlated if they belong to the same factor.

(closer to 1) the better. Normalization was done using the formula presented in Equation (3.2). The final indices were taken to represent the level of each of the 5 social capital components. These are later used as explanatory variables in other Chapters. To compute an overall social capital index, all the items used in the construction of the indices for the individual social capital components were entered into factor analysis at the same time and one indicator, also ranging from 0-1 generated using the same procedure explained above. Next, the descriptive statistics for the individual components of social capital are presented.

3.7.1 Descriptive Statistics on Social Participation

In the context of the current study, social participation is used to imply the intensity of group membership and participation. It is a measure of how individuals interact socially with fellow community members within groups. Social participation was captured through the items listed in Table 3.7. Three components had Eigene values above Kaiser's criteria of 1. These components explained 65% of the variance in the nine (9) original variables. Considering the correlations between these factor loadings and the individual variables, component 1 represents involvement in groups, component 2 represents participation in water management while component 3 represents participation in communal activities. The KMO statistic was 0.7 which is above the acceptable limit of 0.5 which is the minimum required to confirm that factor analysis objectives have been achieved.

The three components were aggregated, rescaled and then averaged to obtain a mean social participation index for each sub-catchment in the Lake Naivasha basin. The mean values are as shown in Figure 3. 7**.** Upper Malewa WRUA had the highest level of social participation. This could be because most of the farmers in the WRUA are irrigators and therefore participation in water projects boosted their social participation. Further, most of the farmers there also grow carrots. These are labour intensive crops especially during first stages of crop establishment and during harvesting. Therefore rotating labour saving groups are common in the area to facilitate pooling of labour.

Table 3.7: Principal component analysis results on social participation

Variables	Components: Involvement in groups	Components: Participation in water management	Components: Participation in communal activities
At least one person in the household is a member of a group	**.820**	.103	.077
Holds leadership position in the group	**.869**	.119	.057
Frequency of active involvement in a group	**.559**	.096	-.042
No of household members in groups	**.923**	.051	.023
Membership in WRUA	.178	**.709**	.044
Membership in Community water project	-.079	**-.773**	-.102
Participation in communal water management	.056	**.739**	.120
Time spent in communal activities (hrs/year)	.066	-.018	**.896**
Participation in communal activities	-.016	.362	**.751**
Summary statistics			
Eigenvalues	2.97	1.80	1.09
% of variance explained	32.99	20.00	12.08
Total % of variance explained	65.07		
Average overall score (0-1 scale)	0.31		
KMO statistic	0.70		
Bartlett's Test of Sphericity			
(36)	885.08		
p	0.000		

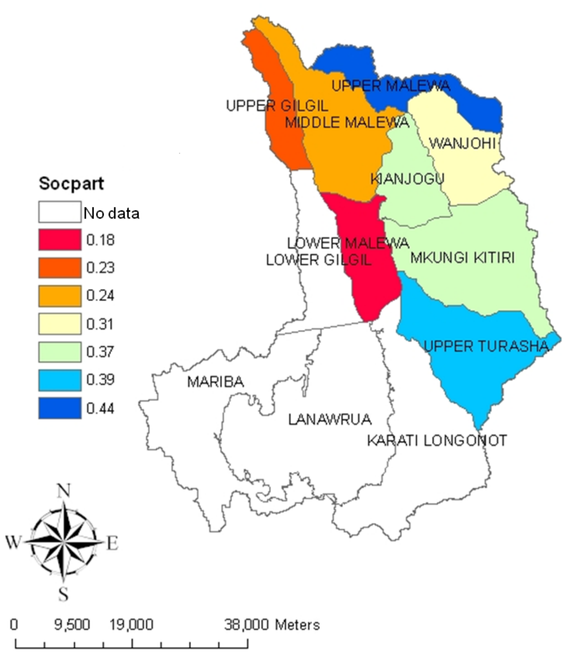


Figure 3. 7 : Average social participation indeces for different WRUAs

3.7.2 Descriptive Statistics on Social Networks

Social networks refer to the interconnectedness between individuals, their family members, friends and other community members through which formal and informal interactions occur. Coined by Barnes (1954) the concept has been used widely to imply nodes of individuals, groups or organizations that tie in different forms of interdependencies such as shared values and norms, kinship and friendship ties and in-cash and in kind exchanges (Serrat 2010). Social networks are fostered through social participation since involvement in groups helps to strengthen individuals' social interactions and consequently networks. Four items were used in the current study to capture social networks.

The results in Table 3.8 indicate that two components had eigenvalues greater that 1 and explained 65% of the variation in the original variables. The two extracted components represent local networks and external networks. Local networks are those that occur within a small span within the community. External networks however span within wide areas beyond the physical boundaries of the community. Both KMO statistics and Bartlett's Test of Sphericity gave satisfactory results.

Table 3.8: Principal component analysis results on social networks

	Rotated Factor loadings	
	Local networks	External networks
Years of household membership in groups	**.827**	.074
Intensity of social interactions (people contacted)	**.829**	.039
Number of household members working outside village	.011	**.794**
Number of months spend away from home	.098	**.771**
Summary statistics		
Eigenvalues	1.499	1.114
Cumulative % of variance	65.33	
Average score (0-1 scale)	0.19	
KMO statistic	0.533	
Bartlett's Test of Sphericity		
χ^2 (6)	71.11	
p	0.000	

As indicated in Figure 3.8 the WRUA average social networks index ranged between 0.12 and 0.23 which is generally low. Lower Malewa WRUA which also had the lowest social participation index also had the lowest social networks. This is because the two components of social capital are somehow complementary.

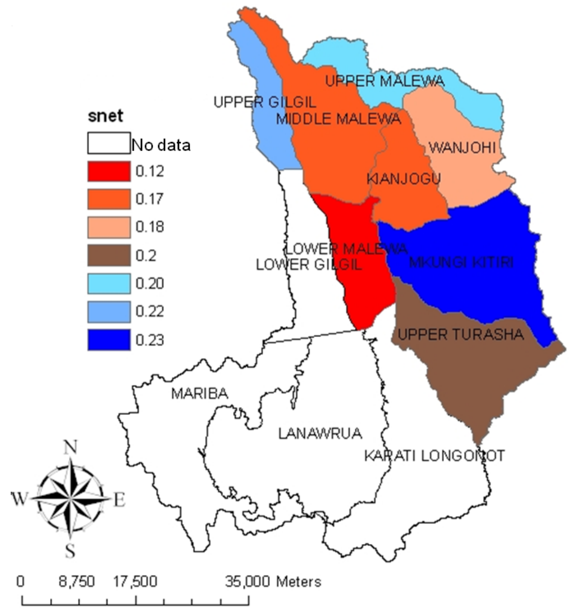


Figure 3.8: Average social networks index for different WRUAs

3.7.3 Descriptive Statistics on Social Support

Social support as used in this study refers to the ability of individuals to secure assistance from different quarters in the community especially in times of need or to perceive that they would receive help in times of distress. The concept therefore has both perception and actual components. The perception components relate to the feeling that an individual is cared for and that in the event of a misfortune, assistance will be available. The actual component is related to evidence that actually assistance has already been accorded to the person during times of distress or need. These two components are what Barrera, Jr (1986) refers to as perceived social support and enacted social support respectively. Social support could be sourced from different quarters including friends, family, neighbours, the government and even humanitarian organizations. Some questions capturing both perceived and received social support were included in the survey instrument and are summarized in Table 3. 9.

Table 3. 9: Principal component analysis results on social support

Variables	Rotated Factor loadings			
	Perceived community support	Actual support	Perceived organization support	Perceived family support
Social support available from close family members	.179	.221	-.284	**.758**
Social support available from close relatives	.192	.324	-.276	**-.681**
Social support available from neighbours	**.686**	.038	.075	-.005
Social support available from mutual support groups	**-.766**	-.042	-.024	-.016
Social support available from religious groups	-.229	**.665**	.495	.079
Receives remittances	.183	**.769**	-.164	-.048
Social support available from NGOs	.176	-.047	**.817**	-.052
Summary statistics				
Eigenvalues	1.366	1.134	1.053	1.035
% of variance explained	17.757	17.038	15.755	14.988
Total % of variance explained	65.54			
Average overall score (0-1 scale)	0.22			
KMO statistic	0.513			
Bartlett's Test of Sphericity				
χ^2 (45)	42.838			
p	.003			

Results in Table 3. 9 indicate that three components capturing perceived social support and one capturing actual social support were extracted. All these components met the criteria of eigenvalues greater that 1 and explained 65% of the variation in the individual variables. Figure 3. 9 presents the average social support scores for the eight WRUAs where the study was conducted. The average social support index ranged between 0.14 and 0.23.

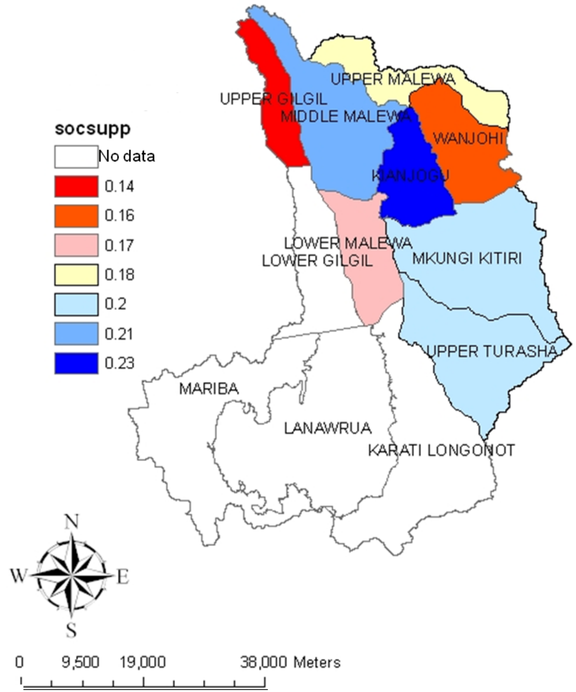


Figure 3. 9: Average social support index for different WRUAs

3.7.4 Descriptive Statistics on Trustworthiness

Trustworthiness can be conceptualized as value judgment that people place on others based on the belief that they can be trusted or not. Trustworthiness facilitates the formation of trust which is an important determinant of collective action. In the current study, estimation of trustworthiness was deemed important because establishing collective action on agri-environmental issues depends to a very large extent on the trustworthiness in the community which helps to establish trust. After factor analysis, two components which had eigenvalues greater than 1 were extracted (Table 3. 10). These components were named perceived trust and proven trust depending on the variables which they were highly correlated with. The two components explained approximately 60% of the total variation in the original four variables. The analysis also satisfied the required criteria based on the KMO statistics and the Bartlett's test of sphericity.

Table 3. 10: Principal component analysis on trustworthiness

	Rotated Factor loadings	
	Perceived Trust	**Proven trust**
A misplaced purse in the community is likely to be returned	**0.808**	.091
Community members more trusted than non community members	**0.818**	-.013
I can trust most people in my community with a loan	.002	**.731**
I have engaged in mutual exchanges with other community members	.068	**.727**
Summary statistics		
Eigenvalues	1.369	1.029
% of variance	34.224	25.716
Cumulative % of variance	59.939	
Average score (0-1 scale)	0.47	
KMO statistic	.508	
Bartlett's Test of Sphericity		
χ^2 (6)	40.225	
p	.000	

On average Mkungi Kitiri WRUA had the highest trustworthiness index while Lower Malewa had the least (Figure 3.10). Combining these indeces and the social participation and social networks indices can be used to predict where in the basin collective action is likely to emerge and succeed. An interesting result was however to see that in Upper Malewa, the level of trust is very low although this was the WRUA with the highest level of social participation. This could imply that a basic level of trust is sufficient for collective action to emerge.

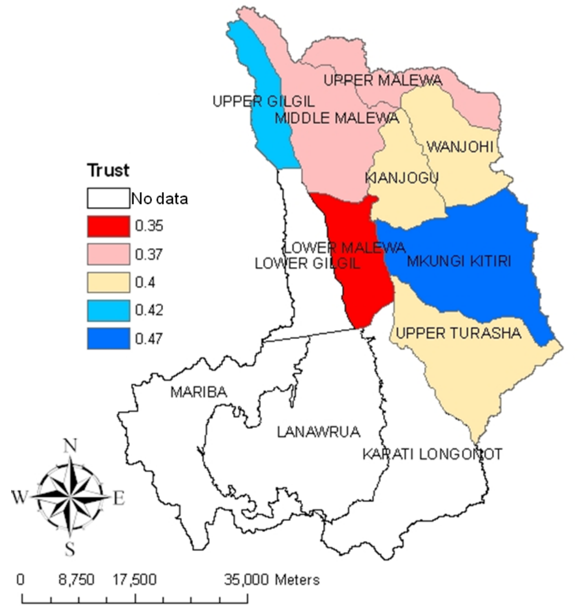


Figure 3.10: Average social trustworthiness index for different WRUAs

3.7.5 Descriptive Statistics on Reciprocity

Reciprocity is a concept that is closely related to trust. In the current study it is used to refer to free exchange of materials such as planting materials and labour. An individual engaged in a reciprocate exchange does so under the assumption that the other parties will do so in the future. This could be through returning exactly what they were given (simultaneous reciprocity) or returning the favour in another way (diffuse reciprocity). What is important though is that at the end, all the parties are left satisfied. Collective action and social cooperation are mainly embedded within the principle of reciprocity. Six items (variables) were used to estimate reciprocity components. Out of these, two components with eigenvalues greater than 1 were extracted explaining approximately 52% of the variation. The two components were named simultaneous reciprocity and diffuse reciprocity (Table 3. 11).

Table 3. 11: Principal component analysis on reciprocity

	Rotated Factor loadings	
	Diffuse reciprocity	Simultaneous reciprocity
I get mutual benefit from communal water management activities	**.762**	.154
I benefit by being a member of the water project	**.813**	-.115
I benefit by being a member of a WRUA	**.652**	-.294
I don't benefit by participating in communal activities	**.539**	.354
My villagers help one another	-.081	**.685**
I have exchanged planting materials with other farmers in the past	-.053	**-.672**
Summary statistics		
Eigenvalues	1.965	1.170
% of variance explained	32.757	19.495
Cumulative % of variance explained	52.252	
Average score (0-1 scale)	0.44	
KMO statistic	.630	
Bartlett's Test of Sphericity		
χ^2 (21)	204.345	
p	.000	

The two components were used to estimate the reciprocity index used in mapping reciprocity in the Lake Naivasha basin (Figure 3. 11). Spatial variation in the degree of reciprocity was observed in the Lake Naivasha basin. Wanjohi WRUA had the highest level of reciprocity while the least levels of reciprocity were found in Kianjogu. It was also observed that mostly the WRUAs which had high levels of trustworthiness also had relatively high incidences of reciprocate exchanges.

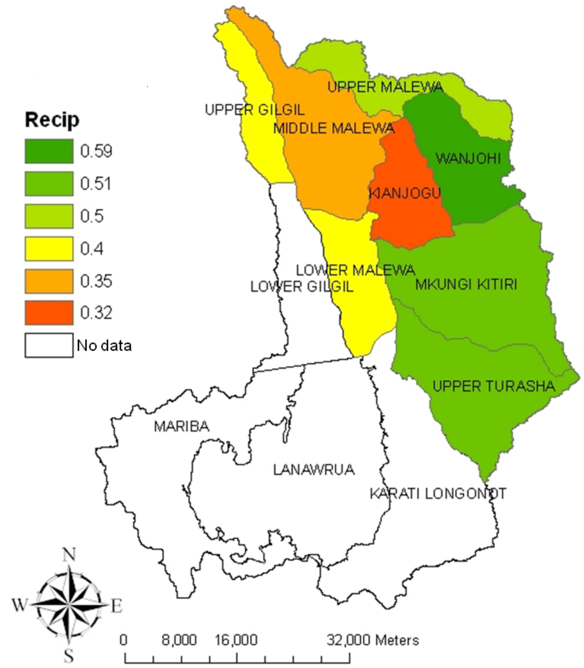


Figure 3. 11: Average social trustworthiness index for different WRUAs

3.7.6 Overall Social Capital Index

After computing the individual social capital components, an overall social capital index was also computed. As indicated in Figure 3.12, social capital scores differed spatially across the eight WRUAs, ranging from 0.34 (Lower Malewa) to 0.59 (Kianjogu). The average social capital index for the entire basin was 0.44. Assessing the social capital of every WRUA can be a good indicator to show where collective action is likely to succeed. However, there is a caveat to this statement. It has to be noted that social capital is only one of the major but not the sole determinants of collective action. Therefore, when assessing the possibility of forming collective action in the Lake Naivasha basin all the community attributes that are relevant for collective action formation have to be assessed.

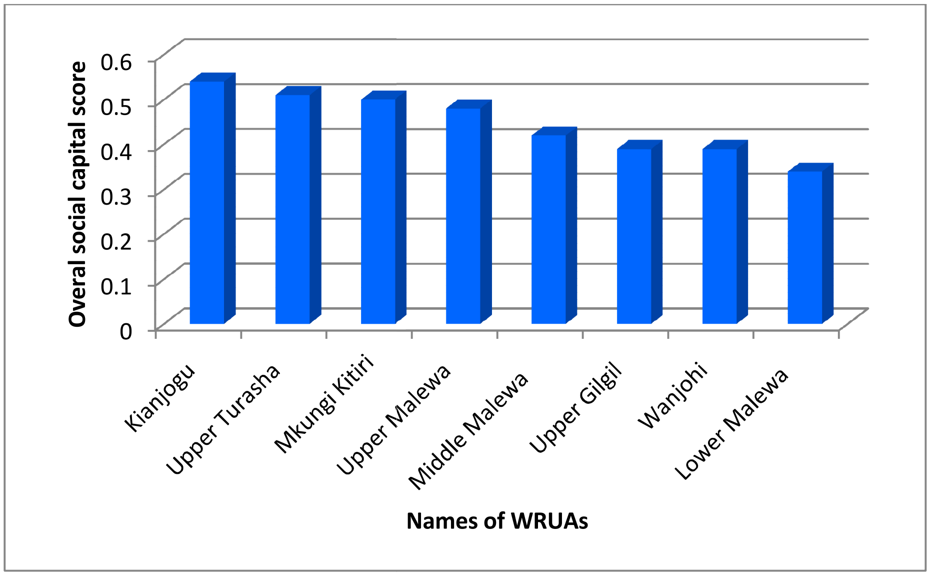


Figure 3.12: Overall social capital index measures for WRUAs in the Basin

3.8 Attitudes and Perceptions among Sampled Farmers

The perception of sampled farmers on a number of aspects related to water management, water use, water rules and status of environmental problems such as water scarcity and soil erosion was assessed using a five point likert scale questions. The survey sought to capture respondent's perceptions on five key elements: (1) Spatial interrelationship between downstream and upstream water users (2) Government water management (3) Communal water management (4) Water rules formulated by the community (5) Water rules formulated by the government. The descriptive statistics for each element are explained next.

3.8.1 Perceptions on Spatial Interrelationship between Water Users

The questions under this category aimed at assessing the extent to which the interviewed individuals perceived the link between their activities and the welfare of others in the basin. The objective was to gauge whether the sample farmers perceived that their farming activities had a negative impact on the environment. Table 3.12 presents the responses obtained during the survey. Generally, the sampled farmers did not strongly perceive that agri-environmental externalities are a problem in the area as indicated by the responses. Majority of the respondents were for the opinion that their farming activities were not related to the status of water resources in the area. Further, majority did not feel that their activities were affecting those downstream neither did they feel that they were being affected by those upstream to their farms.

Table 3.12: Perceptions on externalities

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
My farming activities affect the people who are located downstream from my farm	99(.32)	123(.40)	3(.01)	48(.16)	35(.11)
There is no relationship between my individual farming activities and the status of water resources in my area	26(.8)	68(.22)	3(.01)	139(.45)	72(.23)
The quality of the water I get is affected by the activities of the people who are upstream	57(.19)	106(.34)	11(.4)	46(.15)	88(.29)

The figures in parentheses are percentages

3.8.2 Perceptions on Government Water Management

Public water management in the Lake Naivasha basin is done by the Water Resources Management Authority (WRMA). The perception of respondents on the performance of the public water administrators was assessed using the statements in Table 3. 13. It emerged that although majority of the respondents were not for the opinion that public water administrators were more efficient than communal ones, they still had confidence in them and satisfaction in the public water management system. However, the split among the respondents on these statements were almost 50-50. This could be because that majority believed that the government had played an important role in streamlining water management issues. The formation of WRUAs to assist WRMA in water management could have enhanced this perception. Ideally WRUAs are supposed to be bottom up initiatives but because of the manner in which they were introduced in the Lake Naivasha basin, they are widely perceived to be government initiatives (top down).

Table 3. 13 : Perceptions on public water management

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Government water administrators are more efficient than the communal water administrators	69 (.22)	108(.35)	33 (.11)	57(.19)	41(.13)
The government has been playing an important role in water management issues	54 (.18)	61 (.20)	25(.08)	98(.32)	70(.23)
Generally speaking I have confidence in government officials managing water issues	45(.15)	76(.25)	33 (.11)	92(.30)	62(.20)
Satisfaction with government water management system	35 (.11)	88 (.29)	33 (.11)	105(.34)	47(.15)

The figures in parentheses are percentages

3.8.3 Perception on Communal Water Management

Respondents were asked to indicate their responses to some statements that were used to gauge their perception on communal water management (Table 3. 14). Majority agreed that after 2005, water management in their area had improved. That is the year when most WRUAs in the watershed were established and therefore started assisting WRMA in water management. Respondents overwhelmingly agreed to the statement that they had confidence in communal water management leadership. They also indicated satisfaction in WRUAs in managing water issues and also in communal water management systems such as community water projects.

Table 3. 14: Perceptions on communal water management

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Water management in my area improved after 2005	44(0.14)	82(0.27)	21(0.07)	106(0.34)	55(0.18)
Satisfaction on local water management systems	22(0.07)	53(0.17)	39(0.13)	102(0.33)	92(0.30)
I have confidence in the Community water management leadership	27(0.09)	29(0.09)	36(0.12)	89(0.29)	127(0.41)
Satisfaction on performance of the WRUAs in managing water	23(0.07)	44(0.14)	92(0.30)	76(0.25)	73(0.24)

The figures in parentheses are percentages

3.8.4 Perception on Water Rules Formulated by the Community

In the Lake Naivasha basin, both formal and informal rules on water abstraction and use have been implemented. Community water rules are mainly established by community water projects to govern the conduct of its members. Some of these are summarized by Willy et al. (2012). The statements in Table 3. 15 were used to gauge the perception of respondents on the design of communal rules and fairness in their enforcement and sanctioning mechanisms. Majority of the respondents showed satisfaction in the communal rules and also the way in which rule breakers are punished. The respondents were also strongly of the opinion that peer monitoring was existing in the community given that majority indicated that people could report rule breakers. However, we note that a substantial number of respondents were in the neutral category which could be an indicator of low awareness of the communal rules. This would be true especially for respondents who were not members of any community water project. Most of the respondents indicated satisfaction in the flat rate water prices they were paying at the time of the survey where a monthly fee of Ksh. 100 (Approx. 1 Euro) was charged regardless of the amount of water used. However, the Water Act 2002 introduced block rate pricing which is yet to be implemented in most parts of the watershed.

Table 3. 15: Perceptions on communal water rules and their sanctioning mechanisms

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The communal methods of punishing those who break rules on water are fair to all	11(0.04)	42(0.14)	62(0.20)	96(0.31)	97(0.31)
I am satisfied with the communal rules governing water use in this area	19(0.06)	26(0.08)	66(0.21)	92(0.30)	105(0.34)
In this area, anybody can report another person if they are breaking water rules	22(0.07)	43(0.14)	50(0.16)	82(0.27)	111(0.36)
I am satisfied with the prices of water we are paying	20(0.06)	40(0.13)	82(0.27)	100(0.32)	66(0.21)

The figures in parentheses are percentages

3.8.5 Perception on Water Rules Formulated by the Government

Government rules governing water management are mainly found in the water Act 2002 (GoK 2002) and the water resources management rules, 2006 (GoK 2006). Some of the rules are summarized by Willy et al. (2012). Just like in the case of communal rules, it can be noted that the neutral category also had many respondents, even more than those in the communal rules case (Table 3. 16). This could also be an indication of low awareness of water management rules which was even lower for the government rules compared to the communal rules. The response to the second statement was meant to capture satisfaction in water permits. However, since majority of the respondents were not even aware of the permit requirement, their responses could have been referring to the method used by the community water projects to allow access to water.

Table 3. 16: Perceptions on government water rules and their sanctioning mechanisms

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The government ways of punishing those who break rules on water are fair to all	32(0.10)	61(0.20)	64(0.21)	82(0.27)	69(0.22)
I am satisfied with the method used in this area to allow people to use water for irrigation	46(0.15)	44(0.14)	76(0.25)	63(0.20)	79(0.26)
I am satisfied with the government rules governing water use in this area	41(0.13)	54(0.18)	72(0.23)	76(0.25)	65(0.21)
Satisfaction on government rules on water access and use	20(0.06)	85(0.28)	55(0.18)	99(0.32)	49(0.16)

3.8.6 Reliability Analysis on Perception Statements

Reliability analysis (RA) was done to assess the internal consistency of the statements in all the above perception elements using the Cronbach's alpha statistic. Reliability analysis is used to determine how closely related the statements are and how well they collectively measure the underlying (latent) construct that the items seek to measure, in this case, perception. Further, dimensionality of the scale was assessed using exploratory factor analysis. Results for factor and reliability analyses are presented in Table 3. 17 . Considering the Cronbach's alpha values elements B-E had high reliability (Cronbach's $\alpha > 0.7$) while only element A had relatively low reliability (Cronbach's $\alpha = 0.6$)

Table 3. 17: Results for reliability and factor analysis

		Descriptive statistics		Reliability analysis	Factor (Dimensionality) analysis		
Perception element	**Number of items**	**Mean perception score**	**Mode perception score**	**Cronbach's alpha**	**KMO**	***p***	***Variance explained (%)***[a]
A	3	7.82	6	0.557	0.597	0.000	53.3
B	4	12.17	10	0.731	0.736	0.000	56.3
C	4	14.04	16	0.777	0.76	0.000	60.4
D	4	14.87	17	0.744	0.76	0.000	57.0
E	4	5.79	6	0.736	0.726	0.000	56.2

a. This is the percentage of the total variance in all variables that is explained by the extracted component(s).
A = Perceptions on Spatial interrelationship between downstream and upstream water users
B = Perceptions on Government Water Management
C = Perception on communal water management
D = Perception on water rules formulated by the community
E = Perception on water rules formulated by the government

CHAPTER FOUR

4 Assessing the Potential for Agri-Environmental Cooperation in Lake Naivasha Basin[11]

4.1 Introduction

The problem of agri-environmental externalities has been a challenge to policy makers for a long time in both low and high income countries. The externalities emanate from the fact that agriculture draws most of the major inputs and natural services from nature, therefore creating direct interdependence between agriculture and the environment (Power 2010). Because of this interdependence, agriculture is usually associated with processes that impact the environment negatively such as deforestation, land degradation, greenhouse gas emissions, soil erosion, water pollution and biodiversity loss. In seeking effective mechanisms for resolving environmental problems emanating from agriculture, researchers have in the recent past increasingly assessed the potential for using cooperative/suasive instruments to deal with agri-environmental externalities. Some of the most studied cooperative initiatives touching on agriculture and the environment include agri-environmental cooperatives, watershed management programmes, ground water management programmes, communal irrigation schemes and voluntary land diversion schemes (Ostrom 1990; White & Runge 1994; Cárdenas et al. 2009; Goldman et al. 2007).

Most of the case studies mentioned here have identified agri-environmental cooperation initiatives as one of the possible instruments to successfully mediate interactions between agriculture and the environment. It has been found that agri-environmental cooperation can help to achieve near Pareto optimal solutions especially where markets and government regulatory instruments have limited success (Lubell et al. 2002). Agri-environmental cooperation is defined as a voluntary collective action initiative that involves a continuum of commitment ranging from awareness creation and information sharing to collaboration of heterogeneous individuals who have shared goals and anticipate benefits from their cooperative efforts (Polman & Slagen 2002). In the current text, collective action and cooperation have similar connotation and therefore these two terms will be used

[11] This chapter is based on:
Willy, D.K., Kuhn, A., Holm-Mueller, K., Mitigating Unilateral Agri-Environmental Externalities through Cooperation: An Assessment of Determinants of Participation in Collective Action Initiatives in a Low Income Country (*Manuscript ready for Submission*).

synonymously. Agri-environmental cooperation entails horizontal non market coordination mechanisms where individuals voluntarily and collectively engage in action selection and implementation, information gathering and sharing, organizational adjustments and conflict resolution (Hagedorn et al. 2002). Action selection in agricultural externalities' context involves collective choice of activities and technologies which involve both generation of environmental goods and services and mitigation of negative externalities produced jointly with agricultural commodities.

Esteban & Dinar (2013) demonstrate that cooperation in management of ground water where externalities are present can yield a Pareto improvement. The study finds that farmers were better off with cooperation than without. Ayer (1997) presents some successful cases of grass root collective action initiatives that were initiated to deal with externalities caused by pesticide application and washing of manure, inorganic fertilizers and eroded soils into water courses in the USA. The author identifies grass root collective action as one of the options for addressing agri-environmental problems that have the potential of moving production closer to a Pareto optimum than would the uncoordinated self-interest decisions of individuals and firms. White & Runge (1994) also present a case of successful cooperation in managing a watershed in Haiti, within a society that had historically been branded incapable of self organization.

From these case studies we identify some fundamental aspects. First, since agri-environmental externalities create collective action dilemmas they would best be addressed using collective solutions (Ayer 1997; Ostrom 1990). Second, due to the large number of individual farmers involved, and the need for economies of scale, generation of ecosystem services will succeed if coordinated at landscape level. Third, coordination mechanisms would succeed if designed to encourage the participation of as many land owners as possible. What we note however, is that empirical studies on the area of agri-environmental externalities in the low income countries are very scanty. Except a few cases (e.g. White & Runge 1994), most of the existing empirical studies on agri-environmental schemes are from high income countries. At the same time, agriculture continues to be a dominant sector in most low income countries and therefore agricultural sustainability is no longer an optional but a priority focal area. Therefore studies in the area of agri-environmental interactions may play a key role in informing policy to guide sustainability in agriculture.

The current study seeks to contribute to the understanding of how collective action around agri-environmental externalities can work in a low income country setting. Using empirical household survey data from a watershed located in rural Kenya, the current study sets out to assess the potential for agri-environmental cooperation in addressing agricultural externalities. The externalities considered in the case study are the unilateral non-point sources of agricultural pollution - siltation and eutrophication - and water scarcity that is attributable to water over-abstraction. The broad goal of the study is achieved in two steps. First, a two step cluster analysis approach is used to identify the cooperative behavior of sample households in the Lake Naivasha basin by assessing their degree of participation in activities involving voluntary provision of public goods in the community. Through this, households are categorized either as cooperators or defectors. Second, the study utilizes a logistic regression model to identify factors that make individuals more likely to cooperate.

The next section describes the research area and the existing collective action opportunities. Section 4.3 presents a theoretical framework to answer the question of why people cooperate and identify theoretically important variables and their hypothesized influence on cooperation. Section 4.4 presents the research methodology, including description of data types and collection methods and empirical framework. Results are presented and discussed in section 4.5 and finally section 4.6 presents a summary, conclusions and policy implications emerging from the study.

4.2 The Need and Opportunities for Cooperation in the Lake Naivasha Basin

The Lake basin is located in the Kenyan Rift Valley at 0º30’ S-0^{0}55' and 36^{0} 09' E-36^{0}24' E. The basin supports a vibrant commercial horticulture and floriculture industry, whose growth has accelerated greatly in the past two decades due to good climatic conditions and existing links to local and international markets for vegetables and cut flowers. The industry promotes economic growth and livelihood support in the basin by offering employment and income opportunities and engagement of small holder farmers in out-grower schemes. Further, the basin supports tourism, fisheries, and pastoral and small holder subsistence food production. Irrigated floriculture occupies about 5025 ha around the Lake (Reta 2011) while small scale farms occupy approximately 210,000 ha, with an average 2.5 ha per farm household.

Expansion of crop land into fragile areas such as steep-slopes and riparian land has been identified as a major cause of increased soil erosion leading to siltation/sedimentation in the water bodies (Becht 2007; Stoof-Leichsenring et al. 2011). Sediment yield in the lake has risen in the past 5 decades, from 1.3 tonnes ha^{-1} $year^{-1}$ in 1947 to 8.9 tonnes ha^{-1} $year^{-1}$ in 2006

(Stoof-Leichsenring et al. 2011) a trend that has been attributed to anthropogenic influences. Although siltation has not caused an alarming impact on the lake depth, it has affected water quality through increased turbidity. This has in return had direct and indirect effects on water quality limiting its use for human activities, fisheries, tourism and agriculture besides causing biodiversity loss (Willy et al. 2012). Over the same period, Kitaka et al. (2002) show that due to continuous nutrient (N and P) deposition, the Lake has degraded into a eutrophic status. Eutrophication and siltation cause poor light penetration, restricting water use for fisheries, drinking and recreation. Poor light penetration associated with eutrophication is also responsible for extinction of benthic flora (Macrophytes) which were an important component of the ecosystem (Becht 2007).

Expansion of agriculture has also had a negative impact on the quantity of water resources in the basin. Becht & Harper (2002) demonstrate the impact of water abstractions on the Lake level. Their model shows a deviation of observed lake level from the simulated level since the onset of intensive flower industry around the Lake in the early 1980's and estimated a drop in the long term average Lake level by 3-4 M as a result of abstractions. This observation is echoed by a number of other studies who confirm the string linkages between the long term equilibrium in water levels and anthropogenic effects (see for example Becht & Harper 2002; Mpusia 2006; Yihdego 2005). Given that the water users share a common pool resource in the form of ground water aquifers and surface water reservoirs, over-abstraction by one user is definitely likely to impose an externality to the other water users. Also, water over-abstraction by upstream users may reduce the downstream flows therefore reducing the amount of water available to the downstream users.

Addressing these agri-environmental externalities has been an institutional challenge in the research area. The nature of the problem implies that any institutional innovation that addresses the upstream-downstream dimensions of the problem will be beneficial for the environment in the Lake and for the growers around the Lake. Since there are no possibilities to enforce measures on upstream users that are beneficial to downstream users and because there exists significant barriers to bargaining between downstream and upstream resource users, any measures implemented to mitigate the negative impacts must be win-win (see Willy et al. 2012) . Mitigating negative externalities emanating from upstream activities is obviously at the interest of the downstream farmers. Also, if the measures are win-win, then they may also be in the self-interest of small-holder cooperatives in the upper catchment. Undertaking them through collective action further improves efficiency and creates substantial private and social benefits. This approach therefore creates a link between the environmental problems at the lake and the collective action in the catchment that is not directly aimed at improving lake water quality or availability.

However, cooperation by individuals is conditional on availability of opportunities to cooperate in the community. In the Lake Naivasha Basin, opportunities to cooperate have been created through community water projects (CWPs), Water resource Users Associations (WRUAs) and community based organizations (CBOs). These collective community initiatives have been organizing various activities which required the participation of community members. Table 4. 1 presents information on the main activities that were organized in different sub-catchments. These activities are used later to assess the tendencies of households to cooperate based on their participation in these activities.

Table 4. 1: Opportunities for cooperation in the Lake Naivasha basin

	Activities organized in the community requiring cooperation				
WRUA	Construction of soil conservation structures	Communal tree planting	Communal water management	Construction of community facilities	Maintenance of access roads
Kianjogu	X	✓	✓	✓	✓
Lower Malewa	X	✓	X	X	X
Middle Malewa	✓	✓	✓	X	✓
Upper Malewa	✓	✓	✓	✓	✓
Mkungi Kitiri	X	✓	✓	X	✓
Upper Gilgil	X	✓	X	X	✓
Upper Turasha	X	✓	✓	✓	X
Wanjohi	✓	✓	✓	✓	✓

✓ Means that the activity was organized in that particular WRUA
X Means that the activity was not organized in that WRUA

The main communal soil conservation activities in the basin are construction of soil conservation structures and volunteer community tree planting. Soil erosion control structures include gabions and check dams at public areas such as road-sides and public land to prevent soil erosion and degradation of such areas. Communal tree planting is also aimed at reforestation of cleared public areas and sometimes on private land. Community water projects represent the most prominent form of collective action in the research area. Communities in most the WRUAs, especially those located close to the Aberdare forest established communal water distribution infrastructure which involved establishing a water intake point and setting up a water distribution piping and storage system. Collective action was needed at the beginning when establishing the water distribution infrastructure. Cooperation is also necessary throughout to maintain the infrastructure and also to facilitate running of the water projects and monitoring and enforcement of rules.

The quality of most rural access roads in the research area is poor, which greatly affects transportation of agricultural output from the farms and therefore increases transport costs for agricultural output. Maintaining such roads requires volunteering of manpower from community members. This is therefore one of the collective action activities organized occasionally in most WRUAs in the research area.

4.3 Theoretical Framework, Variables and Hypotheses

4.3.1 The Theory of Collective Action: Why Do People Co-operate?

The understanding of why people cooperate or fail to cooperate in the provision of public goods has increased tremendously in the past decades. As we generally know it, co-operation entails creation of collective benefits which are shared by all people involved regardless of their individual share in the costs of providing the benefits. Because of this nature of collective goods, everyone has an incentive to free ride on the efforts of others. However, if everyone free rides then the benefits are not produced and therefore there will be nothing to free ride on (King & Walker 1992). Given this fact, it is important for theory to answer the question of why people cooperate or fail to do so. This is synonymous to understanding why some individuals would overcome the temptation to pursue self interest goals while others would choose to free ride on the efforts of others. Individual cooperation may be viewed to be motivated by utility maximization, where each person's utility depends on how they value the collective good (Reuben 2003). Given that each individual weighs out the costs and benefits of cooperating differently, a rational self interested individual will only cooperate if the marginal benefits of cooperating will equal the marginal costs (Reuben 2003). At the end, it is unlikely that rational individuals will generate outcomes that are socially optimal since individuals do not necessarily consider the interest of others in the group. This section highlights some important theoretical aspects that could help to explain the behavior of individuals in a collective dilemma. We identify the theoretical explanations to help explain the circumstances under which some individuals will cooperate while others defect.

In the book '*The Logic of Collective Action',* Mancur Olson (1965) offers a clear explanation on group and organizational behavior, showing when it will be at the best interest of individuals to contribute individual efforts towards the provision of a collective good. Olson considers individuals engaged in the production of a collective good. In his model, the utility that each individual generates from the collective good is assumed to be depended on the total amount of the good produced. Further, the total amount of the collective good produced depends on the contribution from each individual. Olson identifies three conditions under which rational individuals will cooperate: (1) if there is substantial coercion, (2) if free riding is easily noticeable within the group and (3) when there are selective incentives. Coercion could either come from social pressure or a legal requirement. The ability to notice free riding depends on the extent to which each person's actions are visible and are likely to affect the utility of others. If the group is too large to the extent that free riding can go un-noticed then collective action is unlikely to occur. Visibility depends on (but is not limited to) the size of the group. Selective benefits on the other hand relate to the question of whether the group offers additional incentives to its members that would not be available to non-members. According to Olson, there will be no substantial participation in collective action unless members are enticed with such selective benefits (p51). However, Olson (1965) also recognizes the possibility of having a privileged group. In a privileged group, one individual or small group of individuals is willing to bear disproportionately larger share of the cost of providing a collective good. This could be because they receive higher utility from the collective good compared to the rest. A good example would be a wealthy resident in a neighbourhood who sole-handedly invests in a security or street lighting system, which also benefits all the neighbours who do not necessarily incur any cost.

4.3.2 Other Theoretical Considerations on Collective Action

Although Olson's theory greatly improved the understanding on cooperation in collective good situations, it did not offer answers to all theoretical questions relating to explaining why collective action emerges and understanding the behavior of individuals in a collective goods situation. It has emerged from a number of other studies that Olson's model can only explain some groups but may fail to explain why collective action emerges even in the absence of coercion and selective benefits.

Oliver (1984) finds that sometimes people will be willing to cooperate if no one else is willing to cooperate. This indicates that either there are some altruistic individuals in the society who will be willing to take the burden of providing a public good even when no one else is willing to do so or some individuals value the collective good more than others.

Studying cooperation in interest groups, King &Walker (1992) find that people are likely to cooperate if they are mobilizing against a collective bad that would threaten a common good. If individuals are convinced that a collective bad (or an externality) is a common threat, they will be willing to self organize towards solving the problem and protect group interests. The study draws a sharp contradiction to the selective incentives condition by Olson (1965). Rather, King & Walker (1992) conclude that under certain circumstances, the collective action dilemma can be overcome without necessarily having the groups provide pure private goods to individual members.

Another framework developed by Hagedorn et al. (2002) introduces the premise that the attributes of individuals and the transactions emanating from their activities are important in situations involving agri-environmental cooperation. The objectives of actors, their resource endowments, value systems, beliefs, attitudes and perceptions play a major role in determining their willingness and ability to cooperate with others and comply with collectively established rules (Hagedorn et al. 2002). Physical, social and human resources facilitate cooperation since they enable individuals to access information, power and social networks which help them to safeguard their interests, whether collective or individual.

Ostrom & Ahn (2009) also emphasize the importance of social capital in emergence and success of collective action. Individual social capital will enable individuals to establish trust and credible commitments which help to overcome collective dilemmas. Gillinson (2004) looks at social capital as both a private and a public good because establishing social networks helps individuals to benefit both privately and collectively. For example, social networks help people to access employment and business opportunities and at the same time build trust that may be very important for collective action in a community.

The position of an individual in a cooperation situation will also influence their incentives to cooperate or defect. Position could either be physical location or social status. Physical location influences the exposure of an individual to an externality and therefore determines the expected benefits from cooperation. For example in a basin, those upstream discharge pollutants on rivers hence inflicting harm on those downstream while the actions of those downstream do not affect those upstream (Quiggin 2001; Van Oel et al. 2009). Exposure and vulnerability to externalities therefore depends on the position of individual farms within the basin. Those extremely downstream may have the highest impacts while those upstream will have to bear the highest abatement costs. Those downstream are facing two different kinds of incentives. On the one hand, if those upstream undertake any efforts there is an incentive for those downstream not to engage in cooperation and free ride. On the other hand, since they are the ones exposed to more harm, they have an incentive to cooperate towards reducing the harm and also to initiate cooperation whereas those upstream under certain circumstances may not have incentives to initiate. However, as discussed earlier, if cooperation creates a win-win such that there are also selective benefits, then the upstream users may have an incentive to initiate a cooperation so as to solve their own prisoners' dilemma. Positions in terms of social status might also influence participation. Opinion leaders and other influential individuals in a community have a higher level of social coercion that will prompt them towards cooperation.

Finally, property rights are important in natural resources situations (Meinzen-Dick & Di Gregorio 2004). Particularly, the degree to which rights over nature components (land for example) are decentralized will affect the motivation to participate in collective initiatives by farmers (Hagedorn 2008). This is so because whether collective action is necessary or not may depend on the nature of property rights. For instance collectively owned resources will be better managed through collective action.

In the next section the key variables influencing cooperative behavior among individuals and their hypothesized signs are identified and explained.

4.3.3 Explanatory Variables and Hypotheses

The degree of participation in collective action is likely to be influenced by both endogenous and exogenous factors. In Table 4.2 the variables that are important determinants of individual participation in collective action are listed and will therefore be used in the analysis. These factors are grouped into seven categories and discussed below.

4.3.3.1 Expected Benefits from Cooperation

Individuals are expected to participate in collective activities if the benefits of participation exceed the costs of engaging in such cooperation. As argued by Olson, (1965) direct economic benefits are likely to encourage individuals to participate in collective initiatives. The benefits that someone expects are likely to be determined by either the nature of activities that they are engaged in or their location in the watershed. For example, farmers who are located at the extreme upstream are not likely to be exposed to externalities compared to those midstream and downstream (White & Runge 1994). The theoretical prediction is that those who stand to gain more are the ones who have the greatest incentives to cooperate. Therefore, in the absence of other incentives, upstream farmers will be more likely to defect than cooperate with those downstream while those midstream and downstream have highest incentives to cooperate. It is therefore hypothesized that households located upstream are less likely to cooperate.

However, if such cooperation will yield other benefits, then individuals will cooperate regardless of their position. Cooperation will be win-win if through cooperation individuals are likely to access selective private benefits, some of which might not be necessarily direct incentives from the group. For example if cooperation is likely to enhance the capacity of the household to generate private income, then cooperation will be the most attractive strategy. The following variables are hypothesized to have an influence on the cooperative behavior of individuals: the slope of the farm (*SLOPE*), whether a household is practicing irrigation or not (*IRR*), location of a farm within a watershed (*HHLOC*) and ownership of a borehole/well (*BHOLE*). Farms on steep slopes are more vulnerable to erosion. Therefore, since cooperation is viewed as a way of improving the conservation of individual farms and therefore generating individual benefits, farmers on such farms are more likely to cooperate. Farmers engaging in soil conservation to minimize siltation will also improve the quality of their land and consequently their crop yields. In the same way, farmers who engage in soil fertility management practices such as crop rotation and mixed cropping also end up saving their fertilizer costs while improving yields and reducing water pollution from nutrients. Ownership of a borehole indicates that the household has managed to solve its water scarcity problems privately and therefore stands to benefit less by co-operating with others especially in matters to do with communal water provision. Therefore this variable is hypothesized to have a negative effect on co-operation.

Table 4. 2: Factors hypothesized to influence cooperation

Variable name	Explanatory variable	Measure	Hypothesized effect on cooperation
LANDTEN	Holds land title deed	Dummy (1=Yes)	+
IRR	Practicing irrigation	Dummy (1=Yes)	+
SLOPE	Farm located in extremely sloping area	Dummy (1=Yes)	+
HHEDUC	Household education	Years	+
EXTN	Perceives externality exists	Dummy (1=Yes)	+
OFFARM	Engagement in off farm activity	Dummy (1=Yes)	-
ASSET	Value of assets owned	Index (0-1)	-
COPBEN	Perception that cooperation is beneficial	Dummy (1=Yes)	+
HHSIZE	Household size	Number	+
TAMK	Distance to nearest tarmak road	Kms	+
AWARE	Awarenes of government water rules	Dummy (1=Yes)	+
CRITZ	Believe that defectors will be criticized	Dummy (1=Yes)	+
TRUST	Trusts other community members	Dummy (1=Yes)	+
EXCH	Exchanged farm inputs previously	Dummy (1=Yes)	+
PEERMON	Existence of community peer monitoring	Dummy (1=Yes)	+
SCARC	Perception that water scarcity is a problem	Dummy (1=Yes)	+
HHLOC	Location of the household	Dummy (1=Extreme Upstream)	-
BHOLE	Owns borehole/well	Dummy (1=Yes)	-
COMME	Proportion of marketed output	Number (0-1)	+

4.3.3.2 Household Capital Endowment

The level of capital that a household is endowed with will facilitate formation and running of agri-environmental cooperation. Capital is important since it helps individuals to overcome transaction costs associated with many agricultural externalities (Lubell et al. 2002). Two types of capital were considered in the current study as explanatory variables: level of education (*HHEDUC*) representing human capital and total assets owned (*ASSET*) representing physical capital. Physical assets are hypothesized to have an inverted U shaped relationship with cooperation. The very poor households may not raise the basic resources needed for cooperation but as wealth increases, households may tend to be more cooperative. However, the relative importance of potential benefits accruing from cooperation may decline with an increase in wealth and therefore at very high assets values cooperation will decline (White & Runge 1994). Finally, human capital was captured through education is hypothesized to be positively correlated with cooperation. Education facilitates access to information and therefore enhancing people's prospects to cooperate with others.

Social capital is an important concept which incorporates density of social networks, the degree of social participation, trustworthiness and norms (Putnam 2000). Social capital has been identified as a key determinant of cooperation within communities. As Janssens (2007) and Ostrom & Ahn (2009) social capital is important for collective action since it enhances the propensity of individual to cooperate. Social participation which involves membership and active participation in community groups enhances formation of social networks. Social network externalities combined with trust enhance the ability of individuals to act collectively with others towards achieving a common goal. In the current study, social capital was not used as an explanatory variable. This was because most of the social capital indicators were also the same variables used in determining the cooperation tendencies. Because social capital also defines cooperation, social capital is highly endogenous and therefore was excluded from the explanatory variables.

4.3.3.3 Trust and Reciprocity

Trust and trustworthiness are complementary to social capital in facilitating cooperation. According to Ostrom & Ahn (2009), trust is the fundamental link between social capital and collective action. Trust is usually enhanced when trustworthy individuals network with one another and they exist within a society where there is fairness in rewarding good behavior and punishing deviance. The level of trust that farmers have on people from both within and outside the community will determine their willingness to cooperate with them at landscape level towards joint provision of ecosystem services. Trust and norms of reciprocity and history of credible commitments between members of a community lowers the cost of cooperation, making establishment of agri-environmental cooperation easier. Reciprocity creates assurance that others will return a kind gesture in future and is based on trust. Trust and faith in the local leadership also creates an assurance that appropriation of benefits will be done in a way that ensures equity and fairness.

4.3.3.4 Property Rights Institutions

Theory has established that security of tenure has a profound effect on investment in natural resources improvement. Land tenure is usually seen as an assurance that individuals can appropriate benefits from their long term investment on land (Kabubo-Mariara et al. 2010; Shiferaw & Holden 2001). In the same way, investment of individual resources in community cooperation and collective action is likely to be influenced by the security of tenure. Individuals will be hesitant to make social investment in community initiatives if they are not assured that they will be able to appropriate their benefits in the future. Therefore in the current study it is hypothesized that security of tenure on land is positively correlated with cooperation.

4.3.3.5 Attitudes and Perceptions

Attitudes and perceptions reflect people's social constructs about situations and are likely to reflect their behavior and influence their tendencies to cooperate with others. Cooperation may be either a consequence or a determinant of attitudes and perceptions. For instance, perceptions on potential benefits from cooperation may be a pulling factor towards cooperation (Yaffee 1998). Conversely, once individuals are involved in cooperation, they form attitudes about their fellow members which may help to further strengthen the cooperation or break it. All the different measures of attitudes and perceptions listed in Table 4. 2 are hypothesized to have a positive effect on cooperation. Successful agri-environmental cooperation will only occur if there is an existing well defined environmental good and service or bad. However, unless these externalities are perceived by those involved to be a real problem, then cooperation around such problems will be unlikely to succeed. Unless the participants feel that there is a well defined ecosystem service there will be no motivations for participation. For instance, downstream victims, who are also potential beneficiaries from the ecosystem services to be generated through cooperation, will only be willing to cooperate with upstream actors if they perceive that the action of those upstream inflicts a damage on them that warrants action.

Social sanctions are also important as mechanisms for enforcing local institutions. Therefore, the extent to which the community members believe in the effectiveness of peer monitoring and social sanctioning mechanisms will drive them towards or away from cooperation. To capture this, respondents were asked to respond to the statement: *''How is it likely that those who do not participate in communal activities will be criticized?''*. Perceptions on whether it is beneficial to participate in collective action activities and whether water scarcity is a problem were also considered and hypothesized to have a positive correlation with cooperation.

4.3.3.6 Communication, Information Sharing and Transaction Costs

Successful agri-environmental cooperation will depend on the existence of mechanisms for communication and information sharing. In many situations involving common pool resources and public goods, establishing effective solutions is usually hindered by high information asymmetry and transaction costs. Cooperation facilitates communication and therefore minimizes information asymmetry through screening, signaling and self selection conditions associated with group memberships (Brouwer et al. 2002). Local cooperation for the environment also helps to facilitate cost effective information gathering from locals who usually have substantial knowledge about local resources that can be used to enhance their management (Hodge & McNally 2000).

Cooperation may also help individuals achieve goals collectively in cases where individual solutions would involve huge costs. Individuals who are likely to be faced by high proportional transaction are also more likely to cooperate so as to overcome the challenge. For example, farmers who are faced by poor road quality are likely to face difficulties while marketing their commodities. Therefore they have an incentive to cooperate since such cooperation is likely to generate private benefits. Road accessibility and quality has commonly been used as a proxy for proportional transaction costs (for example see Vakis et al. 2003). In the current study, the distance to the nearest tarmac road was used as a measure for road quality and therefore a proxy for proportional transaction costs. Access to information was captured using awareness of at least one government rule (*AWARE*) on water management as a proxy. Both variables were hypothesized to have a positive correlation with cooperation.

4.4 Data and Empirical Framework

4.4.1 Data

The current study utilizes primary data that was collected through a household survey conducted among 307[12] households in the Lake Naivasha basin in April-July, 2011. A multistage stratified random sampling procedure was used to select households included in the sample. In the first stage, 8 Water Resource Users Associations (WRUAs) were purposively selected forming the sampling strata. For each stratum a sampling frame was generated with the help of WRUA officials and village elders. A random sample of households was then drawn from each WRUA, proportional to size. A semi-structured interview schedule was then administered through personal interviews with household heads

[12] However, seven cases were regarded as outliers in the cluster analysis and therefore were dropped from the logistic regression analysis.

and/or their spouses as respondents. A semi-structured and pretested interview schedule was administered through face-to-face interviews on the household heads and/or their spouses. During the survey, respondents were asked questions with regard to their previous participation in activities organized at community level and requiring participation from community members. Data was also captured on their individual attributes such as socio-economic attributes, capital endowments (physical, natural, social and human capital), perceptions and attitudes. The household data was complemented by information gathered during focus group discussions involving key informants drawn from each WRUA.

4.4.2 Empirical Framework

4.4.2.1 The Two Step Cluster Analysis Approach

Cluster analysis is an approach that groups similar items together based on information contained in the data on characteristics of the subjects. Observations are allocated into groups such that statistical association is high within a group but low across the groups (Mooi & Sarstedt, 2011). Cluster analysis was used to assess the tendencies to cooperate or defect among sampled farmers in the Lake Naivasha basin. The first step in this process was to select ideal variables that would be used in clustering. Since the objective was to cluster households based on their co-cooperativeness, variables which captured previous participation of households in activities involving voluntary contribution to collective efforts were used. The different forms of participation indicated in Table 4.1 were considered in selecting the variables. In most rural areas, collective action may not be a solution to a single problem but rather solves different problems for different people (White & Runge 1994). To avoid assigning individual to the wrong category, the availability of cooperation opportunities within each WRUA was also considered so that those who did not participate in a certain activity because it was simply not organized within their locality were not regarded as defectors.

After selecting the variables, selection of a clustering method was necessary. The two step cluster analysis procedure developed by Chiu et al. (2001) was preferred over other traditional clustering methods since it is the most appropriate method when there are both categorical and continuous variables among the clustering variables. The two step cluster analysis is an explorative tool that can help to reveal natural groupings that would otherwise not be apparent (IBM Corp. 2012). Using this procedure, the sampled households were clustered into cooperators and defectors. The Cluster analysis results were validated by splitting the data into two and carrying our cluster analysis on each data segment to see if the results were similar. Further, cluster analysis is usually sensitive to the ordering of the data. To control for the possible ordering bias, the data was sorted by the last digit in ascending order.

4.4.2.2 The Logistic Regression Model

Having assigned every respondent to either the cooperators' or defectors' category, the next task was to identify a model that could be used to assess the influence of different covariates on the cooperative behavior of the sampled households. Given that the dependent variable is binary in nature the logistic model was chosen. A logistic model is used to model the choice between two discrete alternatives. It is assumed that the choice to cooperate or to defect is based on a latent variable, which represents the utility difference between cooperating and defecting. The utility difference is assumed to be dependent on the benefits expected from cooperation and other individual characteristics. For every individual the utility difference between cooperation and defection is represented by equation (4.1) (Verbeek 2012):

$$y_i^* = x_i'\beta + \varepsilon_i \tag{4.1}$$

where y_i^* is the unobserved latent variable representing the utility difference between cooperation and defection, x_i are the observed characteristics, β is a vector of regression coefficients and ε_i are the unobserved characteristics which are independent of all x_is. What can be observed however is the decision to cooperate (y_i) such that $y_i = 1$ if an individual cooperates or $y_i = 0$ otherwise. An individual will choose to cooperate if y_i^* exceeds a threshold level, say 0 such that:

$$y_i = \begin{cases} 1 \; if \; y_i^* > 0 \\ 0 \; if y_i^* \leq 0 \end{cases} \tag{4.2}$$

The general form of the logit model can therefore be given by:

$$P[y_i = 1|x_i] = G(x_i, \beta) \tag{4.3}$$

where $G(\cdot)$ is the standard logistic distribution function which takes values between 0 and 1 (Verbeek 2012). Equation (4.3) can be re-written in terms of odds ratios as shown in equation (1.4):

$$log\frac{p_i}{1-p_i} = x_i'\beta \quad or \quad \frac{p_i}{1-p_i} = exp(x_i'\beta) \tag{4.4}$$

where p_i is the probability of observing the outcome $y_i = 1$ (cooperation) and $p_i/1-p_i$ is the odds ratio which is equivalent to Exponentiated coefficients. The odds ratio can be interpreted as the number of times by which the odds of the outcome $y_i = 1$ will be higher than the odds of the outcome $y_i = 0$ (defection) if the j_{th} predictor increases by one unit. However, to see the effect of an explanatory variable on the probability of being a co-operator (p_i), the marginal effects are estimated. From equation (4.4) we can solve for the probability pi yielding the equation:

$$p_i = \frac{\exp{(x_i'\beta)}}{1+\exp{(x_i'\beta)}} \tag{4.5}$$

The marginal effects are estimated by taking derivatives of (4.5) with respect to x_i. The average marginal effects are preferred over the usual marginal effects computed at means. The marginal effects at means are criticized for the following reasons: (a) in ideal situations, no individual is likely to have mean values for all covariates, (b) for categorical variables, means are not an appropriate measure of central tendency, and (c) this approach computes effects for only one set of values, the means. To overcome these shortcomings, Average marginal effects (AMEs) are used. Average marginal effects are generated by computing a marginal effect for each individual and then averaging all the computed effects. The empirical formulation of the model used in the analysis was:

$$\begin{aligned} COOP_i = {} & \beta_1 SLOPE + \beta_2 COPBEN + \beta_3 HHEDUC + \beta_4 HHSIZE + \beta_5 LANDTEN \\ & + \beta_6 PEERMON + \beta_7 OFFARM + \beta_8 CRITZ + \beta_9 HHLOC + \beta_{10} IRR \\ & + \beta_{11} SCARC + \beta_{12} AWARE + \beta_{13} EXTN + \beta_{14} TAMK + \beta_{15} BHOLE \\ & + \beta_{16} EXCH + \beta_{17} COMME + \beta_{18} ASSET + \beta_{19} TRUST + \varepsilon_i \end{aligned} \tag{4.6}$$

COOP was the dependent variable taking the value of 1 if individual *i* was a co-operator and 0 if a defector. The explanatory variables are as described in Table 4. 2. Equation (4.6) was estimated using logistic command in STATA 12 after which the average marginal effects were obtained using the *margins* post estimation command.

4.5 Results and Discussions

4.5.1 Cluster Analysis Results: Cluster Membership

Using cluster analysis, each household was categorized either as a cooperator or a defector. Cooperators are individuals who voluntarily contribute to community collective efforts towards achieving shared goals regardless of what others do. *Defectors* on the other hand are individuals who despite the existence of opportunities to cooperate choose not to abide by the rules of cooperation but free ride on the efforts of others.

Cluster analysis results indicate that there were 181 households (60.3%) in the defectors category and 119 (39.7%) in the cooperators category. The cooperative behavior differed spatially across the WRUAs. The highest cooperation rates were found in Upper Turasha and Upper Malewa WRUAs while defection was more among households in Lower Malewa and Upper Gilgil WRUAs (χ^2 =49.35, p<0.001).

Table 4. 3 presents percentages of households in each of the category based on the variables used to the generate clusters. Note that the percentages in the table should be compared horizontally. Chi-square (χ^2) statistic was used to test the null hypotheses that the percentages of individuals in the two categories are not statistically different. For most of the variables, the null hypotheses were strongly rejected and therefore there are significant differences in the percentage of individuals falling under the two categories.

The households in the cooperators category are those who participated in all activities that were organized in the community that required communal participation in terms of contribution of household time and finances. On average the cooperators spend 37.1 (SD=60.83) hours on communal activities ranging from 1 to 384 hours within 2010. Cooperators made an average financial contribution of Kshs. 1,152 ranging from zero contribution to Kshs. 11,000. As shown in Table 3 group membership and membership in Water Resource User Associations (WRUAs) was dominated by cooperators while membership in community water projects (CWPs) was dominated by defectors. About 55% of all those who indicated membership in WRUAs were cooperators while 51.4% of CWPs members were defectors. Despite this dominance in CWP membership, defectors did not participate in any of the activities that required voluntary contribution; neither did they contribute finances towards collective initiatives. A large percentage of the households in the defectors category showed incidences of free riding. For example none of the defectors had participated in a water related communal activity that is required for all CWP members. Also, only 62% of the defectors had made financial contributions towards communal water management activities. Majority of those who had exchanged planting materials with other farmers were defectors. Exchange of planting materials is based on the expectation that individual efforts will be reciprocated by their exchange partners. Defectors also had majority of the group memberships (58.2% against 41.8% of cooperators). Membership in groups such as rotating savings and credit associations (commonly called Merry-Go-Round) are also based on reciprocate assurance since they are formed by people with close social ties and friendships and therefore once a member contributes their finances or time, they are assured that they will recover their contribution later or benefit in another way.

Table 4. 3: Attributes of cooperators and defectors

		Defector	**Cooperator**	χ^2 statistic
WRUA membership	No	75.3%	24.7%	29.72***
	Yes	44.5%	55.5%	
Financial contribution towards water management	No	72.9%	27.1%	27.17***
	Yes	46.9%	53.1%	
Time commitment towards communal activities	None	100%	0.0%	300.01***
	Moderate	0.0%	100.0%	
	High	0.0%	100.0%	
Exchanged planting materials with other farmers	No	71.4%	28.6%	2.03
	Yes	58.9%	41.1%	
At least one household member has membership in a group	No	65.5%	34.5%	191.03
	Yes	58.2%	41.8%	
Membership in community water project	No	81.1%	18.9%	23.19***
	Yes	51.4%	48.6%	
Participation in water related communal activity	No	84.6%	15.4%	183.37***
	Yes	0.0%	100.0%	
Involvement in communal tree planting exercise	No	66.5%	33.5%	46.972***
	Yes	0.0%	100.0%	
Involvement in communal soil conservation exercise	No	61.6%	38.4%	9.312***
	Yes	0.0%	100.0%	
Involvement in construction of communal facility	No	61.6%	38.4%	9.312***
	Yes	0.0%	100.0%	
Involvement in maintenance of communal access roads	No	62.2%	37.8%	14.112***
	Yes	0.0%	100.0%	

*** indicates significance at the 0.01 level.

4.5.2 Determinants of the Probability of Being a Co-operator

Table 4. 4 presents the odds ratios and average marginal effects obtained using logistic regression model. Considering the model summary statistics and their significance levels given at the bottom of Table 4. 4, we can reject the null hypothesis that all the regression coefficients are simultaneously equal to zero. The McFadden's pseudo R^2 is 0.21 which is satisfactory.

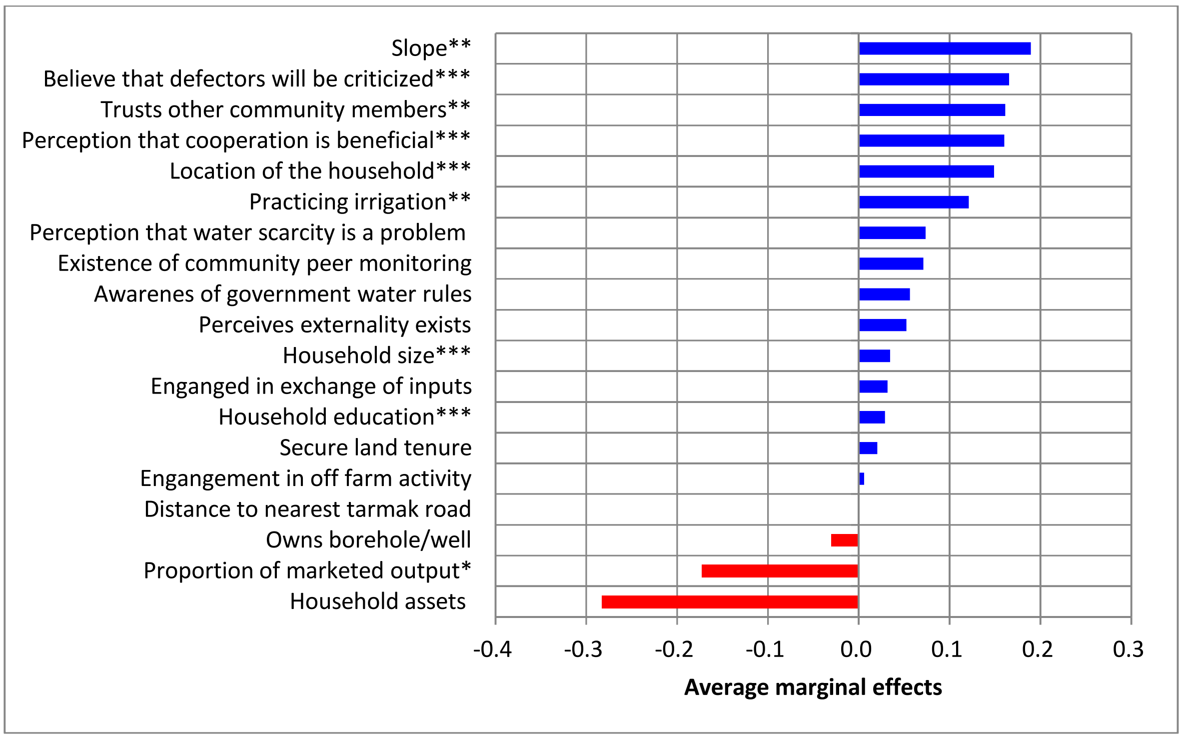
Table 4. 4: Odds ratios and marginal effects of determinants of tendencies to cooperate

Explanatory variable	**Odds Ratio**	**Std. Err.**	**Average marginal effects**	**Std. Err.**
Holds land title deed	1.12	0.347	0.02	0.056
Practicing irrigation	1.97**	0.690	0.12	0.062
Farm located in extremely sloping area	2.87**	1.415	0.19	0.086
Household education	1.17***	0.063	0.03	0.009
Perceives externality exists	1.34	0.432	0.05	0.058
Engangement in off farm activity	1.03	0.426	0.01	0.074
Value of assets owned	0.21	0.279	-0.28	0.240
Perception that cooperation is beneficial	2.44***	0.825	0.16	0.058
Household size	1.21***	0.083	0.03	0.012
Distance to nearest tarmak road	1.00	0.038	0.00	0.007
Awarenes of government water rules	1.37	0.421	0.06	0.055
Believe that defectors will be criticized	2.52***	0.953	0.17	0.066
Trusts other community members	2.46**	0.973	0.16	0.069
Enganged in exchange of inputs	1.19	0.550	0.03	0.083
Existence of community peer monitoring	1.49	0.471	0.07	0.056
Perception that water scarcity is a problem	1.50	0.448	0.07	0.053
Location of the household	2.29***	0.774	0.15	0.058
Owns borehole/well	0.84	0.341	-0.03	0.073
Proportion of marketed output	0.38***	0.207	-0.17	0.096
Model summary statistics				
Number of observations	299			
LR chi2(19)	82.84***			
Log likelihood	-159.56			
Pseudo R2	0.21			

*,**,*** indicates significance at the 0.1, 0.05 and 0.01 levels respectively

The average marginal effects are the values by which the probability of an individual being a cooperator increases or decrease when a continuous explanatory variable increases by one unit. For a dummy explanatory variable, the average marginal effect represents the effect of a discrete change of an explanatory variable from 0 to 1. On the other hand, the odds ratios represent the multiplicative factor of the odds of being a defector relative to that of being a cooperator when an explanatory variable increases by one unit. For example, an odds ratio of 1.2 associated with the household size variable implies that with an increase of household size by one person, the odd ratio of being a cooperator will be 1.2 times higher than that of being a defector. That implies that an increase in household size makes someone more likely to be a cooperator.

In Figure 4. **1** the average marginal affects presented in Table 4. 4 are graphed to visualize the relative importance of different covariates in predicting the probability of cooperation. The positive marginal effects are those that encourage cooperation while the negative ones are those that discourage cooperation.



*,**,*** indicates significance at the 0.1, 0.05 and 0.01 levels respectively

Figure 4. 1: Graphical presentation of the AMEs of the unconditional cooperator model

Eight covariates had a positive significant influence on the probability of being a cooperator while one had a negative significant influence. These factors can be placed in four distinct categories: *household endowments, expected benefits, trust, attitudes and perceptions*.

In the first category, household size and average household education level had positive significant effects on the probability of being a cooperator. Household size represents labour availability and therefore households who have more labour resources have less labour constraints and therefore can allocate part of their labour to cooperative initiatives. The average household level of education is a measure of human capital. Human capital enhances cooperation due to the skills that individuals acquire through education which enable them to engage with other parties in the community. However, the fact that households who lack substantial skills tend to defect has the intuitive implication that cooperation may fuel marginalization and benefits associated with cooperation may accrue to those who are already better off as also observed by Lubell et al. (2002). Our results fail to reject the hypothesis that the trust that an individual has on other community members enhances cooperation. Since trust is the thread that ties people together, if an individual has high trust on fellow community members, then they will have confidence in the good will of others and will be assured that others will keep their part of the agreement in the cooperation. Trust makes cooperation easier since it minimizes transaction costs that people may incur when searching for credible cooperation partners and also reduces the need for costly enforcement since individuals depend on credible commitments established through previous experiences with others. Our results are in agreement with those of previous studies such as those of Baland & Platteau (1996).

In the expected benefits category, three variables had a positive significant effect on the probability of being a cooperator. Households who were practicing irrigation in the Lake Naivasha were more likely to cooperate. Water for irrigation can be seen as a selective benefit that only water project members can access, therefore an individual is likely to benefit privately through cooperating with others. Therefore there is an incentive for irrigators to participate in collective action so as to maintain a flow of these benefits. Farmers who have alternative access to water for example through ownership of a private borehole or well were found to be less likely to cooperate. However, the effect of this factor was insignificant. The slope of the farm had a positive significant effect on cooperation confirming our hypothesis. Extreme slope makes cooperation attractive since the expected benefits from cooperation are higher. It could also be that in such areas, the problem of extreme soil erosion is more visible and therefore farmers in these areas will be willing to cooperate to solve the common problem. Our results strongly reject the hypothesis that farmers located upstream are likely to defect. A possible explanation to this finding is that since most cooperation generates other selective benefits, this is a win-win for the farmers located in extreme upstream and therefore an incentive for them to cooperate. Being located in the extreme upstream WRUAs also implies that the households are closer to the sources of rivers from where most community water projects have their points of common water intake. Therefore, by virtual of it being technically easier to tap water and distribute among its members without additional pumping costs makes it attractive to cooperate and establish a common water distribution system. Cooperation may further be boosted by the fact that most of extremely upstream households are also located in extremely sloped areas.

Two variables representing attitudes and perceptions were found to significantly influence cooperation. For obvious reasons, individuals who perceived that participating in communal activities is beneficial were also more likely to cooperate. The second factor was the belief that those who defect are likely to face social ridicule. Those who responded to the positive were found to be also more likely to cooperate. This result can be used to infer that informal constraints and internal sanctions such as fear of social exclusion and public ridicule are effective tools that facilitate cooperation in a society. These instruments work through guilt and fear of loss of self respect. However, their effectiveness will depend on the extent to which an individual identifies with others in the community (Bardhan 1993).

Finally, against our hypotheses, the proportion of marketed output had a negative influence on cooperation. This result implies that agricultural commercialization works against environmental cooperation in the research area. This could be explained by competition between different cooperation options in the community. Majority of the commercial farmers such as those engaged in production of export crops and other high value commodities such as dairy indicated that they had memberships in farmer groups and cooperatives. Therefore, it could be that their engagement in enterprise specific cooperation prevented them from participating in environmental cooperation.

4.6 Summary, Conclusion and Policy Implications

The objectives of this study were twofold. First the study sought to identify the cooperative behavior of sample households in the Lake Naivasha basin by assessing their degree of participation in activities involving voluntary provision of public goods in the community. Second, the study sought to identify the factors that make some individuals to either be cooperate or defect when required to participate in community collective initiatives. The first objective was achieved through a two step cluster analysis procedure which was used to identify the category where each household belonged to given the observed previous degree of participation. Logistic regression was then used to identify the factors determined the probability of cooperation.

Results indicate that majority of the sampled households in the Lake Naivasha basin were defectors (61%). In line with theoretical expectations free riding was the dominant strategy in the Lake Naivasha basin case study just like in any other prisoner's dilemma situation. This is because self interested iindividuals tend to pursue strategies which seem to yield higher individual expected pay-offs. However such decisions might not be socially optimal. Results from the logistic regression model indicate that the choice of the decision to cooperate or defect was significantly influenced by expected benefits, human capital and labour endowments. Further, informal sanctions, norms of trust and attitudes/perceptions emerged as significant factors that are positively correlated with cooperation. These factors can be seen as catalysts that can be used to enhance cooperativeness and discourage defection in the study area and in other watersheds facing a similar challenge.

From these results, a number of implications that are relevant for policy can be drawn. First, given that defection was the dominant strategy in the basin, there is need for strategies to encourage cooperation so as to address agri-environmental issues effectively in the Lake Naivasha basin or any other similar watershed. This will also help to achieve economies of scale in provision of ecosystem services. Second, perceptions of watershed farmers could be boosted through campaigns and community education programmes that help to create awareness on environmental externalities associated with agriculture. Farmers should be made aware of the relationship between conservation and the long term productivity of their land, so that they can perceive that cooperation for the environment also creates private benefits. Third, social sanctions can be encouraged by increased local participation in planning and resource management. This is a tool that should be used to achieve effective rule monitoring and enforcement at substantially low transaction costs.

CHAPTER FIVE

5 Estimating Returns to Multiple Soil Conservation Practices in Lake Naivasha Basin[13]

5.1 Introduction

Land degradation is a major threat to agricultural productivity and food security in many developing countries (Bewket 2007; Kassie et al. 2008; Mazvimavi & Twomlow 2009). Land degradation is mainly attributed to inappropriate agricultural practices and other activities and processes that reduce the economic and ecological productivity of land (OECD 2012). Soil erosion is one of such processes. Besides the on-site effect of reducing the productivity of land, soil erosion also causes off-site effects such as eutrophication and siltation (Mbaga-Semgalawe & Folmer 2000). Soil erosion also threatens species in both terrestrial and aquatic ecosystems through the degradation and pollution of their habitats. Due to the myriad negative effects caused by soil erosion, soil conservation can undoubtedly generate both private and social benefits. Private gains emerge from increased crop productivity while social benefits emerge from better ecology and reduced water treatment costs, longer life of reservoirs, and many other benefits (Miller et al. 2008). For this reason, significant efforts have been made by governments and development agencies to promote soil and water conservation technologies among farmers in developing countries (Bekele 2005; Kassie et al. 2008). However, despite these efforts, the adoption of soil conservation practices has been below expectations (Khisa et al. 2007; van Rijn et al. 2012). This raises the question of whether and to what extent soil conservation practices can generate economic benefits substantial enough to motivate farmers into adopting and maintaining them.

Whether soil conservation practices are win-win has been an important research focus in the past, generating mixed findings. While some studies (for example Bekele, 2005; Kassie et al., 2008; Otsuki, 2010; Pender and Gebremedhin, 2007; Shively, 1998; Vancampenhout et al., 2006) conclude that soil conservation practices help to enhance cropland productivity on degraded lands, other studies (for example Kassie et al., 2011 and Shiferaw and Holden 2001) found that under certain circumstances, some soil conservation may not necessarily be 'win-

[13] This chapter is based on the paper:
Willy, D.K., Zhunusova, E., Holm-Mueller, K., Forthcoming. Estimating Effects of Multiple Soil Conservation Practices on Crop Productivity: A Case Study of Smallholder Farmers in the Lake Naivasha Basin, Kenya. *Land Use Policy* (Revised manuscript submitted).

win'. What we observe from these studies is that evaluation of conservation practices should be context specific. On the one hand, if appropriately selected and given sufficient time, soil conservation practices (SCPs) are expected to reduce soil erosion rates, improve agricultural land quality and enhance crop yields (Lutz et al. 1994; Shively 1998). On the other hand due to their land requirements soil conservation practices may lead to a decline in crop yields. Pagiola, (1994) finds that this was an important issue for the Kitui and Machakos regions of Kenya where he finds that the effective production area falls faster that the increase in yields therefore leading to an overall production decline. From a private optimization point of view, adoption rates are likely to be low if costs exceed the benefits (Lutz et al.1994 ; Pagiola, 1994). Farmers are particularly concerned with high labor and land requirements for implementation and maintenance of some soil conservation technologies since these resources are usually the most limiting among low-income farmers (Shiferaw & Holden 2001).

Due to the varied potential effects of soil conservation practices, it is necessary sometimes to combine multiple soil conservation technologies within the same farm so as to generate substantial benefits. However, literature on the assessment of complementary effect of multiple soil conservation practices (MSCPs) is currently scanty.

In the current study it is hypothesized that implementing multiple soil conservation practices as a conservation package can generate substantial private benefits in-terms of higher crop productivity. Therefore, the research question that is explored here is whether the net value of crop production for farmers who have implemented multiple soil conservation practices are higher than those of the farmers who have not. This is motivated by the tenet that farmers are likely to sustain conservation practices on their farms partly if benefits exceed costs (Shiferaw & Holden 2001). The main goal of this study is to estimate the effect of implementing multiple soil conservation practices (MSCPs) on the value of crop production among smallholder farmers in the lake Naivasha basin, Kenya. This helps us to generate information that can be used in evaluating the returns to a soil conservation package as opposed to assessing returns to individual soil conservation practices. Six practices were considered in this study namely: Tree Planting, *Fanya Juu* Terraces, Grass Strips, Napier Grass, Contour farming and Cover crops. The study uses Propensity Score Matching (PSM) to analyze matched observations of farmers who have implemented multiple soil conservation practices and those who have not.

The rest of the paper is structured as follows: the next section summarizes previous research on returns to soil conservation practices. Section 5.3 then describes the methodology employed in this study, including data collection and sampling methods and analytical techniques. Results and discussions are presented in section 5.4, while section 5.5 concludes and draws policy implications.

5.2 Literature on Returns to Soil Conservation Practices

As has already been mentioned, despite the unanimous agreement in literature that most soil conservation technologies control erosion and generate off-site positive effects, such technologies remain poorly adopted[14] in many developing countries (Khisa et al. 2007; Pretty et al. 1995; van Rijn et al. 2012). This state of affairs has been the driving force behind many government efforts to promote soil conservation and has also received substantial focus in research. Studies in this area have focused on assessing the effect of soil conservation practices on crop productivity using either econometric approaches (for example Bekele, 2005; Kassie et al., 2008; Nyangena and Köhlin, 2009; Otsuki, 2010; Pender and Gebremedhin, 2007; Shively, 1998) or Cost Benefit Analysis(CBA) (for example Araya and Asafu-Adjaye, 1999; Ellis-Jones and Tengberg, 2000; Lutz et al., 1994; Posthumus and De Graaff, 2005; Shiferaw and Holden, 2001; Tenge, 2005). Regardless of the method used, most findings converge to one agreement that the effect of soil conservation on crop productivity is context specific and depends on various factors. The current study seeks to advance the debate by looking at how the combination of multiple soil conservation practices may influence the value of crop production.

A study by Kassie et al. (2008) analyzed the impact of stone bunds on the value of crop production in Ethiopia and revealed that their effects on crop productivity differed with agro-ecological settings. Implementing stone bunds increased crop productivity in low rainfall areas whereas in the high rainfall areas this was not the case. Beside the agro-ecological conditions, studies conducted in Kenya by Nyangena and Köhlin (2009) and Otsuki (2010) found that the erosion status of the farm was a major determinant of the effect of agro forestry, bunds and terracing on crop productivity.

A study by Araya and Asafu-Adjaye (1999) in Eritrea found that plots where stone and soil bunds, *Fanya Juu* terraces and double ditches were implemented yielded negative net present values (NPVs) . However, when the authors accounted for social benefits, the NPVs were positive, emphasizing on the fact that even when SCTs are not economically viable for

[14] There is however some exceptions found in literature. For example Pagiola & Dixon (1998) find high adoption rates in El-Salvador than it is commonly assumed.

individual farmers, the net gain to the society can be positive. This finding is confirmed by Shiferaw and Holden (2001) who applied a different approach to Ethiopian small-holder farms and concluded that SCPs only yielded positive benefits at very low discount rates. A similar study conducted by Tenge (2005) among smallholder farmers in the West Usambara Highlands in Tanzania estimated the financial efficiency of bench terraces, *Fanya Juu* terraces and Grass Strips and revealed that profitability of these SCPs depended on soil type, slope and opportunity costs of labor and farmers' subjective discount rates. For instance, *Fanya Juu* terraces constructed on both moderate and steep slopes were economically viable only for farmers with low opportunity costs of labor, whereas farmers with high opportunity costs could only benefit from the practice if it was constructed on gentle slopes. Similarly, implementation of grass strips on steep slopes with both stable and unstable soils for farmers with high opportunity costs would yield negative NPVs and Internal Rate of Return (IRR) below the market discount rate (Tenge 2005). However, soil erosion is often present on steep slopes with unstable soils that accelerate soil surface movement and run-off. Consequently, smallholder farmers with farms located on extremely sloped areas would need additional incentives to make soil conservation practices economically attractive for them. A study by Posthumus and De Graaff, (2005) among Peruvian farmers arrives at similar findings, and also finds the type of crop enterprise an important determinant of the profitability of soil conservation practices.

Most of the studies highlighted here analyze soil conservation practices in isolation not taking into account the possible effect that may result from integrating more than one soil conservation practices in one farm/plot. Further, as Kassie et al., (2011), Kassie et al. (2008) and Shively, (1998) indicate, any analysis on the effect of soil conservation practices on the value of crop production that ignores the presence of self selection may yield biased estimates. Self-selection problem arises because farmers are not randomly assigned to the groups of adopters and non-adopters, but they choose themselves to adopt a soil conservation technology based on their individual attributes which influence adoption behavior and the attributes of their farm, and of the individual plots on their farm. Consequently the counterfactual effect, that is, the production level that farmers would have achieved had they not implemented multiple soil conservation practices is not observable (Kassie et al. 2011). Therefore, a mere comparison of the difference in crop productivity between implementers and non-implementers of multiple soil conservation technologies would yield biased estimates of the effect of MSCPs on crop production, because this effect is likely to be correlated with farm- and farmer-specific unobserved characteristics (Shively 1998). Further, unobservable variables that simultaneously affect the technology choice variable (level of implementing multiple soil conservation practices) and the outcome variable (value of crop production) may cause hidden bias (Rosenbaum 2002). Following Kassie et al., (2008), the current study seeks to address the two problems by analyzing the effect of multiple soil conservation practices on the value of crop production using the Propensity Score Matching (PSM) and exogenous switching regression approach.

5.3 Methods, Data Types and Description of Variables

5.3.1 Analytical Framework

This chapter utilized Propensity Score Matching (PSM) technique to assess the effect of implementing multiple soil conservation practices on the value of crop production. Exogenous switching regression was then applied to check the robustness of the PSM results following Kassie et al., (2008).

5.3.1.1 Propensity Score Matching (PSM) Technique

The idea of estimating propensity scores was initiated by Rosenbaum and Rubin, (1983) who proved that self-selection bias can be removed through adjustment using propensity scores of treated and non-treated groups. The method has then found wide application in medical and economic research (Caliendo & Kopeinig 2008; Dehejia & Wahba 2002) to address self-selection problems. Self-selection bias is likely in the current study because assignment of treatment (whether to implement multiple soil conservation or not) is not random. Rather, individuals choose themselves to receive a treatment or not based on various farm- and farmer-specific characteristics, economic and institutional factors. Therefore, those who implement multiple soil conservation technologies might be systematically different from each other and from those who do not implement. To calculate the effect of soil conservation practices on crop productivity (treatment effect), this self-selection problem has to be addressed (Kassie et al. 2008; Mendola 2007). PSM, which involves computation of a propensity score for each individual helps to achieve this objective.
A propensity score is the conditional probability of taking a treatment given a vector of explanatory variables as indicated in equation (5.1) (Rosenbaum & Rubin 1983).

$$p(x) = Pr[D = 1|X = x] \tag{5.1}$$

where p(x) is a propensity score, and *Pr* is the probability of implementing multiple soil conservation efforts (taking a treatment, D=1) conditional on the vector of observed covariates, x. In our case the dummy variable indicating the treatment effect takes the value of 1 if a farmer has implemented at least two soil conservation practices and 0 if the farmer has implemented only one soil conservation practice. The explanations on how the treatment variable was generated are offered in the next section.

A probit model was applied to estimate the predicted probabilities (propensity scores) of implementing multiple soil conservation efforts. The probit model is as specified in Equation (5.2) (Greene, 2003 and Verbeek, 2008):

$$\Pr(D = 1|X) = G(z) = \int_{-\infty}^{X'\beta} \phi(z)dZ = \Phi\,(X'\beta) \tag{5.2}$$

where $G(z)$ is a function taking values between 0 and 1, $\Phi(z)$ is the standard normal cumulative distribution function, z is the vector of covariates and $\phi(z)$ is the standard normal density function. The probabilities were estimated using the method of maximum likelihood which maximizes the log-likelihood function:

$$\ln L = \sum_{y_i=0} ln\left[1 - \Phi\left(X_i'\beta\right)\right] + \sum_{y_i=1} ln\,\Phi\left(\mathrm{X}_\mathrm{i}'\beta\right) \tag{5.3}$$

The empirical probit model estimated is specified in Equation (5.4):

$$Y_i^* = X_i\beta_i + u_i, \qquad u_i \sim N(0,1), i = 1, \dots, N \text{ and } Y_i = \begin{cases} 1 \; if \; Y_i^* > 0 \\ 0 \;\; if \; Y_i^* < 0 \end{cases} \tag{5.4}$$

where Y_i^* is a latent variable representing the decision to implement multiple soil conservation practices and Y_i is observed status of implementing multiple soil conservation technologies for each household, X is a matrix of explanatory variables which include farmer and farm characteristics, institutional and socio-economic factors, the βs are the parameters to be estimated and u_i is a normally distributed error term.

The predicted probabilities obtained by estimating equation (5.4) are used as propensity scores for matching the samples of implementers of multiple soil conservation practices and non implementers. After propensity score estimation, a matching algorithm to match each adopter with a non-adopter with similar propensity scores is used. In this study, the nearest neighbor matching (NNM) method with caliper after imposing non replacement and common support conditions was used. A caliper or a tolerance level on the maximum propensity score distance allowed was imposed to improve the matching quality (Caliendo & Kopeinig 2008).The no replacement condition - where every untreated observation is considered only once- was made to avoid an increase in the estimator variance that occurs when replacement is allowed. The common support condition implies that only comparable observations from the treated and non-treated groups are entered into the analysis, for which a researcher has to define the *region of* common support (Caliendo & Kopeinig 2008). The region of common support can be determined by excluding all observations among the control individuals whose values of the outcome variable are lower than the minimum value among the treated individuals or higher than the value of the outcome variable among the treated individuals (Dehejia & Wahba 2002). All the observations that are outside the common support are excluded from the analysis. It was also necessary to check the balancing property of the sample, which ensures that households within the treated and control groups have similar propensity score, that is, they should have the same distribution of covariates (Mendola 2007). The balancing property shows how well the samples were matched (matching quality). In this study, the quality of matching was checked using the standardized bias method. This method calculates bias in mean differences of covariates for treated and control groups after matching. An average bias in mean difference less than 5% is considered tolerable (Caliendo & Kopeinig 2008). After estimating the propensity scores, the causal effect of multiple soil conservation on crop productivity can be calculated. This effect is called Average Treatment Effect on the Treated (ATT) and is represented as follows (Grilli & Rampichini 2011).

$$ATT = E[Y(1) - Y(0)|\, D = 1] \tag{5.5}$$

where Y is the outcome variable on which the technology effect has to be estimated. In our case, this is the value of crop production per hectare. $Y(1)|D=1$ is the observed value of crop production for treated and $Y(0)|\, D=1$ indicates what would happen to the treated had they not received the treatment (counterfactual). In reality, Y(0)| D=1 is not observed, so the best substitute - the control group of non-treated that are similar in distribution of covariates to the adopters is used (Mendola 2007). ATT is then calculated as the difference in outcome variables between groups of treated and non-treated that are matched according to their propensity to implement multiple soil conservation technologies. Thus, PSM ensures that the estimated technology effect is only due to the treatment and not because of other covariates by taking care of self-selection bias. However, the estimated treatment effect could have hidden bias as a result of unobserved heterogeneity. To test the sensitivity of the ATT to unobserved heterogeneity, the Rosenbaum, (2002) bounds test was used. The bounds test establishes the point at which the estimated results would no longer hold or in other words how the ATT is robust to unobserved heterogeneity. PSM techniques might yield inconsistent estimates especially due to unobserved heterogeneity. Therefore, to ensure consistency and robustness of the PSM results, exogenous switching regression as complementary method to PSM was used following Kassie et al (2008).

5.3.1.2 The Exogenous Switching Regression Model

After running PSM, two samples are generated and used in estimating the exogenous switching regression models. One sample consists of treated individuals who are within the region of common support and for whom a match was found among the untreated individuals. The other sample consists of untreated individuals who are both on common support and are also matching those in the treated sample. In a switching regression model, the outcome equations depend on the regime, that is, the treatment condition. The general exogenous switching regression model can be described in equations (5.6-5.8).

$$lnZ_{i1} = W_i\beta_{i1} + v_{i1} \;\; (if \;\; Y_i = 1) \tag{5.6}$$

$$lnZ_{i0} = W_i\beta_{i0} + v_{i0} \;\; (if \;\; Y_i = 0) \tag{5.7}$$

$$Y_i^* = X\alpha + u_i \qquad and \qquad Y_i = \begin{cases} 1 \; if \; Y_i^* > 0 \\ 0 \;\; if \; Y_i^* < 0 \end{cases} \tag{5.8}$$

where Z_i is the value crop production per ha for each household i, W_i is a vector of explanatory variables that are hypothesized to influence the value of crop production; β_i and α are vectors of regression coefficients, and u_i and v_i are the random unobserved attributes.

Note that Y_i^* is the selection equation signifying whether a farmer has implemented MSCPs or not and is the same equation used in estimating propensity scores. The unobserved characteristics affecting Z_{i1} (or Z_{i0}) are uncorrelated with those affecting Y_i^*, that is, the error terms of the outcome equations are independent from those of the selection equation , hence the use of exogenous switching regression.

5.3.2 Description of Dependent and Explanatory Variables

Table 5.1 presents summary statistics of dependent and explanatory variables used in the binary probit model that was used to estimate propensity scores. Construction of the dependent variable was done considering the fact that most of the soil conservation practices require certain time period and need to be implemented on substantial area of land for their effect on crop productivity to be visible. De Graaff et al. (2008) claimed that "actual adopters" are those farmers undertaking significant amount of efforts to conserve their land from degradation. The following composite criterion was developed and used to determine who qualified to be implementers of MSCPs and those who did not.

The first criterion was that each of the six soil conservation practices considered in the study must have been consistently implemented for at least 2 years. Second, the soil conservation practices must have been implemented at a substantial extent, a criteria also used by Willy and Holm-Mueller (2013) and third, a farmer will count as having implemented multiple soil conservation practices if (s)he had implemented two or more of the soil conservation practices. The choice of explanatory variables was based on literature review on adoption of soil conservation practices.

Table 5.1: Description of covariates used in generating propensity scores

Variable	Implementers of MSCPs (N= 203)		Non implementers of MSCPs (N=92)	
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**
Gender of household head (Male=1)	0.88	0.324	0.82	0.390
Age of household head (years)	56.55	13.908	52.07	13.821
Farm size (ha)	2.41	2.889	3.26	5.462
Square of farm size (ha)	14.12	50.206	40.16	172.597
Dummy for primary education[1] (1=Yes)	0.45	0.499	0.48	0.502
Dummy for secondary education[1] (1=Yes)	0.26	0.438	0.28	0.453
Dummy for post secondary education[1] (1=Yes)	0.06	0.245	0.03	0.179
Number of adults in the household	3.29	1.506	3.30	1.765
Dummy for attending training (1=Yes)	0.28	0.448	0.26	0.442
Distance to the river (Kms)	2.27	3.377	1.75	2.325
Household asset ownership (value)	0.37	0.120	0.31	0.114
Proportion of marketed output (%)	0.46	0.291	0.47	0.299
Perceives soil erosion as a problem in the region (1=Yes)	0.53	0.500	0.45	0.500
Dummy for cattle ownership (1=Yes)	0.95	0.217	0.87	0.339
Dummy for secure land tenure (1=Yes)	0.67	0.471	0.54	0.501
Dummy for access to extension (1=Yes)	0.47	0.500	0.42	0.497
Dummy for location in Kianjogu WRUA[3] (1=Yes)	0.15	0.356	0.07	0.248
Dummy for location in Lower Malewa WRUA[3] (1=Yes)	0.10	0.305	0.10	0.299
Dummy for location in Middle MalewaWRUA[3] (1=Yes)	0.19	0.395	0.18	0.390
Dummy for location in Upper Malewa WRUA[3] (1=Yes)	0.11	0.318	0.11	0.313
Dummy for location in Mkungi Kitiri WRUA[3] (1=Yes)	0.11	0.312	0.13	0.339
Dummy for location in Upper Gilgil WRUA[3](1=Yes)	0.10	0.305	0.15	0.361
Dummy for location in Upper Turasha WRUA[3] (1=Yes)	0.14	0.351	0.11	0.313
Log of off-farm income per year	4.72	5.094	3.06	4.963

2. No education is the reference category 3. Wanjohi WRUA is the reference category.

Descriptive statistics of the outcome variable and covariates used in the exogenous switching regression models are presented in Table 5. 2. The dependent variable was computed by multiplying the output (in Kgs) of each commodity produced at the farm with the final price of that commodity that was paid to individual farmers. The value of crop production per hectare for each household was then computed by aggregating the values of all commodities produced and dividing the outcome with the total land under crops. For statistical reasons (skewed distribution of the outcome variable) the natural log of the value of crop production was used as a dependent variable in the exogenous switching regression models.

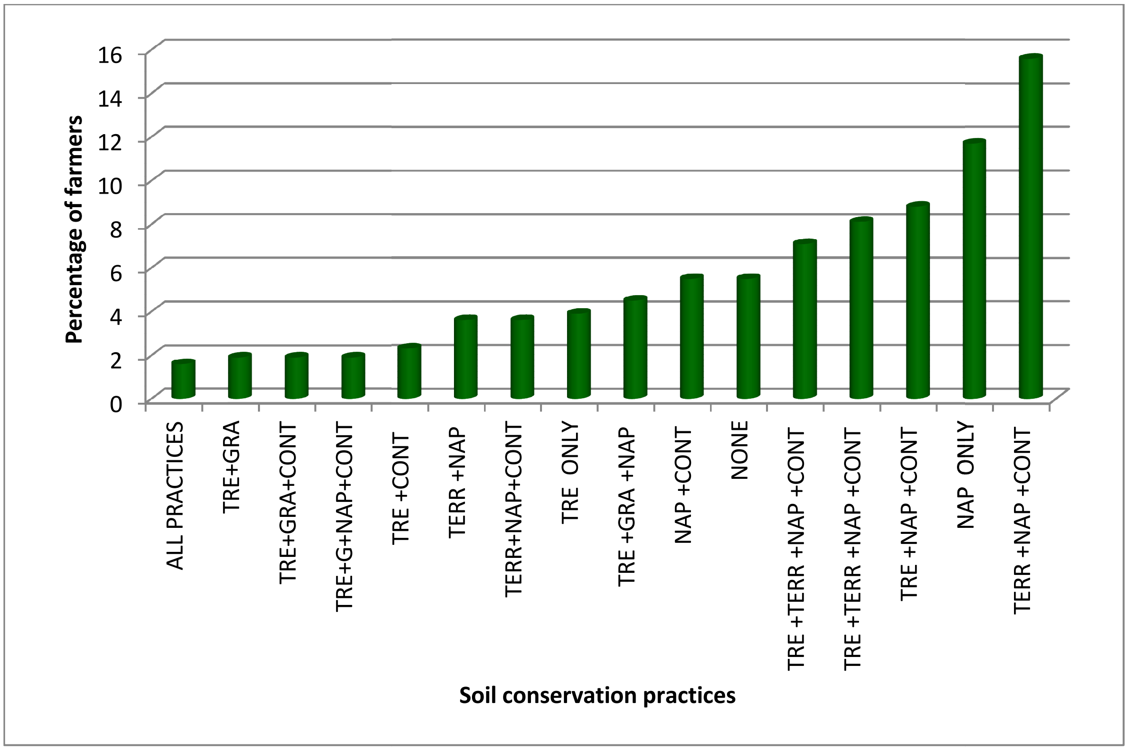
Table 5. 2: Summary statistics of variables used for exogenous switching regression

Variable	Treated sample (N=82)		Control sample (N=93)	
	Mean	Std. Dev.	Mean	Std. Dev.
Value of crop production in Ksh. per ha	192,344	166,222	169,612	157,833
Log of Value of crop production per ha	11.85	0.837	11.34	2.050
Number of adults in the household	3.26	1.497	3.29	1.761
Years of living in the community	31.10	13.121	24.88	15.187
Number of credit sources accessed	1.21	0.797	1.24	0.772
Land under crops (ha)	1.07	0.701	1.24	1.931
Distance to the river (kms)	1.59	2.678	1.74	2.315
Dummy for farm experiencing erosion (1=Yes)	0.72	0.452	0.63	0.484
Dummy for engagement in exchange of materials (1=Yes)	0.89	0.315	0.85	0.360
Dummy for membership in farmers group(1=Yes)	0.17	0.379	0.17	0.379
Dummy for attainment of primary education(1=Yes)	0.51	0.503	0.48	0.502
Dummy for secondary education(1=Yes)	0.22	0.416	0.28	0.451
Dummy for post secondary education(1=Yes)	0.01	0.110	0.03	0.178
Dummy for subjective norms(1=Yes)	0.57	0.498	0.57	0.498
Dummy for ownership of mobile phone(1=Yes)	0.94	0.241	0.94	0.247
Dummy for ownership of radio(1=Yes)	0.93	0.262	0.92	0.265
Dummy for membership in religious group(1=Yes)	0.02	0.155	0.03	0.178
Dummy for membership in village group(1=Yes)	0.23	0.425	0.23	0.420
Dummy for membership in water project	0.73	0.446	0.62	0.487
Age of household head (years)	54.06	13.845	52.31	13.950
Log of off-farm income per year	3.39	4.690	3.15	5.004
Dummy for manure application	0.43	0.498	0.35	0.481
Dummy for use of hired labour	0.39	0.491	0.26	0.440
Log of fertilizer cost per year	8.84	2.921	8.67	2.853
Household located in the Kinangop plateau	0.44	0.499	0.39	0.490
Distance to nearest tarmac road (kms)	7.27	22.484	4.54	3.866

5.4 Results and Discussions

5.4.1 Descriptive Statistics and Opportunity Costs of Soil Conservation Practices

Figure 5.1 presents some descriptive statistics on implementation of multiple soil conservation practices in the Lake Naivasha basin. The most popular type of combination of soil conservation practices observed in the study area was that combining terraces, Napier grass and contour farming, which had been implemented by close to 16% of the sample households. Only a small proportion (1.6%) had implemented the entire package of soil conservation practices.



TRE=Tree planting; GRA=Grass strips; CONT=Contour farming; NAP=Nappier grass; TERR= Terraces

Figure 5.1: The major combinations of soil conservation practices

The choice by each farmer on the specific combination of practices to implement is usually determined by farmer and farm attributes. Farmers choose the combination of soil conservation practices that suits their local conditions such as topography and soil types which vary considerably between farms and sometimes within the same farm. In that case, the efficiency of soil conservation practices will depend on the overall soil conservation package. As reported by the interviewed farmers, the choice of the soil conservation practices to be implemented was based on information sourced from formal sources (56%), informal sources (42%) and the media (2%). The formal sources included public extension service providers, farmer field schools and NGO extension service providers while informal sources were mainly neighbours. It is also expected that the effect of each specific combination on the value of crop production might differ. However the current study estimates the effect of the entire soil conservation package and the issue of effects of specific combinations of soil conservation practices is beyond the scope of this study.

5.4.2 The Effect of MSCPs on the Value of Crop Production

Table 5.3 presents the results of propensity score matching (PSM) generated using the *psmatch2* Stata command module developed by Leuven and Sianesi (2003). According to the Log likelihood test, the probit model used in the estimation of propensity scores is significant at the 0.01 level ($p<0.01$). The Pregibon's *linktest* (Pregibon 1980) used to check model misspecification, rejects the null hypothesis that the model is mispecified. The prediction power of the model is also strong as indicated by the percentage of correct predictions (77.9%). Table 5.3 indicates that farm size, gender of household head, asset ownership, regional dummies and the proportion of marketed output had statistically significant effects on the behavior of farmers in terms of undertaking multiple soil conservation practices. Since this model was used merely as a statistical tool to estimate the propensity scores, only a brief behavioral interpretation to the results will be offered here. The positive influence of household assets implies that household wealth helps to ease the constraints on resources needed when implementing multiple soil conservation practices. Farm size had a negative significant effect on implementation of MSCPs. Since soil conservation practices compete directly with crop enterprises for land, farmers with smaller parcels of land are unlikely to implement multiple soil conservation practices. Another possible reason for this would be that smaller parcels of land are unlikely to vary in attributes and therefore a single soil conservation practice would be sufficient. Finally, some location dummies had significant positive effects on implementation of MSCPs. Location attributes such as altitude and weather conditions might determine whether a farmer engages in multiple soil conservation practices or not.

Table 5.3: Results of the probit model used in generating propensity scores

Covariates	Coefficients	Std. Err.	Marginal effects
Gender of household head (Male=1)	0.38	0.258	0.13
Age of household head (years)	0.01	0.008	0.00
Farm size (ha)	-0.12**	0.062	-0.04
Square of farm size (ha)	0.00	0.003	0.00
Average Household education level (years)	-0.01	0.031	0.00
Number of adults in the household	-0.05	0.056	-0.02
Dummy for attending training (1=Yes)	-0.05	0.204	-0.02
Distance to the river (Kms)	0.02	0.034	0.01
Household asset ownership (0-1 index)	4.63***	1.101	1.51
Perception on soil erosion as a problem in the area	0.27	0.177	0.09
Dummy for cattle ownership (1=Yes)	0.41	0.376	0.15
Dummy for secure land tenure(1=Yes)	0.11	0.209	0.04
Dummy for access to extension(1=Yes)	0.30	0.202	0.10
Natural log of off-farm income per year	0.03	0.019	0.01
Dummy for location in Kianjogu WRUA (1=Yes)	1.33***	0.511	0.26
Dummy for location in Lower Malewa WRUA (1=Yes)	0.82**	0.414	0.20
Dummy for location in Middle Malewa WRUA (1=Yes)	0.37	0.352	0.11
Dummy for location in Upper Malewa WRUA (1=Yes)	0.51	0.391	0.14
Dummy for location in Mkungi Kitiri WRUA (1=Yes)	0.11	0.321	0.04
Dummy for location in Upper Gilgil WRUA (1=Yes)	0.02	0.328	0.01
Dummy for location in Upper Turasha WRUA (1=Yes)	0.26	0.299	0.08
Proportion of marketed output (%)	-0.60**	0.327	-0.20
Constant	-2.39***	0.658	
Model summary statistics			
Number of observations	293		
LR χ^2 (24)	70.24***		
Pseudo R^2	0.19		
Log likelihood	-145.61		
% of correct predictions	77.9		

*,**,*** indicate significance at 0.1, 0.05 and 0.01 levels respectively.

The effect of implementing MSCPs was estimated using two outcome variables: the value of crop production and the log of the value of crop production. The estimates of average effect of implementing multiple soil conservation technologies on the value of crop production per hectare (ATT) are presented in Table 5.4. As shown in the table, t-tests were conducted to assess the quality of the matching to ensure that the distribution of covariates is equal between the treated and control samples independent of the treatment. The t-statistics obtained (p>0.1) indicates that satisfactory matching quality was achieved for all covariates included in the model. The test of the balancing property was done considering only those observations that were on common support. Results indicate that farmers who had implemented multiple soil conservation practices generated 34.45%[15] higher value of crop

[15] The percentage was computed using the formula: percent change in Y = 100 (e^{diff} - 1), where diff =mean difference on the log. variable and Y is the value of crop production. For more about this formula see the Sports science journal webpage: http://www.sportsci.org/resource/stats/contents.html.

production than those who did not. The monetary equivalent of this effect will be discussed later together with the opportunity costs of implementing soil conservation practices.

Table 5. 4: Effect of implementing multiple soil conservation practices (MSCPs)

	OUTCOME VARIABLES	
	Value of crop production per hectare	**Log of value of crop production per hectare**
Before matching		
Mean difference	6,000	0.181
t-stat	0.36	1.416**
After matching		
ATT	13,627	0.296[a]
t-stat	0.61	1.89**
Balancing property		
Attained?	YES	YES
Standardized mean bias	5.2%	5.2%
Common support condition		
Imposed?	YES	YES
N on common support	170	170
Number of observations		
Total	293	293
Treated	80	80
Controls	90	90

** Value statistically significant at the 0.05 level.
a- The outcome variable was computed by dividing the total value of crop production by the land under crops
b- The outcome variable was computed by dividing the total value of crop production by the land under crops plus the degraded land that was not usable

Soil conservation practices involve both direct costs and indirect costs. Direct costs emerge from the investment of scarce farm resources such as land and labour on initial installation[16] and maintenance of soil conservation practices. Indirect costs emerge since farmers have to forego crop production and wages so as to allocate land and labour towards soil conservation practices. As elaborated by Ellis-Jones and Tengberg (2000), opportunity costs[17] in implementation and maintenance of soil conservation practices arise from two main components. The first component is the gross margin of the crops that would have been grown in the portion of land occupied by the soil conservation practices. For every year, since that portion of land cannot be available for crop production, then the output foregone constitutes the opportunity cost. The second component was the opportunity cost of labour used in maintenance of soil conservation practices. To evaluate the opportunity cost of labour,

[16] In the current study since we are assessing the benefits during one specific time period, we do not factor in the initial installation costs but rather the opportunity costs for that specific time period.
[17] However, note that contour farming and cover crops which are part of the soil conservation practices analyzed in the current study do not involve real maintenance costs or compete with crops for land and therefore their opportunity cost of land and labour was taken to be zero.

the labour requirement estimates provided by Ellis-Jones and Tengberg (2000) and the wage rates reported by farmers were used. The wage rates differed with locations ranging between Ksh. 100 (1 €) and 250 (2.5 €) with a mean of Kshs. 150 (1.5€).

The opportunity costs are unique for every region and could also differ even for every farmer because they depend on farm and farmer circumstances such as the slope of the farm, the prevailing wage rates for the off-farm employment opportunities that each farmer has access to and the gross margins of the enterprises that each farmer has, which is in turn dependent on prices. Table 5.5 presents the opportunity cost estimates under four categories. The categorization aimed at capturing the unique attributes that determine the magnitude of opportunity costs. Each category considers the slope of the farm, productivity of each farm based on the average gross margin and the wage rate. Low productivity farmers where those whose gross margins were in the first and second quartiles while the high productivity farmers were those in the third and fourth quartiles. To facilitate meaningful comparison of the opportunity costs and the benefits generated by soil conservation practices as presented in Table 5.4, the opportunity costs were computed for the reference year (2010) and therefore did not include the initial outlay costs incurred when the soil conservation practices were implemented.

The figures in Table 5. 5 indicate that the extremely sloping farms had higher opportunity costs partly because larger land in these areas was dedicated to soil conservation practices. Opportunity cost of land formed a larger part of the total opportunity costs.

Table 5. 5: Opportunity costs of implementing MSCPs

		Category 1: Low productivity , moderately sloped	**Category 3: Low productivity , extremely sloped**	**Category 2: High productivity , moderately sloped**	**Category 4: High productivity , extremely sloped**
(1)	Gross margin (Kshs/ha)	2,644	1,850	100,084	61,195
(2)	Average land lost to SCPs (Ha)	0.36	1.12	0.26	0.39
(3)	% of total land under SCPs	14%	21%	14%	15%
(4)	Opportunity cost of land (Ksh)	1,291	9,804	23,366	29,811
(5)	Opportunity cost of labour (Kshs)	937	3,406	653	1,134
(6)	Total Opportunity cost (OC) (KSh)	2,228	13,210	24,019	30,945
(7)	Average farm size (ha)	1.41	1.23	1.04	0.80
(8)	Total opportunity cost (Kshs/Ha)	1,580	10,740	23,095	38,489
(9)	Average value of crop production (D=0)	21,662	39,529	102,041	66,446
(10)	Value of crop production attributable to MSCPs[a]	7,582	13,385	35,714	23,256
(11)	Difference between OC and Benefits	6002	3095	12619	-15233

a. This value is obtained by multiplying row (9) with 34.5%

At this point, the effect of soil conservation practices in monetary value can be computed. Given that MSCPs were found to generate 34.5% higher value of crop production, the monetary value under each category can be computed by multiplying the figures in row (9) of Table 5.5 with this percentage. This computation indicates that the value of crop production that can be attributed to multiple soil conservation practices ranged between Kshs. 7,582 and Kshs. 23,256 per ha per year (row (10)). Comparing these marginal benefits with the opportunity costs (row (8) we can see that under category 1-3, the marginal benefits are large enough to cover the opportunity costs, while in category 4 the costs outweigh the benefits. The benefits generated by MSCPs are substantial since they range between 16-50% of the annual wages considering the average wage rate. Four issues emerge from these results. First, high productive farms located in extremely sloped areas had opportunity costs larger than the additional benefits since in such areas soil conservation measures occupy more land. This is consistent with what Pagiola, (1994) found in the case of Kitui and Machakos regions of Kenya where he found that steeper farms required closer spacing of terraces and therefore reducing the cultivable land even further. Secondly, reduction in effective area combined with loss of soil fertility as a result of soil erosion seems to work against farmers located in extremely sloped areas as seen in the differences between category 1 and 2. Third, a cross tabulation between the categories and adoption of soil conservation practices indicates that despite farmers in category four having opportunity costs larger than the benefits generated by the soil conservation practices, majority of them were implementers of MSCPs. This could imply that there are other motivations to implementing soil conservation practices beside the economic benefits. Finally, we see that although farmers in category 2 have low productivity; they still had a positive benefit from soil conservation. This implies for such farmers, soil conservation was indeed beneficial since is the highly degraded land that is likely to benefit more from soil conservation efforts.

5.4.3 Robustness and Sensitivity Analysis of the ATT

5.4.3.1 Determinants of the Value of Crop Production

Exogenous switching regression analysis based on matched observations of implementers and non implementers of multiple soil conservation practices was used to check the robustness of the results obtained through PSM. Table 5 presents the results of exogenous switching regression models. The results in

Table 5. **6** indicate that the coefficients of the cost of fertilizers, size of land allocated to crops and proportion of marketed output were consistent in sign and significance for both implementers and non implementers of MSCPs. The positive influence of fertilizer use on crop productivity is obvious. The negative effect of land under crops is consistent with theoretical expectation that farmers with smaller parcels of land are able to optimize their production better and receive higher yields compared to those with larger parcels. Otsuki (2010) claimed that smaller plots tend to be more productive than larger plots, especially in the case where households mostly use family labor for crop production. The proportion of marketed crop output, a proxy for agricultural commercialization had a positive effect on the value of crop production. Farmers who are commercial oriented are also most likely to have higher productivity as confirmed by the results since they are also likely to use more purchased inputs. The crop output for the implementers of MSCPs however seemed to be more responsive to external inputs as indicated by the significant coefficients of use of pesticides and manure in the model for implementers of MSCPs. Against expectation, more educated implementers of soil conservation practices were found to have lower value of crop production. A possible explanation to this finding is that more educated individuals dedicate much of their effort to off-farm income generating activities. This result was confirmed by the fact that farmers who participated in off farm income generating activities had slightly lower value of crop production (mean difference = Ksh. 1,967, $t_{(291)} = 0.108$). Likewise, access to extension services was found to negatively influence the value of crop productivity. As also indicated by Gautam, (2000) who also found a similar result, it would be misleading to interpret this result to imply that extension has a negative effect on crop productivity. Rather, this negative effect could be as a result of endogeneity issues. For instance, it could be that given the demand driven extension model used in Kenya, access to extension is biased in favour of elite and more productive farmers who can afford the services. This fact may therefore make it difficult to identify the effect of extension on productivity from cross-sectional data (Gautam 2000).

Table 5. 6: Determinants of value of crop production

Explanatory variables	Implementers of ISCTs	Std. Err.	Non Implementers of ISCTs	Std. Err.
Dummy for engagement in off-farm activity	0.39**	0.172	0.15	0.180
Dummy for use of hired labour	0.27	0.160	0.15	0.223
Land under crops	-0.37***	0.112	-0.39***	0.094
Cost of fertilizer per year (Ksh.)	0.0001**	0.0002	0.0001**	0.0003
Age of household head (years)	-0.01*	0.006	0.00	0.008
Soil erosion perceived present (1=Yes)	-0.32*	0.169	-0.14	0.195
Dummy for engagement in exchange of materials	0.30	0.240	0.32	0.289
Dummy for use of pesticides	0.32*	0.187	0.08	0.222
Livestock ownership (TLU)	0.02	0.020	-0.01	0.023
Distance to nearest tarmac road	0.02	0.019	0.02	0.027
Dummy for post secondary education	-0.90*	0.497	0.30	0.514
Dummy for use of manure	0.37**	0.156	-0.03	0.191
Proportion of marketed output	0.86***	0.353	1.85**	0.376
Number of interacted with by household	0.001	0.001	0.00	0.001
Dummy for practicing irrigation	0.24	0.190	0.28	0.237
Access to extension services	-0.38*	0.200	0.13	0.218
Dummy for location of household	-0.13	0.198	0.04	0.208
Slope of the farm (1=Extremely sloping)	-0.32	0.272	-0.29	0.307
Constant	10.71***	0.588	10.18**	0.628
Model summary statistics				
Number of Observations	80		90	
F-statistics	$F_{18,61} = 7.99$***		$F_{18,71} = 4.55$***	
R-squared	0.70		0.54	

*,**,*** indicates parameters are significant at the 0.01, 0.05 and 0.1 levels respectively.

Table 5. 7 presents mean differences in predicted value of the log of crop production per hectare. The results indicate a significant positive influence of implementing multiple soil conservation practices on the value of crop production per hectare. In general, results of the exogenous regression analysis are consistent with those obtained with Propensity Score Matching (PSM). The mean difference of the predicted value of the log of value of crop production was 0.29. When translated into a percentage, this implies that implementers of MSCPs had 33.6 % more value of crop production compared to non implementers. Considering the categories presented in Table 5, this would imply that implementing multiple soil conservation practices would generate additional value of crop production ranging between Ksh. 7,279 and Kshs. 22,325. Both PSM and exogenous switching regression show a significantly higher value of crop production for individuals who had implemented MSCPs.

Consistency in the sign of the effect is satisfactory while the slight difference in the figures obtained from the two approaches could be due to the use of different approaches which is acceptable so long as the differences are within a reasonably narrow margin.

Table 5. 7: Differences in means of predicted logarithm of the value of crop production

	Number of observations	**Mean**	**Std. error**
Implementers	80	11.98	0.080
Non-Implementers	90	11.27	0.089
Mean difference		0.29	0.120
T-test		2.428***	

*** indicates statistics are significance at the 0.01 level

5.4.3.2 Sensitivity of the ATT to Unobserved Heterogeneity

The sensitivity of the ATT to unobserved heterogeneity was assessed using the Rosenbaum (2002) bounds test. The results on Table 5. 8 indicate that the treatment effects are not very sensitive to hidden bias caused by unobserved heterogeneity which results from unobserved covariates - such as individual skills or personal abilities - that might simultaneously affect the treatment and outcome variables. The upper bound of the p-value (p+) becomes insignificant when the sensitivity parameter (Γ) is equal to 1.2. This implies that the probability of receiving treatment by two individuals with the same observed covariates can differ by up to 20% without altering the inference on the treatment effect. These results indicate a relatively low sensitivity of the ATT to hidden bias, and therefore the estimated effect is a result of implementation of multiple soil conservation practices.

Table 5. 8: Bounds test results indicating sensitivity of treatment effects to hidden bias

Sensitivity parameter (Γ*)	**Level of significance (p^+)**	**Level of significance (p^-)**	***Confidence interval***	
1	0.026	0.026	-0.001	0.634
1.05	0.040	0.016	-0.048	0.659
1.1	0.058	0.010	-0.076	0.690
1.15	0.080	0.006	-0.111	0.722
1.2	0.107	0.004	-0.137	0.747
1.25	0.139	0.002	-0.158	0.769
1.3	0.174	0.001	-0.175	0.799
1.35	0.214	0.001	-0.210	0.821
1.4	0.256	0.001	-0.232	0.847
1.45	0.300	0.000	-0.261	0.870
1.5	0.346	0.000	-0.286	0.897

*This parameter represents the odds ratio and measures the degree of departure from equal treatment between observations. A value of 1 implies that the odds ratio of treatment is the same and therefore the study is free from hidden bias.

5.5 Summary, Conclusions and Policy Implications

The main objective of this study was to estimate benefits of implementing multiple soil conservation practices. Using data obtained from smallholder farmers in Lake Naivasha basin, Kenya, the study employed Propensity Score Matching (PSM) to estimate the additional value of crop productivity that can be attributed to implementation of MSCPs. Investigating returns to soil conservation practices is of crucial importance for successful promotion of soil conservation technologies because farmers will continiously use MSCPs if they believe that they are profitable. PSM was used to address self-selection bias and evaluate conservation technology effect on the value of crop production.

Consistency of the resulst was checked using exogenous switching regression models and t-tests, while sensitivity of the results to unobserved heterogeinity was checked using bounds test. From the PSM, matched samples of implementers and non implementers of MSCPs were obtained to ensure uniformity in the samples such that the individuals who were compared differed only in the treatment.

The estimated average treatment effects (ATT) obtained through PSM method show that implementation of MSCPs yields positive significant effects on the value of crop production per hectare. The results were confirmed by the alternative approach used. However, to make a more reasonable conclusion, these benefits were compared with opportunity costs of soil conservation practices. Results indicate that soil conservation practices will only generate positive benefits that are large enough to cover the opportunity costs only under certain circumstances. The marginal benefits were found not to be high enough to cover the opportunity costs associated with the implimentation of MSCPs in highly productive and extremely sloped farms. The results reveal that the magnitude of benefits from soil conservation practices will depend on land productivity and the slope of the farm. Indirectly, the prices of output and input might also influence these benefits.

Also, the fact that majority of farmers whose marginal benefits were not large enough to cover the opportunity costs still implemented MSCPs could indicate that there are other non economic motivations to soil conservation. These could be intrinsic social incentives (Willy & Holm-Mueller 2013) or the ability to access labour from communal labour sharing mechanisms (Pagiola 1998). Our study also reveals that it is beneficial to combine multiple soil conservation practices into a soil conservation package. A previous study by Zhunusova, (2012) in the same basin where this study was conducted found that individually, terraces had a negative effect on crop productivity. However, as revealed in the current study, when such a practice is used within soil conservation package involving MSCPs, the overall effect is positive. This result highlights the importance of using the approach of assessing the complementary effects of different soil conservation practices such as the one used in the current study.

Given these findings, policies that emphasize on multiple approaches to soil conservation are encouraged, where comprehensive soil conservation packages that suit farmers' local conditions are promoted. The suitability of soil conservation practices vary with topography, soil types and other parameters. These parameters vary greatly even within the same farm and therefore farmers need technical assistance in selecting the practices that are best suited to their local conditions. Also, given that economic benefits are not the sole determinants of soil conservation, it is also imperative for policy makers to identify and address any other constraints to the implementation of MSCPs. There is an opportunity for future research where a dynamic assesment is done that incorporates time preference considerations in the assessment of the effect of multiple soil conservation practices on the value of crop production.

CHAPTER SIX

6 Effects of Social Influence and Collective Action on Soil Conservation Efforts[18]

6.1 Introduction

The agricultural sector plays a key role in livelihood support and economic development in Sub-Saharan African (SSA). However, statistics indicate that historically agricultural productivity growth in SSA has been lower than in the rest of the world (OECD & FAO, 2012). The stagnation in productivity growth can be attributed to suboptimal external input use, pests and diseases, soil degradation, frequent and prolonged droughts, and poor market integration among other challenges (World Bank, 2008). Soil degradation which occurs mainly through soil erosion and loss of soil fertility is a major challenge to SSA agriculture because it not only causes a decline in crop yields and desertification but also increases crop production costs in the long run. Smallholder farming systems in SSA are characterized by high rates of land fragmentation, intensive tillage of land, nutrient mining and extraction of crop residues to feed livestock. These practices accelerate soil degradation and soil erosion, making agriculture one of the most serious sources of non-point water pollution. In cases where rural agriculture has intensified, increased use of inorganic fertilizers leads to infiltration of Nitrogen and Phosphorous from agricultural fields to surface water bodies (Berka et al. 2001). Effective soil erosion control could therefore enhance long term productivity of farmers' most valuable physical asset-land, mitigate the negative impacts of soil degradation on crop yields and the environment and also boost efforts towards rural poverty alleviation.

Achieving substantial adoption and diffusion of soil and water conservation practices and other agricultural innovations in SSA has been a challenge in recent decades, a trend that authors attribute to low awareness, negative attitudes and insufficient financial capacity among other factors (Khisa et al., 2007; Pretty et al., 1995 and van Rijn et al., 2012). However, it is noted that sometimes even when the right conditions prevail, adoption rates may still remain low. As Lynne et al. (1988) note, awareness, right perceptions and

[18] This Chapter is based on the article:
Willy, D.K., Holm-Mueller, K., 2013. Social Influence and Collective Action Effects on Farm Level Soil Conservation Effort in Rural Kenya. Ecological Economics 90, 94-103.

substantial capacity are necessary but not sufficient conditions for the adoption of soil conservation practices. This observation raises the question: Why would farmers not adopt a practice even when economic incentives seem sufficient?

To answer this question, we have to seek other factors beyond individual capacity and perceptions that could explain farmers' choices such as social factors. Given that soil and water conservation practices are associated with benefits that are partly public goods, one of the important aspects to consider is the effect of communal coordination mechanisms on individual adoption behavior. Collective action is cited as one of the most successful coordination mechanisms for natural resources management and also for increasing agricultural production (Meinzen-Dick et al., 2002 and Ravnborg et al., 2000). Collective action can be defined as what happens when individuals voluntarily contribute to an effort towards achieving an outcome (Poteete & Ostrom 2004) or when voluntary action is taken by individuals within a group to achieve a common goal (Meinzen-Dick & Di Gregorio 2004). At community level, the effects of collective action are clear since individuals are able to mobilize local resources as an avenue for seeking solutions to societal problems, especially where isolated individual efforts to solve these problems are not tenable (Swallow et al. 2002). What is not clear is the indirect role of participation in collective action as a driver for individual efforts on soil and water conservation. Do individuals who participate in collective action acquire certain network externalities which enable them to implement better practices? To explain this we need to look at how collective action emerges and operates. Social networks and social participation which are important components of social capital enable individuals to engage in frequent interactions with others and facilitate the access to information and sharing of knowledge and better access to markets through collective bargaining. Reciprocity based on trust and trustworthiness is also an important feature that facilitates collective action since individuals within a social group may engage in informal exchanges with each other in the hope that the counterparts will reciprocate (Pretty & Ward 2001). Through reciprocate exchanges; individuals are able to minimize costs associated with acquisition of inputs hence making technology adoption easier. Social networks and repeated interactions create mutual social influence between individuals within a group, a phenomenon that is manifested through subjective norms and neighbourhood social influences. A subjective norm is defined as "a person's perception that most people who are important to him or her think (s)he should or should not perform the behavior in question" (Ajzen & Fishbein 1975). Neighbourhood social influences relate to the degree of prompting that an individual receives from peers. There is however limited evidence in the literature on the direct role of neighbourhood social influences and subjective norms in determining soil conservation effort.

Against this backdrop, the current study seeks to analyze the effect of neighbourhood social influence and participation in collective action initiatives on soil conservation effort among smallholder farmers in Lake Naivasha basin, Kenya. Soil conservation effort is measured by the number of soil conservation practices that a farmer has implemented among a variety of practices: Terracing, Napier grass, Contour farming and Filter grass strips. The study seeks to ascertain whether social capital facilitates collective action which then enhances individual action and whether social control that may emerge from social networks within a community may substitute for pure economic incentives to undertake individual action on soil conservation. To achieve the stated objectives, a two stage econometric estimation procedure was applied to primary data collected during a household survey among 307 randomly selected small-scale farmers.

The rest of the chapter is structured as follows: section 6.2 presents our theoretical and conceptual frameworks and empirical models and section 6.3 describes the study area and data collection methods. Section 6.4 presents and discusses descriptive and regression results, while section 6.5 concludes and draws policy implications.

6.2 Theoretical and Conceptual Frameworks

6.2.1 The Agricultural Household Model

Following Fernandez-Cornejo (2007), our theoretical model modifies the agricultural household model (Singh et al., 1986) to accommodate participation in collective action initiatives and technology adoption decisions. The agricultural household model explains farm household optimization behavior by maximizing utility (U) as per the objective function:

$$Max\ U = (G, L, H, \varphi) \tag{6.1}$$

where G = purchased consumption goods, L= leisure, H = factors exogenous to the current decisions such as human capital, and φ = other household characteristics. Household utility is maximized subject to:

$$Income\ constraint\ : \quad P_g G = P_q Q - W_x \boldsymbol{X'} + \boldsymbol{WM'} + I \tag{5.2}$$

Technology constraint : $Q = Q[X(\tau), F(\tau), \boldsymbol{H}, \tau, \boldsymbol{R}],\ \tau \geq 0$ (5.3)

Time constraint : $T = \boldsymbol{F}(\tau) + \boldsymbol{M} + \boldsymbol{L},\ \ \boldsymbol{M} \geq 0$ (5.4)

where P_g and P_q denote the prices of purchased goods and farm output respectively, G and Q are quantities of purchased goods and farm output respectively; W_x and X are row vectors of price and quantity of farm inputs which is a function of the intensity of technology adoption (τ); I is exogenous income, $\boldsymbol{R}$ is a vector of exogenous factors that shift the production function; and T denotes the total household time endowments, which is split between off farm activities, M; Leisure, L and farm work, F which is a function of the intensity of technology adoption (τ) since some technologies are labour saving hence freeing some labour time for allocation to other activities. The technology constrained measure of household income is obtained by substituting (6.3) into (6.2) (Huffman, 1991):

$$P_g G = P_q Q[X(\tau), \boldsymbol{F}(\tau), \boldsymbol{H}, \tau, \boldsymbol{R}] - W_x \boldsymbol{X}(\tau)' + \boldsymbol{W}\boldsymbol{M}' + I \quad (6.5)$$

The first order optimality conditions (Kuhn-Tucker conditions) are obtained by setting up the langragian function (6.6) and maximizing $\mathcal{L}$ over (G, L) and minimizing the function over the Langrage multipliers (λ, μ):

$$\mathcal{L} = U(\boldsymbol{G}, \boldsymbol{L}, \boldsymbol{H}, \varphi) + \lambda\{\mathrm{P_q Q[X(\tau), \mathbf{F}(\tau), \mathbf{H}, (\tau), \mathbf{R}] - \mathbf{W}_x \mathbf{X}(\tau)' + \mathbf{WM}'} + I - \mathrm{P_g G}\} + \mu[\mathrm{T - F(\tau) - M - L}] \quad (6.6)$$

Reduced form equations of the household model obtained from the Kuhn-Tucker conditions of (6.6) can used to obtain optimizations for off farm participation decisions and decisions on adoption of technology. The household decision to participate in off-farm activities depends on the relation between the wage rate and the marginal product of farm labour. This relation can be used to obtain the demand functions for on-farm labour and leisure and eventually the supply function for off farm time. Non-zero optimum off farm time allocation occurs when marginal product of farm labour is equal to the wage rate, or when the wage rate exceeds the reservation wage (Fernandez-Cornejo 2007). On the other hand, the optimal extent of adoption will occur when the value of marginal benefit of adoption is equal to the marginal cost of adoption, which includes the marginal cost of production inputs and the marginal cost of farm work brought up by adoption of the technology, valued at the marginal rate of substitution between leisure and consumption of goods. Fernandez-Cornejo (2007) suggests the use of implicit function theorem to derive expressions for off-farm labour supply and technology adoption as a function of wages, prices, human capital, non-labour income and other exogenous factors. These factors may be replaced in the reduced form representations of farm labour supply and technology adoption by observable farm and farmer characteristics.

6.2.2 Conceptual Framework and Hypotheses

Adoption and diffusion of agricultural technologies has been studied extensively since the inaugural work by Ryan & Gross (1943) and Rogers (1962). Previous studies have identified key determinants of soil conservation technology adoption which can be categorized into personal characteristics such as age, gender and education level (Napier et al. 1984 ; Doss and Morris, 2001), economic factors like income, farm size and household asset ownership(Ervin & Ervin, 1982; Kabubo-Mariara et al., 2006; Marenya & Barrett, 2007 and Nkonya et al., 2008); physical factors like slope, altitude, climate and soil quality (Kabubo-Mariara, 2012); social and institutional factors such as credit, access to extension services, land tenure and perceptions on existence of soil erosion problem and the benefits of engaging in soil conservation (Ervin & Ervin, 1982; Kabubo-Mariara, 2012; 2007; Meinzen-Dick & Di Gregorio, 2004 ; Migot-Adholla et al., 1991; Place & Swallow 2000; Rogers, 1995 and Shiferaw & Holden, 1998).

To understand individual decision making beyond a purely individual perspective, behavioural approaches have also been used initiated by Lynne & Rola (1988) and Lynne et al. (1988) who applied the Theory of Reasoned Action (TRA) developed by Ajzen & Fishbein (1975) in the analysis of farmers attitudes and conservation behavior. TRA links behaviour to attitudes and social norms. An application of TRA to water conservation behaviour by Lynne et al (1995) finds a positive influence of community (subjective) norms on the likelihood and intensity of adoption. Technology adoption can be seen as a social process where individuals' decisions are conditioned by the social context within which they exist (Barrett et al. 2002). The social environment can be viewed as a complex pattern of a) individuals interacting and working together to achieve common goals and b) the possibilities of individuals influencing each other towards performing certain behaviours. The social influence-technology adoption link is expressed through subjective norms and neighbourhood social influences which are embedded within social norms and social capital. Neighbourhood social influences facilitate social learning, a process that helps to shorten the adoption process. Frequent interaction with potentially influential agents also creates network externalities (Foster & Rosenzweig, 1995, Kim & Park, 2011, Nyangena, 2006) and fosters the formation of social capital.

Social capital is a composite concept which encompasses *social participation*, *social support*, *social networks*, *reciprocity* and *trustworthiness* and enhance the ability of individuals to cooperate hence formation of collective action (Ostrom & Ahn, 2009) which can support or even make up for the lack of individual action in natural resources management. As Meinzen-Dick et al. (2002) indicate, participation in collective action initiatives is influenced by household and community characteristics such as distance to the market, level of social capital, location of a household within a resource supply system, group size and leadership quality. Participation in collective action may also be influenced by the perceived benefits of participation and attitudes on the usefulness of such participation. As Meinzen-Dick et al., (2002) note, the presence of other organizations facilitates participation in collective action since it provides an opportunity for boosting social capital and organizational density especially when an individual is also involved in the activities of these other organizations. The number of adults in a household and the number of years of living in a community may further enhance the capacity of a household to participate in collective action. Figure 6. 1 shows relationships between dependent and explanatory variables and hypothesized signs of these relationships.

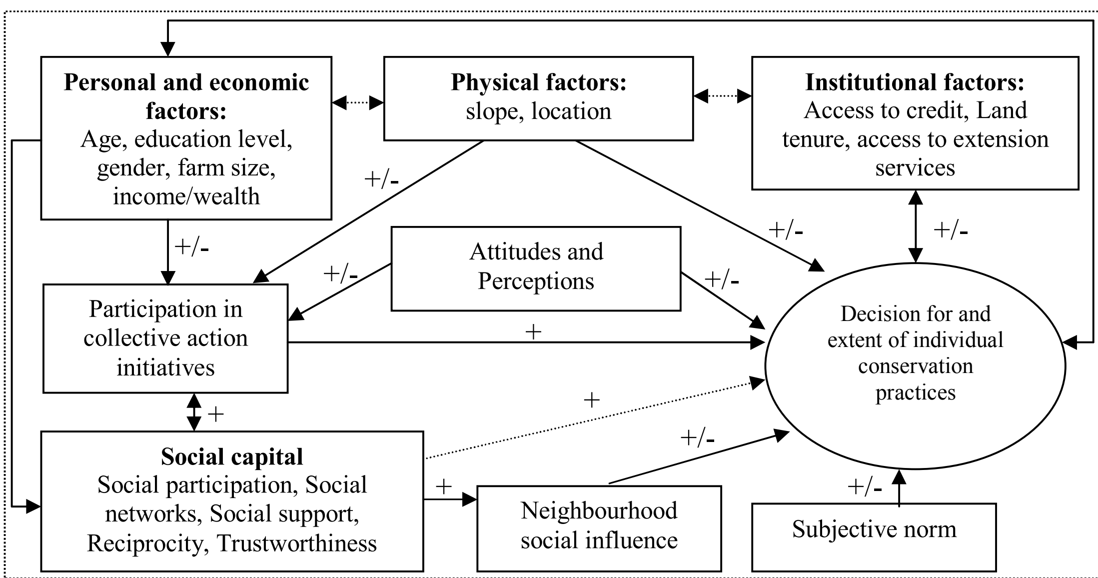


Figure 6. 1: Conceptual framework
Source: Authors' conceptualization.

6.2.3 Binary and Ordered Probit Regression Models

To estimate the decisions to participate in collective action initiatives and soil conservation effort empirically, a two stage econometric model is specified to address self selection problems. Participation in collective action exhibits self selection because the households' decisions to participate in collective action are not random but rather individuals self select into participation depending on –among other attributes- specific household characteristics including their expected gains from participation and level of social capital. In the first stage, a binary probit model was used to regress participation in collective action initiatives on farmers' perceived benefits of participation, level of social capital and other personal attributes. A binary probit model was chosen because of the nature of the dependent variable which takes the value Y_{1i}=1 if a farmer was participating in collective action initiatives and Y_{1i} = 0 otherwise. The observed decision (Y_{1i}) is however assumed to represent a latent variable Y_{1i}^{*} which represents farmers' utility acquired from participation in collective action. We observe Y_{1i} if the underlying latent variable Y_{1i}^{*} exceeds a certain threshold following the decision rule:

$$Y_{1i} = \begin{cases} 1 & if\ Y_{1i}^{*} > 0 \\ 0 & if\ Y_{1i}^{*} \leq 0 \end{cases} \qquad (6.7)$$

Participation in collective action is specified as follows:

$$Y_{1i} = \boldsymbol{X}'_{1i}\boldsymbol{\beta_1} + \varepsilon_1 \qquad (6.8)$$

where Y_{1i} is a dummy participation variable, X'_{1i} is a vector of explanatory variables conditioning the decision to participation in collective action, which include the perceived benefits, level of social capital and other household characteristics. β_1 is a vector of coefficients to be estimated and ε_1 captures stochastic disturbances, assumed to be normally distributed.

In the second stage, the effect of participation in collective action, neighbourhood social influence and subjective norms on the soil conservation efforts was estimated. The inverse mills ratio (Heckman 1979) generated from the first stage entered the second model as an explanatory variable. The number of soil conservation practices that a farmer has implemented was used to represent the effort of soil conservation. Each farmer faces multiple choices on the number of soil conservation practices which they can implement, with a possibility of multiple adoptions. To account for the multiple adoption possibilities and the ordinal nature of the dependent variable, an ordered probit model was used. Among the four soil conservation practices considered in this study, five possible choices are generated: $Y_{2i} = 0$ (none of the practices implemented), $Y_{2i} = 1$ (only one practice implemented) $Y_{2i} = 2$ (two practices implemented); $Y_{2i} = 3$ (three practices implemented) and $Y_{2i} = 4$ (four practices implemented). However, since there were too few farmers (~ 2%) who had implemented all the four practices, this category was merged with the one with 3 practices, ending up with four categories. To model the four soil conservation effort outcomes we use an ordered response model:

$$Y_{2i}^{*} = \boldsymbol{X}'_{2i}\boldsymbol{\beta}_2 + \hat{Y}_{1i}^{*}\alpha + \boldsymbol{S_i}\gamma + \boldsymbol{N_i}\vartheta + \varepsilon_2; \quad \varepsilon_1 \backsim NID(0, \sigma^2) \tag{6.9}$$

and

$$Y_{2i} = \begin{cases} 0 \text{ if } Y_{2i}^{*} \leq \theta_1, \\ 1 \text{ if } \theta_1 < Y_{2i}^{*} \leq \theta_2, \\ 2 \text{ if } \theta_2 < Y_{2i}^{*} \leq \theta_3, \\ 3 \text{ if } \theta_3 \leq Y_{2i}^{*} \end{cases} \tag{6.10}$$

where Y_{2i}^{*} can be interpreted as the soil conservation effort, θ_1 are threshold parameters to be estimated simultaneously with the other coefficients: $\boldsymbol{\beta_2}, \boldsymbol{\alpha}, \boldsymbol{\gamma}$ and $\boldsymbol{\vartheta}$. Y_{2i} is the number of soil conservation practices implemented by farmer i ; X'_{2i} is a matrix of control explanatory variables, $\hat{Y}_{1i}^{*}$ are the inverse Mills ratio values obtained from the binary probit model in step one, S_i and N_i are row vectors representing households' subjective norm and households' neighbourhood social influence index respectively and ε_2 are stochastic disturbances, assumed to be normally distributed. The parameters in both models were estimated using maximum likelihood in STATA 11.

6.3 Variable Description

Descriptions of the variables used in the estimations and their descriptive statistics are presented in Table 6. 1. The dependent variable for the first model was participation in collective action initiatives (*CAPART*). In the study area, there are several collective action initiatives including community mutual support initiatives, maintenance of rural access roads, and maintenance of communal water infrastructure and collective efforts for managing natural resources such as community water supply organizations. Individuals may choose to engage in the communal collective action initiatives either by contributing finances or by allocating time to these activities or both. Participation was measured by asking respondents whether they had participated in any of the collective action initiatives in the community either through contribution of their time or financial resources. Individuals who had participated in at least one collective action initiative by either of the means were considered as participants.

The dependent variable in the second model was the number of soil conservation practices implemented (*SCEFFORT*). The respondents were asked to give information on the soil conservation practices they had implemented on their farms, the year when first adoption occurred and the extent of implementation of these practices. The farmers where considered as adopters only when the extent of implementation was above a certain threshold (these thresholds are presented in Table 3). An ordered dependent variable was then generated by counting the number of soil conservation practices that each farmer had implemented.

The explanatory factors considered in the participation in collective action initiatives model were: the number of years a household has lived in the community (COMYEARS), number of adults in the household (ADULTS), distance to the nearest tarmac road as an indicator of access to markets (DSTAMAK), contacts with an external organization (EXTORG), whether a farmer thinks it is beneficial to participate in CA or not (PERCBEN), whether the household is located close to a river source or not (RIVPROX) and the level of social capital. Social capital was hypothesized to be an important precondition for participation in collective action. The role of social capital as a driver for participation in collective action was assessed using the indices of five components of social capital: *social participation*, *social networks*, *social support*, *reciprocity* and *trustworthiness*. These indices were generated by explorative factor analysis using Principal Components Analysis (PCA). PCA was conducted in three steps: First, respondents were asked specific questions that were used as indicators of each of the 5 components of social capital. Second, PCA with orthogonal rotation was carried out on these items. Sampling adequacy for the analysis was verified using Kaiser-Meyer-Oklin (KMO) statistic while Bartlett's test of sphericity was used to test whether correlations between items were large enough for PCA. Third, the components obtained from step 2 with Eigenvalues greater than 1 were selected for further analysis. The factor scores in each PCA component were summed up for each social capital component to obtain a single score and normalized on a 0-1 scale. The final indices were taken to represent the level of each of the 5 social capital components and were used as explanatory variables in the regression model. The PCA results and complete list of the specific questions/indicators used in the PCA are as provided in Chapter 3.

In the second model the personal attributes used as explanatory variables to estimate soil conservation effort included: gender of household head (GENDER), farm size (FARMSIZE) and household education level (HHEDUC). Institutional variables included land tenure (LANDTEN), access to extension services (EXTSERV) and access to credit (CREDTACES). Cattle ownership (CATOWN) was included in the model to control for direct benefits generated from soil conservation practices while perception that soil erosion is a problem (PECEROYES) was used to capture farmers' attitude and perceptions towards soil erosion. The inverse mills ratio generated from the participation in collective action initiatives model was used as a proxy for the probability of participating in collective action on soil conservation effort.

A neighbourhood social influence variable was included to represent the social pressure. A neighbourhood social influence (NEISOCINFL) indicator for each farmer i located in village k with N individuals at time *t* was computed using the expression below as formulated by the authors:

$$NSI_{it} = \frac{\sum X_{it}}{\sum_{i=1}^{N-1} P_{kt}} \qquad (6.11)$$

where X_i represents the behaviours performed by farmer i that are similar to those of their peers in the village (for example the number of technologies adopted or not adopted), P_{kt} are the behaviors performed by all other farmers within the village except *i.* Finally, the believe that individuals would adopt a technology just because those who are important to them think that they should was used to capture subjective norms (SUBNORM).

Table 6. 1 : Description of dependent and explanatory variables

Variable	**Description/Measurement**	**Mean**	**Std. dev**	**Expected sign**
Dependent variables				
CAPART	Participation in collective action initiatives (1=Yes)	0.49		
SCEFFORT	Soil conservation effort (Ordered numbers: 0,1,2,3)	1.65	0.89	
Explanatory variables (Binary Probit)				
PERCBEN	Participation in CA beneficial? (1=Yes)	0.68		+
DISTTMK	Distance to the nearest tarmac road (Kms)	5.01	12.15	+
COMYEARS	Length of time household has lived in the community (Years)	29.48	14.62	+
ADULTS	Number of adults in the household	3.28	1.57	+
ASSETINDEX[a]	Level of household wealth	0.35	0.12	+
SNETINDEX[a]	Intensity of social networks	0.19	0.14	+/-
SPARINDEX[a]	Intensity of social participation	0.31	0.18	+
SCSPINDEX[a]	Degree of social support	0.19	0.11	+
TRUSTINDEX[a]	Level of trustworthiness	0.45	0.33	+
RECINDEX[a]	Level of involvement in reciprocate exchanges	0.44	0.21	+
RIVPROX	Farm located close to river source (1=Yes)	0.24		+
EXTORG	Involvement with an external organization	0.26		+
Explanatory variables (Ordered Probit)				
FARMSIZE	Size of the farm (ha)	2.60	3.83	-
HHEDUC	Average years of schooling completed	7.30	3.35	+
CREDTACES	Number of credit sources accessible to the household (Number)	1.30	0.79	+
DSRIVER	Distance from the farm to the nearest river (Kms)	2.10	3.06	-
MILLSRATIO	Inverse Mills ratio	0.48	0.305	+
NEISOCINFL	Neighbourhood social influences index (0-1)	0.669	0.179	-/+
GENDER	Gender of household head (1=Male)	0.86		+
SUBNORM	I would adopt a technology because those important to me think I should (1=Yes)	0.65		+
PECEROYES	Perception that soil erosion is a problem (1=Yes)	0.50		+
CATOWN	Ownership of cattle by household (1=Yes)	0.92		+
LANDTEN	Land owned with title deeds (1=Yes)	0.62		+
EXTSERV	Contact with extension service providers (Dummy 1=Yes)	0.46		+
LOCDUMMY	Location of the household (1=K-Plateau)	0.36		+

a. These variables are measured by an index, with values ranging from a minimum of 0 to a maximum of 1.

6.4 Results and Discussions

6.4.1 Participation in Collective Action

Results indicate that 49% of the sampled households were participants in collective action initiatives. Time expenditure on communal activities was split between the activities indicated in Table 6. 2. On average, households spend about 43 hours per year, ranging from 1 to 384 hours on collective action related activities. A larger proportion of this time is spent on water related activities, since this is a major form of collective action in the area. Financial contribution to communal activities averaged at Kshs. 1,758 (17€) ranging from Kshs. 100 (1€) to Kshs. 11,000 (110€) within the year 2010.

Table 6. 2: Household time expenditure on communal activities

Communal collective action activity	% of households who participated	% time spend on activity
Water management activities	77.2	68.8
Tree planting	12.0	10.7
Access road maintenance	5.0	8.1
Soil erosion control	2.9	3.4
Construction of communal facilities	2.9	9.0

Source: Authors' survey data

6.4.2 Trends on Implementation of Soil Conservation Practices

Farmers in the Lake Naivasha basin have been using various strategies to control soil erosion since 1960s. The most popular soil conservation practices are: bench terraces, Napier grass, filter grass strips, contour farming, crop rotation, cover crops, planting of trees and inter-cropping. Among these practices, four practices were selected for in-depth analysis in this study because of their direct role in soil erosion control and permanent nature. Napier grass (*Pennisetum purpureum*) is a perennial plant native to Africa that is usually used as fodder. When planted on slopes, Napier grass controls soil erosion by formation of a natural barrier which obstructs soil movement. Napier grass has fibrous and rhizomatous roots with fast tillering characteristics which makes it an effective medium for soil erosion control (Mutegi et al., 2008). However, this rooting characteristic also makes it a potential competitor with crops for nutrients. Bench terracing is a practice that involves construction of bunds along the contour by digging ditches and heaping the soil on the upper or lower part to form an embankment, suitable especially for farms with moderate and steep slopes (Chow et al., 1999). These embankments prevent soil erosion by holding rain water and preventing run-off. By trapping soil particles, bench terraces also reduce phosphorus transportation to water bodies. Although this is a good measure against soil erosion, some studies have indicated that bench terraces may cause low crop yields in the short run, especially in high rainfall areas (Kassie et al., 2011; 2008; Tang, 1998). Filter grass strips is a practice involving planting strips of grass along and/or across gullies and water ways to act as a sediment filter. The commonly used grasses in the study area for this purpose are cock's foot (*Dactylis glomerata*) and Elmba Rhodes grass (*Chloris gayana*) which are also used as fodder. Vetiver grass also (*Vetiveria zizanoide)* is suitable for soil erosion control (Dalton et al. 1996). Finally, contour farming involves tilling land across the slope and establishing crops on the furrows formed by tillage. The technique controls erosion by slowing down run-off and redirecting it around the hill-slope. The practice also prevents the movement of soil particles and fertilizer loss.

Table 3 presents summary statistics for the four soil conservation practices. Given the duration that these practices have been in use in the study area, the practices were mature at the time of the study therefore we are not likely to generate biased and inconsistent parameter estimates that can be obtained if practices are studied when they have just been introduced (Marenya & Barrett 2007).

Table 6. 3: Soil conservation practices implemented by sampled farmers

Soil conservation practice	**Adopters (%)**	**Extent of adoption**			**Threshold**	**Length of practice (years)**	
		Mean	**SD**	**Unit**		**Mean**	**SD**
Napier grass	76.6	0.14	0.15	ha	2% of farm	12.6	11.22
Bench terraces	31.8	264.7	322.29	m/ha	50 m/ha	17.1	14.16
Contour farming	38.0	0.72	0.510	ha	10% of farm	17.9	13.96
Filter grass strips	20.5	267.1	314.59	m/ha	50 m/ha	12.7	12.83

Source: Authors' household survey data.

The trends of long term diffusion of the soil conservation practices (Figure 3) indicate that the penetration rate of these practices has been low, with only Napier grass having penetrated more than 50% of the potential adopters by 2011.

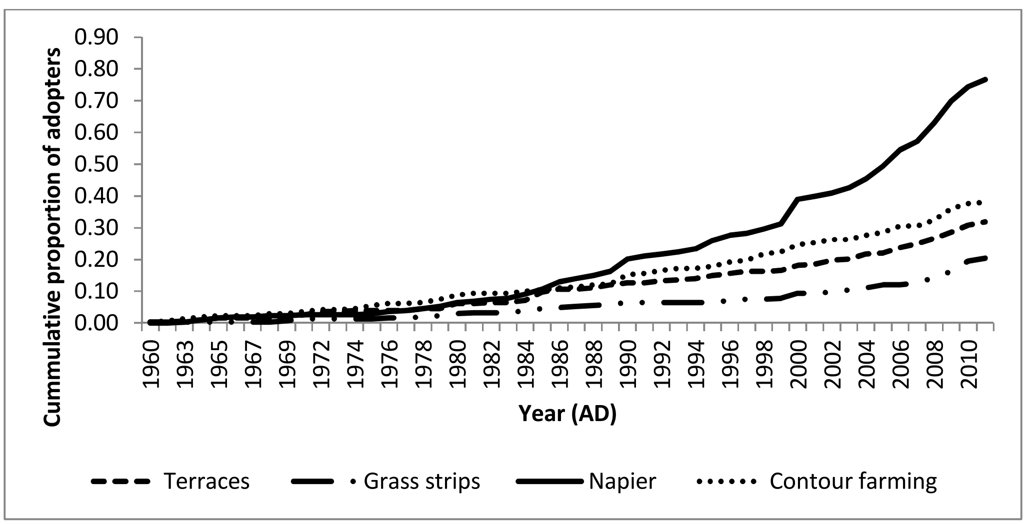


Figure 6. 2: Trends in diffusion of soil conservation practices in the study area
Source: Authors' household survey data

6.4.3 Binary and Ordered Probit Regression Results

Table 6. 4 and Table 6. 5 present regression estimates from the binary and ordered probit regression models respectively. Both models are highly significant ($p<0.01$), based on the likelihood ratio test for the null hypotheses that all the coefficients in each model are simultaneously equal to zero. Pregibon's link test for model specification (Pregibon, 1980) and Hosmer–Lemeshow statistic were used to assess the fit of the models. Given that $p > 0.1$ in both cases, we fail to reject the null hypothesis that the models accurately fit the data.

6.4.3.1 Determinants of Participation in Collective Action

Participation in the collective action initiatives was found to be significantly influenced by all the components of social capital included in the model. Social participation, social support, reciprocity and trustworthiness had significant positive influences on participation in collective action. It is worth noting that the different components of social capital are embedded and complement each other as indicated by their strong joint influence on participation in collective action (*Wald statistic* = 68.56, $p < 0.01$). For example, social participation, which was measured by the degree of household membership and active participation in communal groups and associations, provides opportunities for individuals to establish social networks and engage in repeated interactions hence form reputation and trustworthiness.

An increase in social participation by one unit increases the probability of participating in collective action initiatives by 41 percentage points. Trustworthiness was measured using indicators that required respondents to express to what extent they felt fellow community members could be trusted and was found to positively influence participation in collective action. A high level of trustworthiness creates trust among individuals in a community and enhances the tendencies of individuals to work together. Most collective action initiatives which involve reciprocate exchanges are built on trust, which ''….involves opportunities for both trustor and trustee to enhance their welfare'' (Ostrom & Ahn 2009). For instance, a farmer will only lend their labour time to other farmers when he/she can trust that they will reciprocate in future. When trust is well established, it eliminates the need for costly monitoring and enforcement since individuals expect others to act in accordance with the shared norms.

Table 6. 4: Determinants of participation in collective action

Variable	Coefficients	Std. error	Average marginal effects
Constant	-4.086***	0.677	
Degree of social support	1.490*	0.882	0.393
Intensity of social participation	5.354***	0.693	1.411
Intensity of social networks	-1.474**	0.698	-0.388
Level of participation in reciprocate exchanges	0.969*	0.524	0.255
Level of trustworthiness	0.683**	0.267	0.180
Farm located close to river source	0.356*	0.207	0.094
Household asset ownership	0.512	0.730	0.135
Perceives participation as beneficial	0.138	0.246	0.036
Distance to tarmark road	0.010	0.009	0.003
Years of living in the community	0.008	0.006	0.002
Number of adults in the households	0.055	0.054	0.014
Involvement with an external organization	0.432**	0.206	0.114
Model summary			
Number of observations	307		
Pseudo R^2	0.32		
LR χ^2 (12 d.f)	136.95***		
Log likelihood	-144.191		
% of correct predictions [a]	76.55		

[a] Model predictions based on the threshold, c = 0.5 *, **, and *** Coefficients are significant at the 0.1, 0.05 and 0.01 levels respectively.

A unit increase in the intensity of social networks reduces the probability of participating in collective action initiatives by 38.8 percentage points. One possible explanation for this result is that because this indicator included networks outside the community, community members with wider and stronger links outside the community may opt out of local communal initiatives and therefore reduce the likelihood of participating in local collective action. This result was supported by the positive influence of distance to the tarmac road indicating that the households in the interior with little access to the outsiders were more likely to participate in collective action initiatives at local level. As expected, households within WRUAs located closer to a river source had a higher probability of participating in collective action by initiatives 9.4 percentage points. Proximity to river sources makes it technically easier and cheaper for individuals to tap water for domestic and irrigation purposes collectively from a common intake, one of the most common forms of collective action in the area.

6.4.3.2 Determinants of Soil Conservation Effort

The estimated average marginal effects in Table 6. 5 are interpreted as percentage changes on soil conservation effort when an explanatory variable changes by one unit. For a positive marginal effect, an increase in explanatory variable would cause an increase in the latent variable, hence the probability that $Y_i=3$ will increase while the probability that $Y_i=1$ will decrease.

Male gender, higher level of education and better access to credit had positive influence on the soil conservation effort as expected. Male headed households are 8.4 percentage points more likely to implement 3-4 soil conservation practices compared to female headed households. This finding is consistent with that of Marenya and Barrett, 2007. Gender differences in soil conservation behaviour are manifested through gender influences on access and control of resources (such as land and labour), and access to information and credit services, factors that are important in determining soil conservation effort. Consistent with human capital theory, increasing the average household education level by one year increases soil conservation effort by 1.1 percentage points.

Access to credit influenced the soil conservation effort positively. Access to credit relaxes the household cash constraint thereby facilitating the acquisition of inputs necessary for establishing soil conservation practices. Secure land tenure and access to extension services had the expected positive influence on soil conservation effort but the coefficients were insignificant. The coefficient of farm size was negative, against expectations. Although it is obvious that soil conservation practices vary with scale of operation, a possible explanation of this finding is that in the Lake Naivasha basin case, farmers with smaller farms could have higher incentives to implement more soil conservation practices to prevent soil erosion from further reducing their actual area of production.

Results indicate that households who perceived soil erosion as a problem in the area also had a higher soil conservation effort. This is in agreement with earlier work by Asafu-Adjay, 2008; Ervin & Ervin 1982 and Rogers, 1995 who identified perception on soil erosion as a key first step preceding decisions to adopt soil conservation practices. Ownership of cattle increased the soil conservation effort by 12.0 percentage points. Farmers are likely to implement soil conservation practices that have win-win benefits such as Napier grass and Filter grass strips which provide fodder to complement those that only create long term benefits of soil erosion control and improved crop productivity such as terraces.

The marginal effect of the inverse mills ratio was 0.044 and significant indicating the presence of a positive selectivity bias in the model. This implies that an individual with average sample characteristics who self selects into participation in collective action implemented more soil conservation practices compared to an individual with average set of characteristics drawn at random from the population. Participation in collective initiatives enhances soil conservation since it creates an opportunity for farmer-to-farmer exchange of planting materials, information and labour. Exchange of labour enables the household to overcome labour constraints and therefore improve their prospects to implement labour intensive soil conservation practices. Community collective action initiatives also boost soil conservation because of the possibility of collective learning, selection of appropriate soil conservation practices and accessing innovations that adapt soil conservation practices to local conditions.

Increasing neighborhood social influence intensity by one unit was found to decrease the soil conservation effort by 16.0 percentage points. Considering that neighbourhood social influences could either be positive (encouraging soil conservation) or negative (discouraging soil conservation) this result implies that the negative neighbourhood social influence among the sampled households is stronger. This may explain the observation that soil conservation effort was generally low. For example only 31.8% of the farmers had implemented terracing which is a more demanding soil conservation practice.

Finally, subjective norms had a significant positive influence on soil conservation effort. The subjective norm considered in the analysis was the believe that individuals would adopt a technology (or not adopt) just because those important to them think they should do so. Individuals who held such believe had a higher soil conservation effort by 9.7 percentage points. As indicated by Ajzen and Fishbein (1975) subjective norms reflect some degree of social pressure and therefore the behavior of referent farmers may influence a farmer's intention on accepting a particular practice.

Table 6. 5: Determinants of soil conservation effort

Explanatory variables	Coefficients β	Std. Err. S.E	Average Marginal Effects Prob (Y_i=0)	Prob (Y_i=1)	Prob (Y_i=2)	Prob (Y_i=3)
Gender of household head	0.353**	0.188	-0.052	-0.070	0.038	0.084
Farm size	-0.051***	0.017	0.008	0.010	-0.005	-0.012
Education level of household	0.048**	0.021	-0.007	-0.010	0.005	0.011
Access to credit	0.229***	0.088	-0.034	-0.045	0.025	0.055
Distance to the River	0.039*	0.022	-0.006	-0.008	0.004	0.009
Subjective norms	0.408***	0.134	-0.060	-0.081	0.044	0.097
Perception that soil erosion is a problem	0.296**	0.127	-0.044	-0.059	0.032	0.071
Cattle ownership	0.500**	0.255	-0.074	-0.099	0.054	0.120
Land tenure	0.127	0.137	-0.019	-0.025	0.014	0.030
Access to extension services	0.042	0.134	-0.006	-0.008	0.005	0.010
Household located in the Kinangop plateau	-0.025	0.146	0.004	0.005	-0.003	-0.006
Neighbourhood Social Influence	-0.668*	0.357	0.099	0.133	-0.072	-0.160
Inverse Mills Ratio	0.184*	0.104	-0.027	-0.037	0.020	0.044
Threshold parameters						
θ_1	-0.245	0.459				
θ_2	1.065	0.462				
θ_3	2.254	0.469				
Model summary						
No. of observations	307					
Pseudo R^2	0.087					
LR χ^2 (13 d.f)	67.49^{***}					
Log likelihood	-356.300					

*, **, and ***: coefficients are significant at the 0.1, 0.05 and 0.01 levels respectively

6.5 Summary, Conclusions and Policy Implications

This chapter has presented an analysis of the effects of social influence and participation in collective action initiatives on soil conservation effort among smallholder farmers in Lake Naivasha basin, rural Kenya. The chapter applies binary and ordered probit models in a two stage regression procedure to cross-sectional data collected through a household survey among randomly selected smallholder farmers. Smallholder farming systems in the research area are associated with practices that render farmlands susceptible to soil erosion causing negative impacts on land productivity and the environment. Therefore, strategies that encourage soil conservation are likely to also offer solutions for dealing with agri-environmental challenges and poverty alleviation.

The binary probit regression results indicated that three components of social capital: *social participation*, *social support*, *reciprocity* and *trustworthiness* had positive influences on the probability of participating in collective action while social networks had a negative influence. Location of households closer to sources of rivers and involvement with external organizations was found to also enhance participation in collective action. It therefore emerges that social capital facilitates collective action. The findings from the ordered probit regression model indicate that participation in collective action initiatives enhances individual soil conservation efforts. This important finding indicates that social control that emerges from peer pressure and intrinsic subjective norms can substitute for pure economic incentives as a motivation for engaging in soil conservation. *Neighbourhood social influences, subjective norms, gender, education level, farm size, access to credit and livestock ownership* also emerge as key determinants of soil conservation effort.

From these findings three main policy implications can be drawn. First, soil conservation could benefit from efforts to encourage participation in collective action and enhanced effectiveness of existing collective action initiatives. One possible approach to achieve this is through policies that recognize local groups and facilitate capacity building through training of trainers within the community to strengthen local knowledge, leadership and innovativeness. Further, community participatory approaches could be enhanced as an incentive for participation in collective action on management of natural resources. Also, strategies that encourage regional social capital formation such as creating an enabling environment for local groups to form and thrive may boost collective action, especially on soil conservation and management of other natural resources. Secondly, the existing extension policy needs to be strengthened to incorporate strategies that recognize the important role played by neighbourhood social influence and subjective norms in dissemination of information and technologies including soil conservation practices.

Third, the results also suggest the need for strengthening of existing policies on access to agricultural credit and those that address gender related challenges on access to resources and information such as the law on affirmative action to encourage soil conservation among marginalized groups.

CHAPTER SEVEN

7 Modeling the Diffusion of Rain Water Harvesting Techniques[19]

7.1 Introduction

According to the World Bank (2013) the annual renewable internal freshwater resources per capita in Kenya averaged at 497.48 M^3 in 2011, placing Kenya among water scarce countries. This figure is projected to drop to 359 M^3 by 2020 (UN-WWAP 2006), mainly due to the increased demand resulting from population growth. In addition to general water scarcity, most regions of Kenya are prone to high rainfall variability which, together with high evaporation rates, results in frequent temporary shortages of available water for rain fed crops and agricultural, domestic and livestock watering uses. Since access to public water infrastructure is underdeveloped in rural areas, agricultural productivity and availability of water for household and livestock use is to a large extent dependent on natural weather conditions, making farm households highly vulnerable to droughts. Also, given the relative importance of water as an agricultural input, water scarcity and unstable supply is likely to have negative impacts on the agricultural sector and on rural development. To deal with the challenge, it is essential that appropriate and affordable adaptive and coping strategies are implemented. Some of the possible adaptive mechanisms to deal with weather related shocks include crop and livestock insurance, diversification of crop enterprises, adoption of drought tolerant varieties (DTVs) and irrigation. Although the first three strategies are also important, this study focuses on irrigation. Irrigation is a strategy that can enhance crop productivity, minimize crop failures and enhance employment in agriculture in the face of extreme dry weather conditions (Jara-Rojas et al. 2012). However, sustainable and reliable supply of water is a critical success factor for irrigation. At the micro-level (household), one of the options for establishing a reliable supply of water and ensuring sustainable food production is engaging in *ex-situ* rain water harvesting (RWH) (Ngigi 2003).

Ex-situ rain water harvesting is a simple and relatively low cost decentralized water supply technique that involves collecting and storing rain water for future use in productive

[19] This Chapter is based on the article:
Willy, D.K., Kuhn, A., Forthcoming. Modelling Diffusion of Rain Water Harvesting Techniques under Uncertain Weather Conditions: A Duration Analysis. *Agric. Water Management*. (Under Review).

activities such as domestic purposes, livestock watering and crop production. RWH enables households to improve their water supply and avert weather related risks and uncertainties. Since households who face frequent droughts also experience excess runoff during the rainy season, they could harness this excess run-off during the rainy season and use it during the dry season or during intra-seasonal dry spells to improve crop productivity especially in dry land farming. The most common *ex-situ* rain water harvesting techniques (RWHTs) are surface runoff harvesting and roof catchment rain water harvesting. Surface runoff harvesting involves diverting water-that flows off land when it rains- from road drainage or ephemeral streams into constructed reservoirs while roof catchment is a technique that involves harvesting rain water from roofs and storing in reservoirs or water tanks. RWH can be viewed as one of the most practical and cost effective solutions to water shortages, especially in improving rural water supply in many parts of the world where centralized water supply solutions prove too costly and ineffective. However, the diffusion of these techniques among rural households has been slow (Kahinda & Taigbenu 2011).

Previous studies on adoption and diffusion of RWHTs have focused mainly on understanding the interactions between rain water harvesting and crop yields (Adekalu et al. 2009; Barron & Okwach 2005; Wimalasuriya et al. 2008); modelling the ecohydrological dynamics associated with RWH (Ngigi 2003; Welderufael et al. 2013); testing and assessing the economic feasibility of RWHTs (Abu-Zreig et al. 2000; Kahinda et al. 2010; Pandey 1991) and assessing the challenges associated with RWH (Kahinda et al. 2007). An equally important aspect of rain water harvesting but which has received limited attention in literature is the identification of constraints to the implementation and spatial-temporal diffusion of RWHTs. A study by Kahinda and Taigbenu (2011) identified poor legislation, financial constraints and organizational issues as some of the constraints to diffusion of RWHTs at National level in South Africa. A few other studies in this vein (for example Jara-Rojas et al. 2012) and Sidibé 2005) have assessed adoption and diffusion at household level to identify the factors that constraint individual efforts to implement *in-situ* rain water harvesting. From these studies, it has emerged that natural and social capital, age, education level, income and access to extension services have a positive effect on the adoption of RWHTs. Differences in adoption behaviour could also be explained by technological advancements that could make the technology affordable and profitable over time, farmers' attitudes towards risk, land tenure, farmers' age, education and land tenure (Fuglie & Kascak 2001; Rogers 1995).

Despite the relative importance of RWHTs in rural development and food security, there is dearth of empirical studies that address the issue of diffusion of these techniques at a wide spatial scale. Beside understanding why some people would adopt a technology while others would not, it is also important to use approaches that help to explain the timing of adoption decisions since in most cases there are significant differences in adoption behaviour over time (Burton et al. 2003; Fuglie & Kascak 2001).

Lags in adoption between farms could have implications on farm performance and survival considering that farms who engage in timely adoption of a technology are likely to accrue the benefits associated with that technology first. Understanding why some individuals adopt a technology earlier than others would therefore be important in facilitating development of strategies and policies that accelerate dissemination of technologies.

This chapter uses a parametric econometric duration model (log-logistic) to analyze the diffusion of two RWHTs in a case study for the Lake Naivasha basin in Kenya's rift valley. The study seeks to assess the trends in diffusion of RWHTs in the 50 years preceding 2010 and identify the drivers and constraints to the diffusion process of these techniques. Specifically the study seeks to analyze the influence of rainfall variability household water demand on the diffusion path of RWHTs over time. Further, the influence of information sources, perceptions on water scarcity and other demographic attributes on the time that farmers wait before adopting run-off and roof-catchment rain water harvesting techniques is explored.

The rest of the chapter is planned as follows: Section 7.2 describes the theoretical and empirical models while section 7.3 describes data collection methods, variables and hypotheses. In section 7.4 we present and discuss descriptive statistics and log-logistic regression analysis results. Section 7.5 concludes and draws policy implications and future research outlook.

7.2 Theoretical, Empirical and Conceptual Frameworks

7.4.1 Epidemic Theory of Innovation Diffusion

A number of theories have been put forward to explain the process of technology diffusion among individuals and explain the lag in technology diffusion among individual farmers or firms. One of the popular theories that explain why and how technologies diffuse among individuals over time is the theory of diffusion of innovations developed by Rogers

(1962), which is one of the epidemic theories of innovation diffusion. According to the theory, the spread of a new technology is driven by the innovation, communication channels, time, and the social system. The basic tenet of the theory is that innovations diffuse contagiously across space driven by exposure to information and knowledge which creates awareness and favourable attitudes/perceptions leading to adoption. It is assumed that there is a population of initial innovative and risk taking adopters who take the lead in adoption of new innovations and then they are imitated by an exponentially growing number of later adopters. Technology diffusion is believed to be mainly driven by contact and communication among individuals within the environment where the technology is disseminated (Calatrava & Franco 2011). Communication facilitates build-up of internal information and experience within the system which circulates as existing users spread it among the potential adopters through contagion. Consequently, individuals will adopt a technology at different times. For every individual, adoption of innovations is assumed to go through five steps: knowledge, persuasion, decision, implementation and confirmation (Rogers 1962).

More recently, some advances on the epidemic theories of technology diffusion have emerged. For example a theory by Karshenas & Stoneman (1993) considers three possible mechanisms that may cause technology adoptions at different times, mapping out the technology diffusion path. The authors call these mechanisms *rank, stock*, and *order* effects. The *rank* effects assume that individuals are heterogeneous in personal attributes causing individual variation in the net benefits obtained from an innovation. Individuals who are likely to achieve high returns adopt the technology earlier and those likely to generate lower returns adopt the innovation later. Secondly, the *stock effects* relate to the costs and benefits that accrue to marginal adopters which are assumed to decline with time. Initial high costs imply that only few firms take up the new technology and benefit from the high returns. High initial profits encourage adoptions of the technology until a point of saturation where a decline in prices causes a decline in profitability and therefore discouraging more adoptions. Finally, the *order effects* are associated with the assumption that the returns a firm gets from adoption will depend on their position in the order of adoption. Adoption decisions are based on the potential effect of waiting (moving down the order) on profitability. Individuals will therefore act strategically depending on their expectations on the number of future adopters.

To model the above mentioned process theoretically, the approach by Karshenas & Stoneman (1993) and also applied by Abdulai & Huffman (2005) is adapted. It is assumed that farmer i in village j may adopt RWH by investing in a RWH technique at an investment cost of C_t at time *t*. The gross benefits that the farm obtains from using the technology in period τ can be represented by $k_{it}(\tau)$. The benefits are a function of individual attributes (X_i) (rank effects), the number of previous adopters ($Z_j(t)$) (stock effects) and the expected number of future adoptions ($V_j(t)$)(order effects). That is, a farmer i, adopting a RWHT at time t, expect the following gross benefits per period in time τ :

$$k_{it}(\tau) = f\left(X_i, Z_j(t), V_j(\tau)\right);\ \tau \geq t, f_2 < 0, f_3 < 0 \quad (7.1)$$

Letting *r* be the interest rate and assuming no depreciation, the increase in present value of gross benefits in time t ($K_i(t)$) will be:

$$K_i(t) = \int_t^\infty b(X_i, Z_j(t), V_j(\tau)) \exp\{-r(\tau - t)\}\, d\tau \quad (7.2)$$

According to Karshenas & Stoneman (1993), the optimal timing of adoption will depend on two conditions. First, the profitability condition requiring that adoption will occur at time t if at that time the technology yields a positive net benefit. The net present value of acquisition of the technology $N_i(t)$ can be expressed as:

$$N_i(t) = -C_t + K_i(t) \geq 0 \quad (7.3)$$

The second condition is called the arbitrage condition because it requires that at the optimal time of adoption, net benefits are not increasing over time. That is,

$$y_i(t) = \frac{d[N_i(t)\exp(-rt)]}{dt} \leq 0 \quad (7.4)$$

where $N_i(t)$ is discounted to ensure a common time basis for evaluation. For each potential adopter, it is the arbitrage condition that determines the optimal adoption time (t^*) such that:

$$y_i t_i^* \leq 0 \quad (7.5)$$

It can be shown that there exists an optimum value of $N_i(t)$ at some time $t < \infty$. To do this, the conditions under which $N_i(t)$ can be bounded are identified. Assuming an upper bound $\bar{b}$ for the benefits $b(\cdot)$ and a lower bound for the cost of the technology $\underline{C}$, then,

$N_i(t) \leq \int_t^\infty \bar{b} \exp\{-r(\tau - t)\} d\tau \leq -\underline{C} + \bar{g}/r$ and $N_i(t)$ is bounded from above. Therefore, it is possible to show that for every potential adopter in the population, there exists an optimum time $t_i^* < \infty$, where net benefits of adoption are maximized. For an individual to be considered an adopter there must be a cost $C_t \geq \underline{C}$ where the net benefits $N_i(t)$ are non negative. Therefore, the limit of $N_i(t)$ as time goes to infinity is given by $lim_{t\to\infty} N_i(t) = lim_{t\to\infty}\left[-\underline{C} + \int_t^\infty \bar{b}\ exp\{-r(\tau - t)\}d\tau\right] = -\underline{C} < 0$. Since it is assumed that every individual is a potential adopter $[N_i(t) > 0\ for\ all\ i]$, then $N_i(t)$ must achieve its maximum at some $t < \infty$. This also implies that for a potential adopter the arbitrage condition dominates the profitability condition and therefore it is the arbitrage condition that determines the optimum adoption time. Combining (7.2) and (7.3) and differentiating $e(-rt) \cdot N_i(t)$ with respect to t yields the following expression of $y_i(t)$

$$y_i(t) = r\,C(t) + \int_t^\infty b_2(X_i, Z_j(t), V_j(\tau))s(t)\exp\{-r(\tau - t)\}d\tau - b(X_i, Z_j(t), V_j(t)) \qquad (7.6)$$

where *s(t)* and *c(t)* are the expected changes in the number of users and the cost of the technology in a small time interval (*t*, *t*+*dt*). Equation (7.6) states that the benefits from waiting for a time interval before adopting is a function of the interest saved, the expected reduction of adoption cost, the net present value of the changes in benefits resulting from a move down the order of adoption for all $\tau \geq t$ and the benefits forgone for not having the technology for the time interval. For simplicity, it is assumed that the marginal benefits from moving down the adoption order at time *t* are independent of the level of future stock of adopters $V_j(\tau)$ for $\tau > t$. Therefore, equation (7.6) can be simplified to:

$$y_i(t) = r\,C(t) + c(t) + b_2\left(X_i, Z_j(t), V_j(t)\right)s(t)/r - b(X_i, Z_j(t), V_j(t)) \qquad (7.7)$$

The exact time of adoption t_i for indivindual *i* can be obtained from (7.6) and (7.7). This model abstracts from real life factors that are known with certainty to the adopters but may not be included in the model directly. These factors may be incorporated into the model through a random error term, ε. Therefore, the stochastic form of equation (7.5) assuming a distribution of ε that is invariant across all individuals over time will be:

$$y_i(t) + \varepsilon \leq 0 \tag{7.8}$$

From equation (7.8) we can establish the empirical model that captures the theoretical process described above. This is best captured by specifying a duration or hazard function. The probability of adopting in the time interval *t*, *t*+*dt* given that an individual has not adopted until that time can be represented as the hazard rate $h(t)$ given by

$$h_i(t) = prob[(y_i(t) + \varepsilon \leq 0)] = \xi[-y_i(t)] \tag{7.9}$$

The unconditional probability of adoption can be expressed as a function of time and the parameters influencing individual adoptions. The density function ($f(\cdot)$) of adoption time can be expressed as $f(t, X, \beta)$ and its associated distribution function is therefore $\mathrm{F}(t, X, \beta)$. The hazard function can then be specified in terms of the density distribution function as follows:

$$h(t) = \lim_{dt \to \infty} \frac{\Pr(t + dt > \tau > t | \tau > t)}{dt} = \frac{f(t)}{S(t)} \tag{7.10}$$

Where $S(t) = prob(dt > t)$ is the survival function, which captures the probability that the non-adoption state will last at least until *t*. The survival function is a monotone non-increasing function of time and measures the probability that the length of the spell is at least *t*. In other words, it provides the proportion of the sample that has not yet adopted up to time t. On the other hand, the hazard function is the instantaneous rate of adoption and gives the rate of change in the survival function with respect to time. It is the probability that adoption occurs at a certain time interval, given that the subject has survived up to the beginning of that interval. Further, since 1-S(t) gives the probability that an individual will have adopted the technology by time t, this could be extended to the population and used to represent the proportion of individuals that has adopted the technology. This is the expected diffusion of the technology.

7.4.2 The Log-Logistic Duration Model

Estimating the hazard function empirically can either be done through parametric or non-parametric procedures. Non-parametric models such as the proportional–hazard model (Cox 1972) are used when a specific functional form of the baseline hazard function is not assumed. The parametric models on the other hand involve the assumption of a parametric distribution for the time-to -adoption and then estimation of the coefficients. The most common parametric functional forms that have been used for duration models are: exponential, log-normal, Weibull, log-logistic, and Gamma probability distributions. The functional form of the hazard function depends on the distribution of the baseline hazard rate; therefore it is important to carefully select the parametric model to be applied in every specific case. To determine the parametric functional form that fits the data, two approaches are commonly used. According to Cleves et al. (2008) a smoothed estimate of the baseline hazard function is generated to determine the functional form. Alternatively, a generalized Gamma distribution model is estimated first and then likelihood ratio or Wald test is used to determine which of the nested models provides a satisfactory fit for the data (Jenkins 2004).

In the current paper, both approaches were used leading to selection of the log-logistic duration model as the one that provides the best fit for the data on the diffusion of run-off and roof catchment rain water harvesting. The log-logistic duration model is an Accelerated Failure Time (AFT) metric model with a non-monotonic hazard function. The ATF models are called so because a positive coefficient in β serves to increase the expected value of the log of time to adoption and also because the marginal effects of the covariates accelerate with time.

The log-logistic duration model has the hazard rate h (t, X, β) which is expressed in equation (7.11).

$$h(t, X, \beta) = \frac{\mu^{\frac{1}{\gamma}} t^{(\frac{1}{\gamma}-1)}}{\gamma\left[1-(\mu t)^{\frac{1}{\gamma}}\right]} \tag{7.11}$$

where γ is the shape parameter and if $\gamma < 1$ then the hazard first raises with time then falls monotonically; $\mu \equiv exp(-\beta^{*'}X)$ where X is a vector representing *rank*, *stock* and *order* explanatory variables and

$$\beta' X = \beta_0 + \beta_1(X_1 + 1) + \beta_2 X_2 + \cdots + \beta_k X_i \tag{7.12}$$

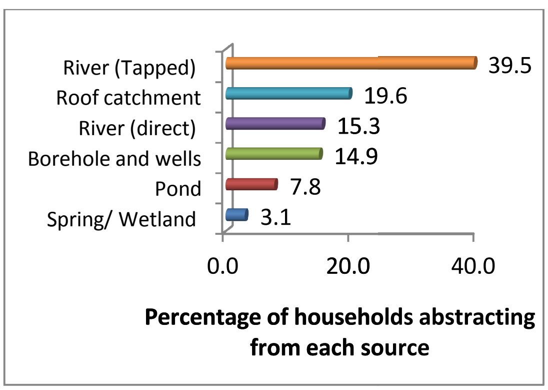
The unknown parameters (β_k and γ) are to be obtained by estimating equation (7.11) using maximum likelihood method subject to right censoring by maximizing the likelihood function:

$$L(\beta,\sigma) = \sum_{i=1}^{n} c_i\{-\ln(\sigma) + X_i + 2ln[1+\exp(X_i)]\} - (-c_i)ln[1+\exp(X_i)] \quad (7.13)$$

The log-logistic model described above was used to identify the factors that influence the length of time that farmers wait before they adopt RWHTs. The hazard rate is the probability that a farmer adopts a water harvesting technology at time *t* given that they have not adopted until that time. The dependent variable is the log of the number of years between the time when the technology became available and the time a farmer eventually adopted the technology. Farmers who had not adopted the technologies by the beginning of 2011 when the survey was conducted were right-censored. The effects of individual characteristics on the hazard function are captured by the covariates included in X.

7.3 Variables and Hypotheses

In the Lake Naivasha basin, crop production is mainly rain fed, while water for activities such as domestic, livestock watering and supplementary irrigation is sourced from boreholes/wells, surface water reservoirs, and other rainfall-dependent sources such as rivers and wetlands (Figure 7. 1). This dependence on rainfall for water for major uses implies that farmers are largely vulnerable to weather related shocks and sensitive to temporally water shortages.



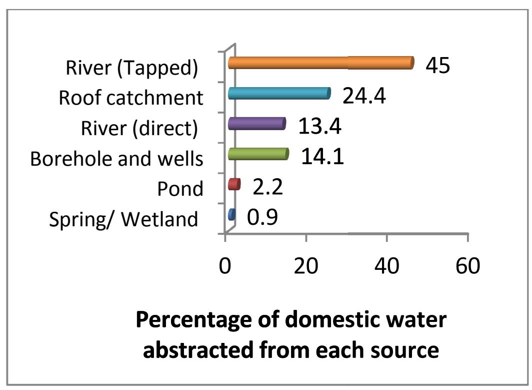


Figure 7. 1: Relative importance of water sources in the Lake Naivasha Basin
Source: Authors' survey data

An interview schedule was used to collect data on rain water harvesting techniques that had been implemented by the farmers. The respondents were asked to recall the year when they first adopted rain water harvesting techniques. This information was then used to compute the time lag from when the rain water harvesting techniques were available to the time they actually adopted, which is used as the dependent variable. We are aware that long time of recall may introduce measurement errors, and therefore during data collection it was ensured that there was substantial probing and also use of check questions to minimize the reporting error. However, although this response error may increase the variance of estimates, it will not cause bias in the coefficients as long as unobserved heterogeneity is identified and handled appropriately (Fuglie & Kascak 2001). Data on the household's socio-economic, demographic and institutional attributes was also collected.

To generate the variables on rainfall variability, daily rainfall data records from sixty-seven rain gauges within the Lake Naivasha basin for the period 1957-2010 were obtained from the Kenya meteorological department. Gaps in the rainfall data were interpolated using the squared inverse weighted distance (IWD) interpolation method (Shepard 1968). In this method, the rain stations close to the one being interpolated contribute more than those far away. (Meins 2013) provides detailed procedures on the process of interpolation of the rainfall data used in this study. The final daily rainfall data was used to construct indicators of weather variability for each of the eight sub-catchments (WRUAs). In this study, the rainfall anomaly index (RAI), Consecutive Dry Days (CDD) and the amount of rainfall per rainy day were used as indicators of rainfall variability. The RAI indicator was developed by Van Rooy (1965) and is based on the long term average of rainfall and reveals by what percentage the rainfall in a particular year is either higher (positive RAI) or lower (negative RAI) than the long term average. On the other hand, CDD (Deni & Jemain 2009) captures the total number of consecutive dry days with no measurable rainfall within a particular year.

The choice of explanatory variables was done systematically by first deciding which variables were theoretically important for the two models and then each variable was examined to decide whether it should be included in the final model or not following the procedure suggested by Hosmer & Lemeshow (1999). To achieve this log-rank test of equality of survival functions was used in the case of categorical variables while for continuous variables the univariate Cox proportional hazard regression, a semi-parametric method was applied. A value of $p = 0.2$ was used as the maximum threshold and therefore all the variables that were significant at the $p < 0.2$ where selected for inclusion in the model.

While it would have been better to include all the relevant time-variant covariates in the models, this was not possible in the current study due to data limitations. Inclusion of time-variant covariates such as farm size, prices and household labour and asset endowments would require panel data indicating the level of these variables at different points in time. However, to assess the change in adoption behaviour with time, the data was split into two sub-periods and estimated regression models for the two sub-periods an approach similar to that of Abdulai & Huffman (2005).

A list of relevant explanatory variables representing *rank, order* and *stock* effects was selected. Variables capturing rank effects included variables on farm and farmer specific attributes such as farmer's age at the time of adoption, education level, and information sources, perceptions on water scarcity and location and rainfall variability indicators. Stock and order effects were captured through the number of previous adopters and the number of expected adopters at village level. The current water use in cubic meters per capita for domestic and non-domestic uses was included as an indicator of household water demand. We hold the household water use behaviour constant and therefore these variables can also be considered time invariant. Table 7. 1 lists the variables used in the current study, their descriptive statistics and hypothesized signs.

Table 7. 1 : Variables used in duration analysis of rain water harvesting techniques

Description and measure	**Mean**	**Expected sign**
Age of household head at the time of adopting roof catchment	44.57	+
Age of household head at the time of adopting run-off harvesting	42.27	+
No formal education attained (1 = yes, 0=No)	0.21	+
Attained primary education level (1 = yes, 0=No)	0.46	-
Attained secondary education level(1 = yes, 0=No)	0.27	-
Attained post-secondary education (1= yes, 0=No)	0.06	-
Number of previous adopters of roof catchment technology(village)	16.55	-
Number of potential roof catchment adopters (village)	23.42	-
Number of previous adopters of run-off harvesting practice(village)	0.63	+/-
Number of expected run-off harvesting adopters (village)	31.56	+/-
Obtained information from informal sources (Dummy: 1=yes)	0.32	-
Perception that water in getting scarce (Dummy: 1=yes)	0.92	-
Ownership of well/Borehole (Dummy: 1=yes)	0.21	-
Access to formal sources of information (Dummy: 1=yes)	0.46	-
Access to credit (Dummy: 1=yes)	0.86	+
Distance from the farm to the nearest river (km)	2.07	-
WRUA located in high altitude region (Dummy: 1=yes)	0.36	+
Number of consecutive dry days per year	49.26	-
Annual rainfall anomaly index	.005	-
Long season rainfall anomaly index	.015	-
Short season rainfall anomaly index	-.001	-
Annual average amount of rainfall per rainy day	3.20	-
Long season average amount of rainfall per rainy day	4.02	-
Short season average amount of rainfall per rainy day	2.95	-
Domestic water demand (M^3/ adult equivalent/year)	13.29	-
Non domestic water demand (M^3/ adult equivalent/year)	37.79	-

7.4 Results and Discussions

7.4.1 Trends in Diffusion of Rain Water Harvesting Techniques

The diffusion path of RWHTs among the sampled households is as shown in Figure 7. 2, while Figure 7. 3 shows the spatial distribution of water ponds in the Lake Naivasha Basin. The earliest adoptions of run-off rain water harvesting and roof-catchment rain water harvesting were in 1960 and 1963 respectively as reported by the respodents. The adoption of both RWH practices was slow in the initial years, but accelerated after 1980, with faster adoption rates reported in the roof-catchment rain water harvesting technique. The period post 2000 displayed a relatively accelerated rate of technology diffusion.

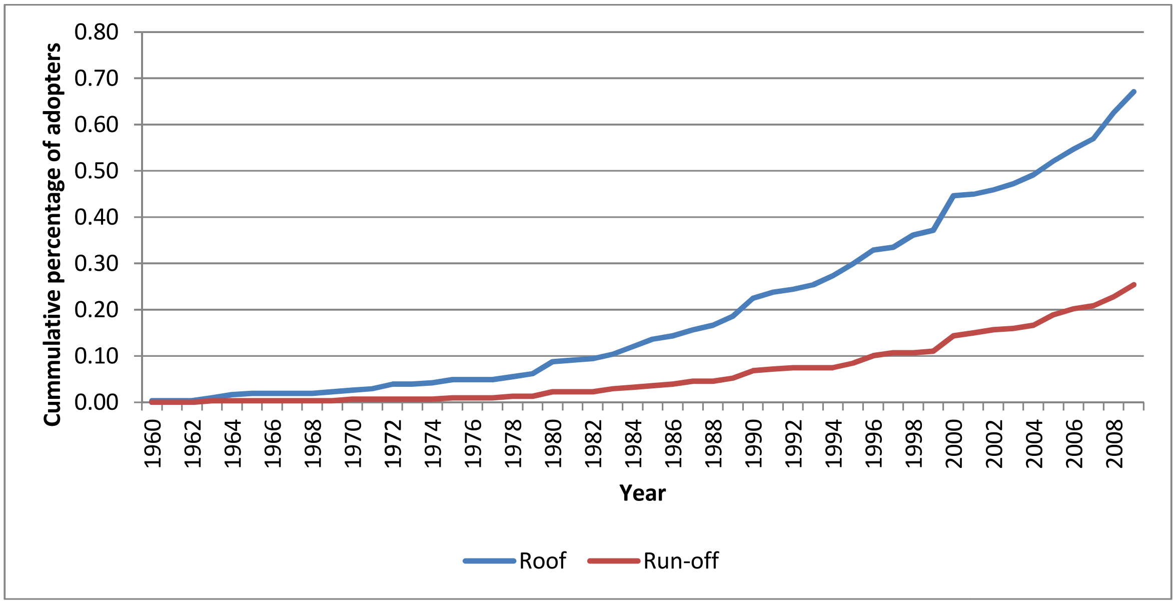


Figure 7. 2: The rate of diffusion of RWHTs among the sampled farmers

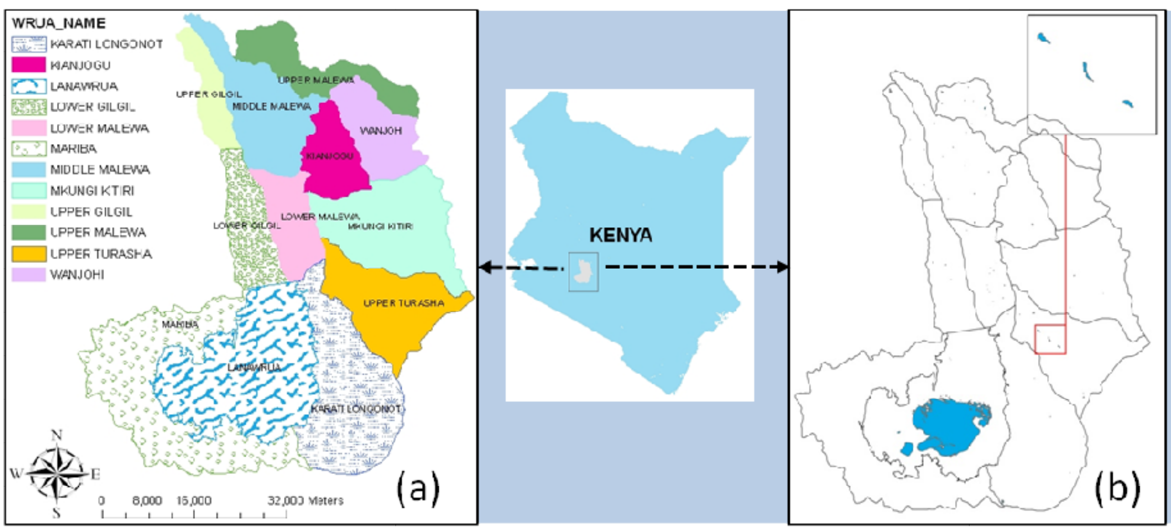


Figure 7. 3: Sub-catchments and distribution of water pans in the Lake Naivasha Basin

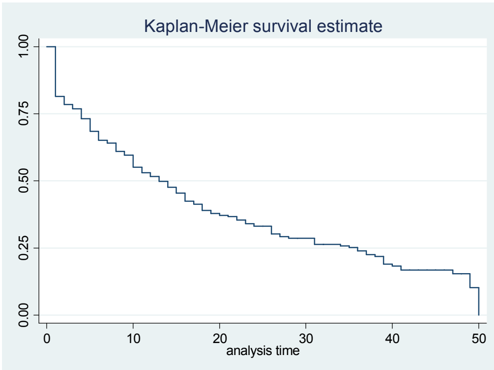
Table 7. 2 presents information on the waiting time until adoption of RWHTs in the eight sub-catchments. The table presents percentages of farmers who adopted RWHTs within each of the specified time periods: less than 10 years, between 10 and 20 years and more than 20 years. The waiting time was shorter in the adoption of roof catchment since 54.7% of all

adoptions occurred within a period of less than 10 years, as compared to 36.8% of run-off harvesting adoptions.

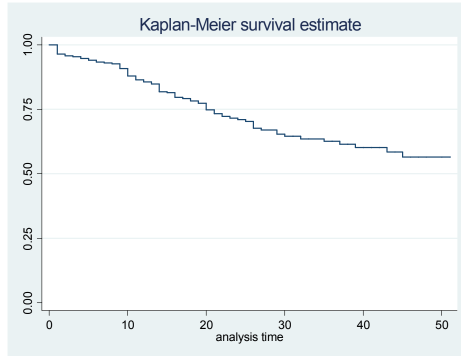
Table 7. 2: Time lags before adoption of RWHTs among sampled farmers

	Run-off harvesting				**Roof catchment**			
	% of adopters per time category			**Mean time to adoption (years)**	**% of adopters per time category**			**Mean time to adoption (years)**
Sub-catchment	**less than 10 years**	**10-20 years**	**Over 20 years**		**less than 10 years**	**10-20 years**	**Over 20 years**	
Kianjogu	46.2	26.9	26.9	**13.08**	65.7	22.9	11.4	**9.74**
Lower Malewa	0.0	0.0	100.0	**12.73**	66.7	14.3	19.0	**9.57**
Middle Malewa	29.2	25.0	45.8	**18.54**	50.0	26.9	23.1	**12.54**
Upper Malewa	0.0	50.0	50.0	**20.00**	43.8	43.8	12.5	**11.37**
Mkungi Kitiri	33.3	66.7	0.0	**8.33**	33.3	33.3	33.3	**16.44**
Upper Gilgil	50.0	40.0	10.0	**10.40**	61.3	25.8	12.9	**10.84**
Upper Turasha	36.8	36.8	26.3	**13.26**	59.5	21.6	18.9	**9.49**
Wanjohi	0.0	100.0	0.0	**13.00**	38.5	46.2	15.4	**11.08**
Total Sample	**36.8**	**32.2**	**31.0**	**14.70**	**54.7**	**26.9**	**18.4**	**11.22**

The Kaplan-Meier estimator, a non-parametric procedure was used to summarize the time taken until adoption (survival time). In the presence of right-censoring, the Kaplan-Meier (K-P) estimator of the survivor function $S(t_i)$ provides a nonparametric and consistent estimate of the underlying survivor function (Burton et al. 2003). The K-P estimates are presented in the step functions in Figure 7.4. The horizontal axis represents the 51 year period between 1960 when first adoptions were reported and 2011 when the survey was conducted. At time t = 0 all subjects are considered non adopters so the survivor function takes the value of 1. All farmers enter the function at t=0 regardless of the calendar time when they begin to be observed. As adoptions occur, the survival rate drops.



4a: Kaplan-Meier survivor functions for Roof catchment



4b: Kaplan-Meier survivor functions for Run-off harvesting

Figure 7.4: Kaplan-Meier survivor functions

7.4.2 Trends in Rainfall Variability in the Lake Naivasha Basin

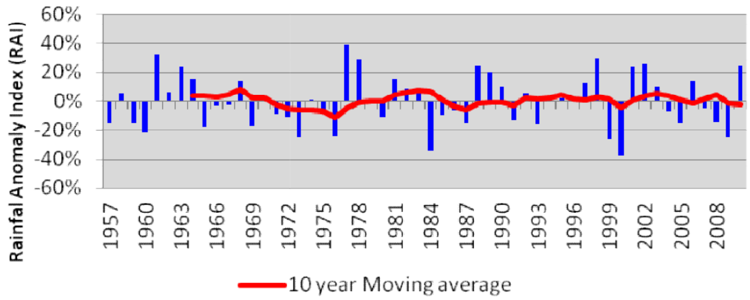
7.4.2.1 Mean Rainfall and Coefficient of Variation

One of the factors that were hypothesized to explain the differences in timing of RWHTs between individuals and sub-catchments is rainfall variability. Variability was higher in the short rains season (October-December) with the amount of rainfall ranging from 79.50 mm in 2007 to 634.38 mm in 1961 (Mean= 218.62 mm; CV= 43.99%). Rainfall in the long rain season (March-May) ranged from 106.86 mm in 2000 to 500.30 mm in 1977 (Mean=321.72 mm; CV = 30.58%). Overall in the basin, the annual rainfall varied from 665.19 mm in 2000 to 1293.75 mm in 1977 with a mean annual rainfall of 974.85 mm (CV=15.33%). The number of rain days ranged from 230 days (1984) to 337 days (2010) with a mean of 283.9 days (CV=8.49%). The number of rain days within the short season varied from 50.9 in 1970 to 90 in 2002 with a mean of 74.5 days (CV=13.1%) while in the long season the average number of rain days was 80.0 (CV=12.3%) and varied from 51.9 days in 1973 to 91.1 days in 2010. Descriptive statistics of variables used as indicators of rainfall variability are explained next.

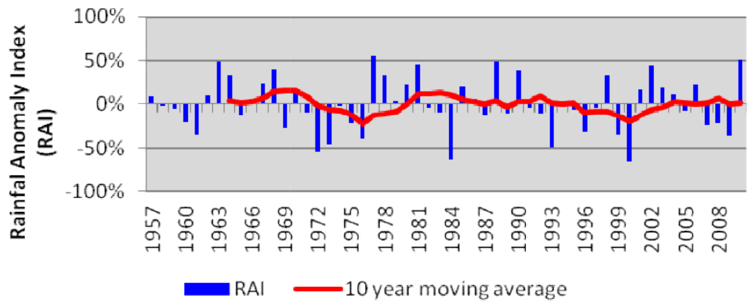
7.4.2.2 Rainfall Variability Indicators

As indicated in Figure 7.5, rainfall variability differed between the seasons. The annual RAI reveals a period of consistently below average rainfall between 1969 and 1979, which was followed by above average rainfall until 1985, after which annual rainfall has been relatively stable. Rainfall in the long rains season was more variable with two ten year time periods (1970-1980 and 1995-2005) where a prolonged below average rainfall was received.

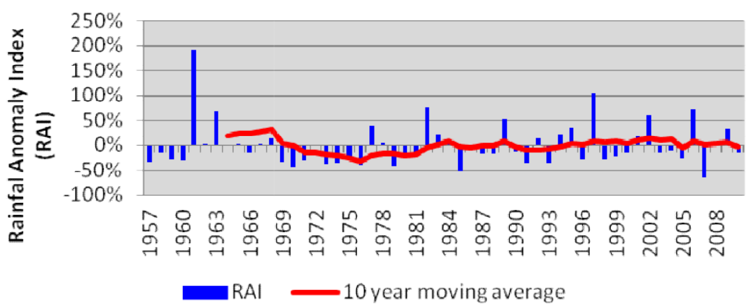
On the CDD indicator, the Lake Naivasha basin experiences an average of 48 consecutive dry days per year (Figure 7. 6). Further there is a general trend of declining amount of rainfall per rainy day annually and seasonally (Figure 7.7). Rainfall variability is hypothesized to be a main driver of the diffusion of rain water harvesting techniques. Specific effects of these indicators on the diffusion path are explored in detail in the next section.



(a) Annual rainfall anomaly index



(b) Long season rainfall anomaly index



(c) Short season rainfall anomaly index

Figure 7.5: Rainfall anomaly indeces in the Lake Naivasha basin

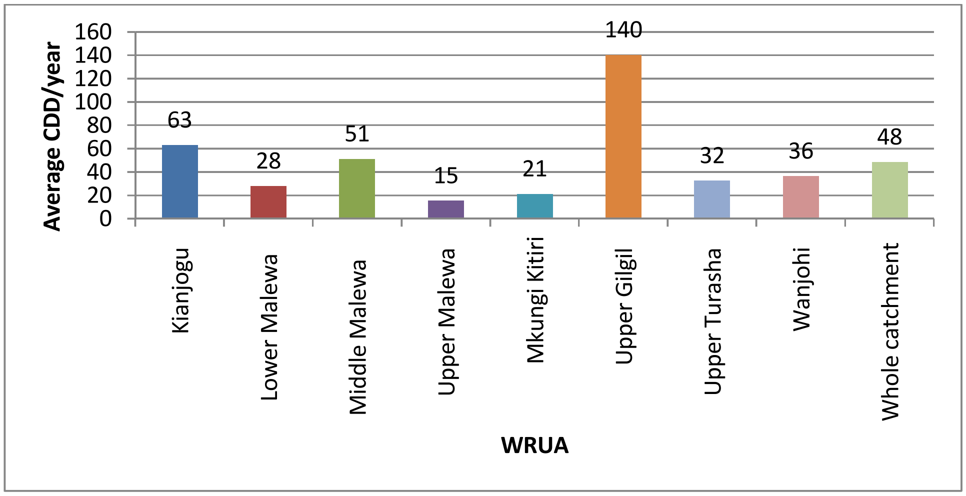


Figure 7. 6: Mean number of consecutive dry days (CDD) by WRUA

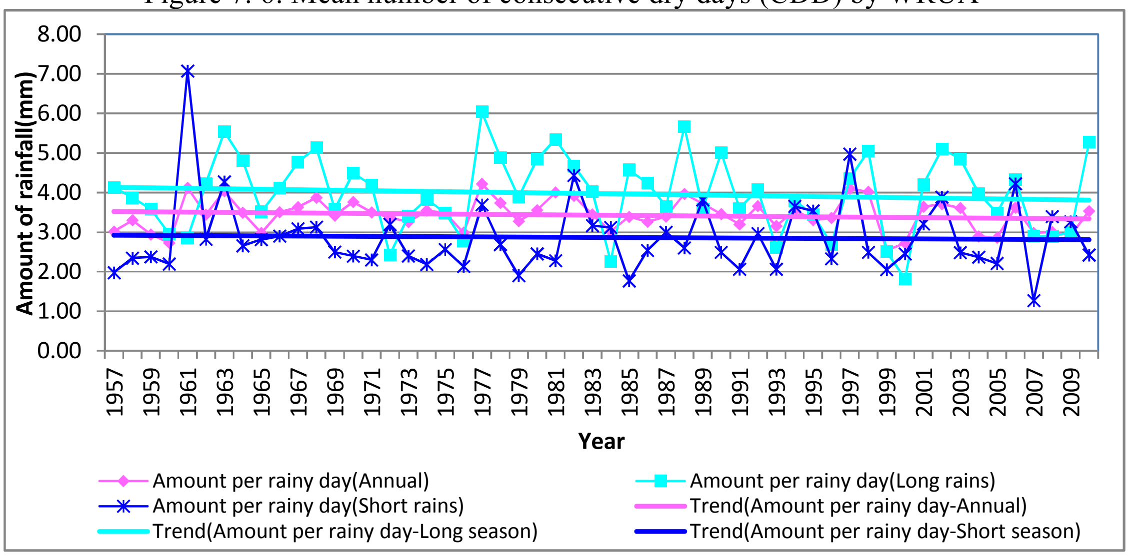


Figure 7.7 : Trends in the annual and seasonal amount of rainfall per rainy day

7.4.3 Determinants of Time to Adoption of Rain Water Harvesting Techniques

Coefficient and time ratio estimates of the determinants of the time to adoption of roof-catchment and run-off harvesting rain water harvesting practices are presented in Table 7. 3. The coefficients can be interpreted directly as marginal effects while the time ratio gives the factor by which the time until adoption is multiplied by if a covariate changes by one unit. In the roof catchment duration analysis model, the estimated Gamma is 0.63 (SE=0.033) while that of the run-off harvesting model is 0.46 (SE=0.042). The values of $\gamma < 1$ indicate that the hazard rates conditional on the covariates are non-monotonic unimodal, that is, the hazard rate first increases then monotonically decreases with time. This further justifies the choice of log-logistic parametric duration model. The coefficient of the log of Gamma was negative and statistically significant at the 0.01 level in both models. This implies that both run-off and roof catchment rain water harvesting techniques exhibit negative time dependence, that is, the longer an individual stays in the non-adoption state, the less he is likely to adopt. The models were tested for unobserved heterogeneity which may result from the fact that some unobserved covariates such as inherent skills may cause some farmers to be more prone to failure (adoption) than others. Using the frailty model approach proposed by Hougaard (1995) the null hypothesis that un-observed heterogeneity is not present was tested. From the test, a near zero frailty variance was observed indicating that there was negligible unobserved heterogeneity in both models. Next the coefficients of covariates that were significant are interpreted.

Age and education level were found to significantly influence the time to adoption of both RWHTs. The estimated time ratio of the variable age was above 1 for both technologies. This indicates that younger farmers adopt rain water harvesting techniques faster compared to older ones. These results are consistent with the findings by He et al. (2007) who also found a negative relationship between rain water harvesting technology adoption and age. A possible explanation to this finding is that RWHTs involve long term investments and older farmers may have short investment horizons and may lack the patience to wait for returns on long term investments such as rain water harvesting. The level of education had a significant reducing effect on the time to adoption of roof catchment RWHT implying education accelerates diffusion of RWHTs. The three indicators used to capture the degree of rainfall variability (RAI, CDD and amount of rainfall per rainy day) were found to have some accelerating effect on the speed of both RWHTs. The number of consecutive dry days and the short season rainfall anomaly index had a negative significant influence on the time to adoption of run-off harvesting technologies while the amount of rainfall per rainy day in the long season had a positive significant influence on the diffusion rate of roof catchment technique. Statistical significant of these variables confirms the hypothesis that households are likely to respond to variability in the weather conditions and undertake private investments towards stabilizing their water supply as an adaptive mechanism.

The possibility of alternative water sources such as groundwater abstraction through sinking of boreholes and shallow wells was found to delay the diffusion of rain water harvesting since the coefficient of ownership of a borehole /well was positive. This finding implies that in periods of surface water scarcity, ground water abstraction may increase since households who have access to ground water resources are unlikely to engage in rain water harvesting.

The coefficient of the number of previous adopters at village level was negative in both practices as expected, but only the coefficient in run-off harvesting practice was significant, implying significant neighbourhood effects on run-off harvesting. These results imply that the possibility of farmers learning from others speeds up diffusion. It could also imply that people in the same sub-catchment are sharing unobserved determinants of adoption of that practice. This result is consistent with that of informal sources of information which were also found to accelerate the diffusion process. Likewise, the coefficient of contact with extension service providers was also negative and significant in the roof catchment rain water harvesting model.

Table 7. 3: Log-normal estimates for determinants of time to adoption of RWHTs

Covariates	**Roof catchment**			**Runoff harvesting**		
	Coef.	**Std. Err.**	**Time ratio**	**Coef.**	**Std. Err.**	**Time ratio**
Age of household head	0.04***	0.01	1.04	0.05***	0.007	1.047
Primary education	-0.10	0.20	0.90	0.07	0.250	1.072
Secondary education	-0.50**	0.23	0.61	-0.37	0.270	0.689
Secondary education	-0.34	0.35	0.71	-0.02	0.396	0.983
Informal source of infom.	-0.40***	0.15	0.67	-0.67***	0.203	0.510
Access to extension	-0.18	0.15	0.84	-0.13	0.172	0.882
Perception on scarcity	-0.35	0.33	0.70	-0.12	0.327	0.887
Credit access	0.06	0.10	1.06	-0.05	0.107	0.952
Owns well/borehole	0.78***	0.20	2.18	0.28	0.218	1.322
Distance to river	-0.02	0.02	0.98	0.00	0.029	0.998
Previous adopters	0.00	0.01	1.00	-0.03*	0.016	0.971
Expected adopters	-0.03**	0.01	0.98	-0.02	0.012	0.982
Location	0.22	0.21	1.25	-0.18	0.280	0.833
Cons. dry days	0.00	0.01	1.00	-0.01**	0.006	0.988
Annual anomaly index	0.91	1.50	2.48	1.10	1.769	3.015
LS anomaly index	-0.73	0.62	0.48	-1.48*	0.793	0.227
SS anomaly index	-0.99	0.91	0.37	-0.81	1.177	0.444
Rainfall/day_Annual	-0.68	0.51	0.51	0.08	0.630	1.081
Rainfall/day_LS	0.71**	0.29	2.04	0.17	0.347	1.182
Rainfall/day_SS	0.09	0.29	1.09	0.36	0.375	1.428
Domestic water demand_	-0.14	0.10	0.87	0.04	0.112	1.044
Water demand for other uses	0.28***	0.07	1.33	0.13	0.085	1.143
Constant	0.28	0.94		0.54	1.052	
Ln_Gam	-0.50	0.056		-0.76	0.090	
Gamma	0.61	0.034		0.47	0.041	
Number of obs.	300			306		
LR $chi^2(22)$	247.98***			222.31***		
Log likelihood	-361.45			-148.64		

***, **, and * imply that parameters are significant at the 0.01, 0.05 and 0.1 levels respectively.

These findings imply that both formal and informal sources of information played a complementary role in facilitating diffusion of RWHTs. However, in both practices, informal sources of information were associated with faster adoption compared to formal sources of information, considering the magnitude of the coefficients. This supports the claim that farmer to farmer exchange of information is likely to play a bigger role in the process of technology diffusion compared to formal channels as a result of neighbourhood social influence and subjective norms (Willy & Holm-Mueller 2013).

The coefficient of the order effects, represented by the number of expected adopters at village level, was negative but significant only in the roof catchment model. This implies that as people move down the adoption order, they are more likely to learn from others' experiences and develop positive perceptions on RWHTs and eventually adopt.

Finally, the coefficients of water demand for domestic and non domestic uses had negative and positive effects on diffusion respectively. Since the household water demand for only one time period was used rather than a time series, these coefficients must be interpreted only as indicative. The negative coefficient of domestic water demand implies that households with higher demand for water are likely to engage in RWH to cushion themselves against short term shortages.

7.4.4 Assessment of Adoption Behaviour along the Diffusion Path

Changes in adoption behaviour along the technology diffusion path were assessed by splitting the data into two time periods. An assessment of the long term trends in the diffusion of rain water harvesting techniques revealed a possible structural change in the year 2000. Therefore, the first time period represented a period associated with slow diffusion that occurred between 1960 and 1999. The second time period was between 2000 and 2010 and was associated with faster diffusion. The estimated coefficients, time ratios and their associated standard errors for the two time periods are presented in Table 7. 4 and Table 7. 5. While most of the variables considered in the study such as age, education, perceptions and alternative water sources had consistent effects over time, information sources and rainfall variability were found to have varying effects on the adoption behaviour in the two time periods.

In the earlier time period, farmers who had contact with extension service providers adopted roof catchment rain water harvesting faster than those who did not. This role of extension service providers even increased in the second time period as indicated by a 33% increase in the coefficient. In both models, the coefficient of access to information from informal sources was negative and insignificant in the earlier time period but became significant in the latter time period. This result indicates that informal sources of information have gained importance in the recent time period playing a crucial role in the diffusion of rain water harvesting techniques. The coefficients of contact with informal sources of information were also consistently larger than the coefficients of contact with formal extension service providers. The fact that informal sources of information seem to have gained importance over access to extension services concur with the general observation that public access to extension services has declined over time especially in remote areas growing low value crops (Milu & Jayne 2006).

The influence of rainfall volatility on the diffusion of RWH practices was also found to vary in the two time periods in both RWH practices. In the case of run-off harvesting, the number of consecutive dry days and short season rainfall anomaly index were found to have significantly influenced the speed of RWH technology diffusion in the earlier period (1960-1999). These effects continued in the latter time period, and also the annual rainfall anomaly index became an important driver of the diffusion process during this time period. As for roof-catchment, the three rainfall variability indicators were associated with faster diffusion of the technique, as indicated by the negative signs of the coefficients. Seasonal variation in amount of rainfall per rainy day was found not to have played an important role in the diffusion of run-off RWHTs. Considering the magnitude of coefficients, rainfall variability seems to have played a bigger role on the diffusion of rain water harvesting in the earlier time period and a lesser role in the latter time period. This result implies that people's sensitivity to rainfall variability might have changed over time, becoming lower in the latter period. There are a number of important insights that can be drawn from this finding. The long term variability in rainfall might be masked by short term peaks which occur consistently (Figure 7.5) and therefore reduce farmer's sensitivity to long term rainfall variability. However given that the process of diffusion continued in the latter period despite the reduced sensitivity to weather variability could indicate that there are other drivers that were important during that time period. One of such factors is informal sources of information which as discussed earlier, gained a significantly larger influence on the process of technology diffusion. The implication of this finding is that social learning and neighbourhood social influences could overcome any external influences on peoples' technology adoption behaviour. Informal information sources in this case have played an important role in the process of diffusion of RWHTs and compensated for the reduced influence of the rainfall variability variables and access to extension services.

Table 7. 4: Determinants of time to adoption of roof catchment : Split time

	1960-1999			2000-2010		
	Coef.	**SE**	**Time ratio**	**Coef.**	**SE.**	**Time ratio**
Age of household head	0.04***	0.009	1.046	0.03***	0.007	1.034
Primary education	-0.04	0.273	0.958	-0.52*	0.290	0.596
Secondary education	-0.48	0.300	0.621	-0.82**	0.321	0.440
Post secondary education	-0.84*	0.454	0.432	-0.28	0.492	0.757
Informal source of info.	-0.17	0.200	0.846	-0.54**	0.214	0.582
Access to extension	-0.14	0.217	0.873	-0.15	0.207	0.859
Scarcity Perception	-0.71	0.460	0.491	0.16	0.440	1.171
Credit access	-0.06	0.130	0.940	0.05	0.130	1.053
Owns well/borehole	0.64**	0.283	1.903	0.29	0.307	1.332
Distance to river	-0.05	0.035	0.949	0.01	0.037	1.006
Previous adopters	0.07***	0.019	1.071	-0.01	0.018	0.995
Expected adopters	-0.06***	0.014	0.943	-0.01	0.024	0.993
Location	0.31	0.279	1.357	0.28	0.301	1.323
Cons. dry days	0.00	0.007	0.999	0.01	0.009	1.010
Annual anomaly index	-0.43	2.168	0.653	0.32	2.480	1.376
LS anomaly index	-1.21	0.914	0.300	-0.40	0.830	0.671
SS anomaly index	-1.75	1.143	0.173	0.17	2.158	1.180
Rainfall/day_Annual	-1.14	0.698	0.319	-1.19	0.739	0.305
Rainfall/day_LS	1.03**	0.366	2.792	1.01**	0.456	2.735
Rainfall/day_SS	0.35	0.414	1.417	0.12	0.396	1.123
Water demand_Dome.	-0.32**	0.143	0.724	-0.08	0.131	0.920
Water demand_other	0.31***	0.096	1.358	0.30***	0.086	1.345
Constant	1.12	1.242		-0.16	1.444	
Ln_Gam	-0.49	0.077		-0.59	0.080	
Gamma	0.62	0.048		0.56	0.045	
No. of observations	307			188		
LR χ^2(19)	278.55***			162.60***		
Log likelihood	-203.48			-178.19		

***, **, and * imply that parameters are significant at the 0.01, 0.05 and 0.1 levels respectively.

Table 7. 5 : Determinants of time to adoption of run-off water harvesting: Split time

	1960-1999			2000-2010		
	Coef.	**SE**	**Time ratio**	**Coef.**	**SE.**	**Time ratio**
Age of household head	0.05***	0.015	1.06	0.04***	0.008	1.04
Primary education	-0.32	0.503	0.73	0.01	0.288	1.01
Secondary education	-0.58	0.582	0.56	-0.31	0.286	0.74
Post secondary education	-0.44	0.741	0.65	0.22	0.425	1.25
Informal source of info.	-0.06	0.422	0.94	-0.48*	0.248	0.62
Access to extension	0.70*	0.378	2.01	-0.15	0.182	0.86
Scarcity Perception	0.13	0.590	1.13	-0.30	0.446	0.74
Credit access	-0.14	0.208	0.87	-0.13	0.113	0.88
Owns well/borehole	0.38	0.451	1.47	0.13	0.243	1.14
Distance to river	-0.08	0.052	0.93	0.09*	0.052	1.10
Previous adopters	0.08	0.046	1.08	-0.04**	0.018	0.96
Expected adopters	-0.08***	0.025	0.92	0.00	0.013	1.00
Location	-0.44	0.513	0.64	-0.06	0.325	0.94
Cons. dry days	-0.02	0.012	0.98	0.00	0.010	1.00
Annual anomaly index	0.85	3.442	2.34	-0.96	2.063	0.38
LS anomaly index	-4.99**	1.941	0.01	-1.16	0.910	0.31
SS anomaly index	-1.18	2.204	0.31	1.61	1.684	5.02
Rainfall/day_Annual	-1.19	1.200	0.30	-0.05	0.803	0.95
Rainfall/day_Long season	0.45	0.639	1.57	0.12	0.393	1.13
Rainfall/day_Short season	1.97**	0.983	7.16	0.10	0.403	1.11
Water demand_Domestic	-0.17	0.240	0.84	0.01	0.136	1.02
Water demand_ other	0.17	0.162	1.19	0.17*	0.091	1.19
Constant	1.43	2.251		1.09	1.281	
Ln_Gam	-0.55	0.147		-0.96	0.111	
Gamma	0.57	0.085		0.38	0.042	
No. of observations	306			272		
LR chi2(19)	131.93***			187.65***		
Log likelihood	-74.11			-79.54		

***, **, and * imply that parameters are significant at the 0.01, 0.05 and 0.1 levels respectively.

7.5 Summary, Conclusions and Policy Implications

This chapter applies a parametric econometric duration model (log-logistic) to analyze the diffusion of rain water harvesting techniques (RWHTs) among smallholder farmers in the Lake Naivasha basin, Kenya. The study utilizes household survey data from 307 farm households who are dependent on rain-fed agriculture in a region where rainfall has historically been relatively volatile. When rainfall is volatile, RWHT helps to stabilize water supply and help farmers avert weather related risks. This study seeks to identify constraints to the spread of RWHTs by exploring how rainfall variability influences the timing of decisions to adopt RWHTs alongside other household and spatial characteristics.

The duration model results reveal that rainfall variability, informal sources of information, education, age of household head, access to extension services and ground water abstraction are the main variables driving the diffusion of RWHT. Further, the number of previous and expected adopters at village level, household water demand and access to extension were also found to be significant determinants of the process of RWHT diffusion.

After splitting the dataset into two separate time periods, results indicate that the adoption behavior of farmers has changed over time. These results indicate that although rainfall variability is a significant determinant of diffusion of RWHTs, farmers' sensitivity to rainfall variability has declined over time. Instead, access to informal sources of information has gained importance in diffusion of RWHT implying that adoption has become more of an endogenous process of social exchange within communities, and less driven by external natural pressure and persuasion by state agents. Two observations stand out here. First, farmers seem to have become less sensitive to rainfall variability as a driver for adoption. RWHTs may increasingly have become part of the standard technology set of a farm household. A second observation was that access to informal information sources became a substantially significant driver of technology diffusion during the later time period, while the role of access to public extension services appears to have declined. The increasing importance of informal information (from family, neighbours or other members of the village community) suggests that adoption has become more of an endogenous process of social exchange within communities, and less driven by external natural pressure and persuasion by state agents.

From these results it can be deducted that farmer to farmer exchange of information can become a powerful driver of adoption in the process of technology diffusion as compared to more formal sources of information. Therefore, technology extension policy should recognize the emerging role of informal information dissemination mechanisms and try to better integrate them into extension models.

CHAPTER EIGHT

8 Overall Conclusions and Policy Implications

8.1 Summary of Research Problem and Objectives

Lake Naivasha is a Ramsar site located in Kenya's Rift valley. The lake Naivasha basin is an important watershed for both local and national economy because of the role it plays in supporting economic activities, providing employment and generating foreign exchange. There are also much formal legislation and other institutional arrangements for coordinating the management and use of natural resources in the basin. However, despite these legislations, the entire lake basin has been facing many environmental challenges compromising its ability to remain sustainable. The basin is grappling with three environmental challenges: siltation, eutrophication and fluctuations in water quantities. Water abstractions are also above the capacity of the resource and illegal water abstraction is ubiquitous. Obviously, a large component of these challenges is linked to anthropogenic pressure. Therefore, assessing the interactions between social and ecosystem components in the basin would contribute towards finding solutions to agri-environmental challenges.

The current study sought to contribute towards finding solutions to these challenges and sustainable management of the Lake Naivasha basin. The overall objective of this study is to make a contribution to sustainable management of Lake Naivasha basin through analyzing the interactions between social and ecological systems in the basin. The analysis seeks to identify the institutional challenges encountered while seeking solutions to agri-environmental externalities and in the process of diffusion of technologies and techniques to mitigate these agri-environmental externalities. The study uses cross-sectional data which was collected during a household survey conducted between April and August 2011. A mix of statistical, econometric and descriptive tools was then used to analyze the data. In the next section the results obtained from each specific objective are summarized.

8.2 Summary of Key Findings

8.2.1 Determinants of Cooperative Behaviour

The objective of chapter four was to identify who were co-operators or defectors among the sampled households. Further the chapter sought to determine the factors influencing cooperation among the sampled households. Two step cluster analysis results reveal that defection was the dominant strategy among the sampled farmers in the Lake Naivasha basin.

Just like in many other prisoners' dilemma situations, this would be expected. Individuals tend to pursue strategies which seem to yield more individual expected pay-offs. However such decisions might not be socially optimal. In order to understand what motivates the cooperative behaviour, a logistic regression model was used. From the model the choice of the decision to cooperate or defect was found to be significantly influenced by expected benefits, human capital and labour endowments. Further, informal sanctions and norms of trust emerged as significant factors that are positively correlated with cooperation. These factors can be seen as catalysts that can be used to enhance cooperativeness and discourage defection in the study area and in other watersheds facing a similar challenge.

8.2.2 The Effect of Soil Conservation on Crop Productivity

In chapter five the effect of implementing soil conservation practices on the value of crop production was assessed. The aim of this chapter was to assess the private economic benefits that are associated with implementation of soil conservation practices. Using a propensity score matching (PSM) model, results indicated that implementing multiple soil conservation practices (MSCPs) yielded positive economic benefits in terms of higher value of crop production. Integration of multiple soil conservation practices into a soil conservation package boosts the benefits that can accrue from soil conservation practices. However, the results indicate that under certain circumstances, the productivity gains associated with MSCPs might not be substantial enough to cover the opportunity costs of these practices in the Lake Naivasha basin case. Therefore, pure private economic incentives offer limited incentives for implementation and continued maintenance of soil conservation practices. To encourage farmers in implementation of soil conservation practices needs additional motivating factors beside pure economic benefits.

8.2.3 Social Motivations on Adoption of Soil Conservation Practices

In light of the results obtained in chapter five, chapter six sought to determine other factors that could motivate adoption of soil conservation practices. The objective of this chapter was to analyze the influence of participation in collective action and social influence on the individual soil conservation effort. A two stage regression procedure utilizing binary and ordered probit regression models was used. The results indicate that collective action facilitates adoption of soil conservation practices. From these results, it can be noted that the ability of an individual to participate in collective action was boosted by their socioeconomic attributes, location in the basin and level of social capital-social networks, intensity of social participation and trustworthiness. Once an individual is participating in collective action, then their potential to implement soil conservation practices is enhanced. An intuitive reasoning behind this finding is that the network externalities - such as training and exchange of information - enhance an individual's capacity to implement certain practices on their private farms. Further, social control emerging from neighbourhood social influences and intrinsic subjective norms may substitute for pure economic benefits and enhance the implementation of soil conservation practices even if they don't seem to be economically attractive. Soil conservation is also constrained by institutional factors such as access to agricultural credit.

8.2.4 Drivers of the Diffusion of Rain Water Harvesting Technology

Finally chapter seven presents an analysis of the process of diffusion of two rain water harvesting techniques. Water harvesting and conservation is a strategy that can be used to minimize the externality associated with water over-abstraction. The major techniques used by households in the Lake Naivasha basin to stabilize household water supply are run-off rain water harvesting and roof catchment water harvesting. However, a substantial impact is likely to be felt if these strategies diffuse to a wider scale in the basin. It was hypothesized that the diffusion of these RWHTs across the basin was driven by both individual and climate related factors.

The results indicate that diffusion of rain water harvesting techniques was influenced by rainfall variability, socio-economic factors and access to information. This study reveals that in the recent past, farmers have become less sensitive to rainfall variability hence reducing the influence of this factor on the diffusion of rain water harvesting techniques. At the same time, access to information through informal sources – such as neighbours- has emerged as a more important determinant of the diffusion of the RWHTs compared to access to information through formal sources- such as public extension services and rainfall variability. Combining these two findings leads to the premise that the diffusion of rain water harvesting techniques in the Lake Naivasha basin has become more of an endogenous process of social exchange within the communities in the study area and less driven by natural pressure and persuasion from external state agents.

8.3 Policy Implications

Agri-environmental externalities are likely to be an important focal area in the future. The current study identifies some areas where policy seeking to mitigate agri-environmental externalities could focus on:

1. The issue of farmer to farmer information exchange emerges as an important driver of the process of transfer technologies for mitigating negative agri-environmental impacts. Policy makers could embark on identifying the best farmer information exchange strategies in the community, improve on these models and incorporate them into dissemination programmes. To enhance efficient and communication of accurate information, policy could also aim at enhancing local knowledge base by frequent training of trainers in the community or establishment of community information centers. Once these systems have been established, they could be used as medium for information dissemination to create awareness on important aspects such as the interactions between agriculture and the environment. This could make use of information and communication technology (ICT) utilizing the widely spread mobile phone technology.
2. There is need for policy to encourage participation in local collective action by eliminating the barriers to such participation through policies that encourage local community participatory approaches. The range of incentives towards participation in collective action around natural resources could also be encouraged through increased devolution of resources and decentralization of state power. The efficiency of collective action could also be enhanced through identification and recognition of local user groups, capacity building and strengthening of local knowledge systems, leadership and innovation.
3. There is need to re-think the demand – driven extension and advisory services model currently used in Kenya. This study confirms previous findings that the role and effectiveness of public extension in the transfer of technology has declined. At the same time, lack of technical support could compromise the ability of communities to sustainably manage natural resources. Although it is a good approach, the demand – driven extension approach might skew access to agricultural information in favour of the elite farmers hence marginalizing disadvantaged groups in the community. There has to be a deliberate effort to ensure that these groups are targeted. Therefore both

demand and supply driven approaches need to be used depending on specific circumstances.

The low efficiency of extension services could also be attributed to lack of resources to facilitate service provision. To ease the burden of provision of extension services currently borne by the government, policy could focus on encouraging pluralistic provision of extension services. New extension models that make more use of other potential media for technology transfer and support such as farmer to farmer information dissemination approaches could be explored. The role of public extension service providers could be more of support and supervisory to educate farmers and building local human capital through training of trainers at community level. These farmer trainers can then be used as agents for technology transfer and technical support for other farmers. Extension could also focus on building of social capital at local and regional level to facilitate regional cooperation. However, this will depend on resource availability therefore the need for improved public investment in the agricultural sector.

4. Participation in collective action was found to be important in mitigating agri-environmental externalities. Policy makers seeking to encourage participation in collective action could do so first be recognizing the existence of successful local initiatives that communities have established to solve local problems. Policy should therefore play a complementary role and that of enhancing local capacity. Successful local social sanctioning mechanisms should be identified and incorporated in the resource management strategies to enhance monitoring and enforcement especially where regulatory instruments face implementation challenges. On the other hand, policy must recognize that collective action may sometimes lead to marginalization of some segments of the society. Therefore it must be ensured that collective action is facilitated in such a way that it does not serve the interests of the elites while marginalizing minority and less effluent groups but rather enhance equity. Expected and selective benefits were found to be a motivation to participation in collective action. Therefore, a possible policy focus is towards empowering local cooperative initiatives to widen the range of selective benefits

8.4 Outlook for Further Research

The debate on how to deal with agri-environmental externalities in the developing countries is far from coming to a close. Although this thesis has attempted to offer some insights into how to address this enormous challenge, a number of gaps still exist that could form a basis for future research. First, although rain water harvesting would be a good solution for solving private water scarcity at household level it would be important to assess the social implication in terms of reduced surface water run-off and ground water recharging. Secondly, while analyzing the private benefits associated with soil conservation practices, only cross-sectional data was used and benefits at one point in time were considered. However, the costs and returns to soil conservation efforts would be estimated better if a dynamic approach is used, which considers a stream of costs and benefits over time. Considering the individual pure rate of time preferences in soil conservation decision making could also be helpful.

References

Abdulai, A. & Huffman, W.E., 2005. The Diffusion of New Agricultural Technologies: The Case of Crossbred-Cow Technology in Tanzania. *American Journal of Agricultural Economics*, 87(3), pp.645–659.

Acheson, J.., 2006. Institutional Failure in Resource Management. *Annual Review of Anthropology*, 35, pp.117–134.

Adekalu, K.O. et al., 2009. Runoff water harvesting for dry spell mitigation for cowpea in the savannah belt of Nigeria. *Agricultural Water Management*, 96(11), pp.1502–1508.

Ajzen, I. & Fishbein, M., 1975. *Understanding attitudes and predicting social behaviour*, New Jersey: Prentice -Hall.

Amblard, L., 2012. The Potential of Collective Action for the Control of Nonpoint Source Pollution in European Rural Areas. In Design and Dynamics of Institutions for Collective Action: A Tribute to Prof. Elinor Ostrom, Second Thematic Conference of the IASC. Utrecht University, Utrecht, the Netherlands.

Anderies, J.M., Janssen, M.A. & Ostrom, E., 2004. A Framework to Analyze the Robustness of Social-ecological Systems from an Institutional Perspective. *Ecology and Society*, 9(1), p.18.

Araya, B. & Asafu-Adjaye, J., 1999. Returns to Farm-Level Soil Conservation on Tropical Steep Slopes: The Case of the Eritrean Highlands. *Journal of Agricultural Economics*, 50(3), pp.589–605.

Asafu-Adjay, J., 2008. Factors affecting the adoption of soil conservation measures: A case study of Fijian cane farmers. *Journal of Agricultural & Resource Economics*, 33(1), pp.99–117.

Ayer, H., W., 1997. Grass Roots Collective Action: Agricultural Opportunities. *Journal of Agricultural and Resource Economics*, 22(1).

Baland, J.-M. & Platteau, J.-P., 1996. *Halting degradation of natural resources: Is there a role for rural communities?*, Rome, Italy: Food and Agriculture Organization of the United Nations.

Bardhan, P., 1993. Analytics of the Institutions of Informal Cooperation in Rural Development. *World Development*, 21(4), pp.633–639.

Barnes, J.., 1954. Class and Committees in a Norwegian Island Parish. *Human Relations*, 7(1), pp.39–58.

Barrera, Jr, M., 1986. Distinctions Between Social Support Concepts, Measures and Models. *American Journal of Community Psychology*, 14(4), pp.413–445.

Barrett, C.B. et al., 2002. The Challenge of Stimulating Adoption of Improved Natural Resource Management Practices in African Agriculture. In *Barrett, C. B., Place, F., and Aboud, A.A. (eds) Natural Resources Management in African Agriculture: Understanding and Improving Current Practices*. Wallingford, UK: CABI publishing.

Barron, J. & Okwach, G., 2005. Run-off water harvesting for dry spell mitigation in maize (Zea mays L.): results from on-farm research in semi-arid Kenya. *Agricultural Water Management*, 74(1), pp.1–21.

Becht, R., 2007. *Environmental Effects of the Floricultural Industry on the Lake Naivasha Basin*, Encshede, The Netherlands: International Institute for Geo-Information and Earth Observation.

Becht, R. & Harper, D., 2002. Towards an Understanding of Human Impact Upon the Hydrology of Lake Naivasha, Kenya. *Hydrobiologia*, 488, pp.1–11.

Becht, R., Odada, E.. & Higgins, S., 2005. Lake Naivasha: Experience and lessons learned brief. In *Lake basin management initiative□: Experience and lessons learned briefs including the final report: Managing lakes and basins for sustainable use, a report for lake basin managers and stakeholders*. Kusatsu: International Lake Environment Committe Foundation (ILEC), pp. 277–298.

Bekele, W., 2005. Stochastic Dominance Analysis of Soil and Water Conservation in Subsistence Crop Production in the Eastern Ethiopian Highlands: The Case of the Hunde-Lafto Area. *Environmental and Resource Economics*, 32(4), pp.533–550.

Berka, C., Schreier, H. & Hall, K., 2001. Linking Water Quality with Agricultural Intensification in a Rural Watershed. *Water, Air, and Soil Pollution*, 127, pp.389–401.

Berkes, F., Colding, J. & Folke, C., 2003. Introduction to “Navigating Socioecological Systems: Building Resilience for Complexity and Change.” In *Navigating Socioecological*

Systems: Building Resilience for Complexity and Change. Cambridge, UK: Cambridge University Press, pp. 1–20.

Bewket, W., 2007. Soil and water conservation intervention with conventional technologies in northwestern highlands of Ethiopia: Acceptance and adoption by farmers. *Land Use Policy*, 24(2), pp.404–416.

Brouwer, F., Heinz, I. & Zabel, T., 2002. The Role of Cooperative Arrangements in Environmental Policies. In *Hagedorn (ed). Environmental Co-operation and Institutional Change*. Cheltenham, UK: Edward Elgar Publishing Ltd.

Bruce, N., 2000. *Public Finance and The Americal Economy* Second Edition., New Jersey: Prentice Hall.

Burton, M., Rigby, D. & Lee, Y., 2003. Modelling the adoption of organic horticultural technology in the UK using Duration Analysis. *The Australian Journal of Agricultural and Resource Economics*, 47(1), pp.29–54.

Calatrava, J. & Franco, J.A., 2011. Using pruning residues as mulch: Analysis of its adoption and process of diffusion in Southern Spain olive orchards. *Journal of Environmental Management*, 92(3), pp.620–629.

Caliendo, M. & Kopeinig, S., 2008. Some Practical Guidance for the Implementation of Propensity Score Matching. *Journal of Economic Surveys*, 22(1), pp.31–72.

Cárdenas, J.C., Rodríguez, L.Á. & Johnson, N., 2009. *Collective Action forWatershed Management: Field Experiments in Colombia and Kenya*, Bogotá D. C., Colombia: Universidad de los Andes (Facultad de Economía) and Cede.

Chiramba, T. et al., 2011. Payment for Environmental Services pilot project in Lake Naivasha basin, Kenya – a viable mechanism for watershed services that delivers sustainable natural resource management and improved livelihoods. In Water in the Green Economy: Towards Rio+20. Zaragoza, Spain.

Chiu, T. et al., 2001. A robust and scalable clustering Algorithm for mixed type attributes in large database environmen. In *Proceedings of the 7th ACM SIGKDD international conference in knowledge discovery and data mining*. The 7th ACM SIGKDD international conference in knowledge discovery and data mining. San Francisco, CA: Association for Computing Machinery, pp. 263–268.

Chow, T.., Rees, H.. & Daigle, J.., 1999. Effectiveness of terraces grassed waterway systems for soil and water conservation: a field evaluation. *Journal of Soil and Water Conservation*, 54(3), pp.577–583.

Cleves, M. et al., 2008. *An Introduction to Survival Analysis Using STATA* second., Texas, USA: Stata press.

Coleman, J.., 1988. Social Capital in the Creation of Human Capital. *The American Journal of Sociology*, 94, pp.S95–S120.

Cox, D.R., 1972. Regression Models and Life-Tables. *Journal of the Royal Statistical Society. Series B (Methodological)*, 34(2), pp.187–220.

Dalton, P.A., Smith, R.J. & Truong, P.N.V., 1996. Vetiver grass hedges for erosion control on a cropped flood plain: hedge hydraulics. *Agricultural Water Management*, 31(1–2), pp.91–104.

Dehejia, R.H. & Wahba, S., 2002. Propensity Score-Matching Methods for Nonexperimental Causal Studies. *Review of Economics and Statistics*, 84(1), pp.151–161.

Deni, S.M. & Jemain, A.A., 2009. Mixed log series geometric distribution for sequences of dry days. *Atmospheric Research*, 92(2), pp.236–243.

Dinar, A., Rosegrant, M.W. & Meinzen-Dick, R., 1997. *Water Allocation Mechanisms: Principles and Examples*, Washington, D.C.: World Bank.

Dorward, A.. et al., 2009. Institutions and the Agricultural Development Challenge in Africa. In *J. F. Kirsten, A. R. Dorward, C.Poulton, and N. Vink (ed) Institutional Economics Perspectives on African Agricultural Development*. Washington, D.C.: International Food Policy Research Institute.

Doss, C.R. & Morris, M.L., 2001. How does gender affect the adoption of agricultural innovations?: The case of improved maize technology in Ghana. *Agricultural Economics*, 25(1), pp.27–39.

Ellis-Jones, J. & Tengberg, A., 2000. The impact of indigenous soil and water conservation practices on soil productivity: examples from Kenya, Tanzania and Uganda. *Land Degradation & Development*, 11(1), pp.19–36.

Enniskillen, 2002. The Lake Naivasha Management Plan – consensus-building to conserve an international gem. *Hydrobiologia*, 488(Developments in Hydrobiology 168)), pp.ix–xii.

Ervin & Ervin, 1982. Factors Affecting the Use of Soil Conservation Practices: Hypotheses, Evidence, and Policy Implications. *Land Economics*, 58(3), pp.277–292.

Esteban, E. & Dinar, A., 2013. Cooperative Management of Groundwater Resources in the Presence of Environmental Externalities. *Environmental and Resource Economics*, 54(3), pp.443–469.

Fernandez-Cornejo, J., 2007. *Off-Farm Income, Technology Adoption, and Farm Economic Performance*, Washington, DC: United States Department of Agriculture. Available at: http://www.ers.usda.gov/publications/err-economic-research-report/err36.aspx.

Field, A., 2009. *Discovering Statistics Using SPSS* 3rd Edition., London: Sage.

Filmer, D. & Pritchett, L.., 2001. Estimating Wealth Effects Without Expenditure Data-or Tears: An Aplication to Educational Enrolment in States of India. *Demography*, 38(1), pp.115–132.

Foster, A.. & Rosenzweig, M.., 1995. Learning by Doing and Learning from Others: Human Capital and Technical Change in Agriculture. *Journal of Political Economy*, 103(6), pp.1176–1209.

Fuglie, K.O. & Kascak, C.A., 2001. Adoption and Diffusion of Natural-Resource -Conserving Agricultural Technology. *Review of Agricultural Economics*, 23(2), pp.386–403.

Gautam, M., 2000. *Agricultural Extension: The Kenya Experience, An Impact Evaluation*, Washington, D.C: World Bank.

Gillinson, S., 2004. Why Cooperate? A Multi-Disciplinary Study of Collective Action. Available at: http://62.58.77.238/downloads/conference 2004/Session 8/maxwell_paper.pdf.

GoK, 1999. *Environmental Management and Co-ordination Act 1999*, Nairobi, Kenya: Government Printers.

GoK, 2004. *Lake Naivasha Management Plan* Kenya Gazzette Supplement no.63., Nairobi, Kenya: Government Printers.

GoK, 2005. *The Forest Act, 2005*, Nairobi, Kenya: Government Printers.

GoK, 2002. *Water Act 2002*, Nairobi, Kenya: Government Printers.

GoK, 2006. *Water Resources Management Rules, 2006*, Nairobi, Kenya: Government Printers.

Goldman, R.L., Thompson, B.H. & Daily, G.C., 2007. Institutional incentives for managing the landscape: Inducing cooperation for the production of ecosystem services. *Special*

Section - Ecosystem Services and Agriculture Ecosystem Services and Agriculture, 64(2), pp.333–343.

De Graaff, J. et al., 2008. Factors influencing adoption and continued use of long-term soil and water conservation measures in five developing countries. *Applied Geography*, 28(4), pp.271–280.

Greene, W., 2003. *Econometric Analysis* 5th ed., Upper Saddle River, New Jersey: Prentice Hall.

Grilli, L. & Rampichini, C., 2011. Propensity scores for the estimation of average treatment e_ects in observational studies. In Bristol. Available at: http://www.bristol.ac.uk/cmm/software/support/workshops/materials/causal-inference/prop-scores.pdf [Accessed October 10, 2012].

Hagedorn, K., 2008. Particular requirements for institutional analysis in nature-related sectors. *European Review of Agricultural Economics*, 35(3), pp.357–384.

Hagedorn, K., Arzt, K. & Ursula, 2002. Institutional Arrangements for Environmental Co-operatives: a Conceptual Framework. In *Hagedorn (ed.) Environmental Co-operation and Institutional Change*. Cheltenham, UK and Northampton, MA, USA: Edward Elgar.

Hardin, G., 1968. The Tragedy of the Commons. *Science*, 162, pp.1243–1248.

Harper, D. & Mavuti, K., 2004. Lake Naivasha, Kenya: Ecohydrology to guide the management of a tropical protected area. *Ecohydrology and Hydrobiology*, 4(3), pp.287–305.

He, X.-F., Cao, H. & Lii, F.-M., 2007. Econometric analysis of the determinants of adoption of rainwater harvesting and supplementary irrigation technology (RHSIT) in the semiarid Loess Plateau of China. *agri cul t u r a l water management*, 89, pp.243–250.

Heckman, J.., 1979. Sample Selection Bias as a Specification Error. *Econometrica*, 47, pp.153–161.

Hodge, I. & McNally, S., 2000. Wetland restoration, collective action and the role of water management institutions. *Ecological Economics*, 35(1), pp.107–118.

Hoekstra, A.. & Hung, P.., 2002. *Virtual water trade: A quan - tification of virtual water flows between nations in relation to international crop trade.*, Delft, The Netherlands: IHE.

Hosmer, D.W. & Lemeshow, S., 1999. *Applied Survival Analysis: Regression Modeling of Time to Event Data*, New York, USA: John Wiley & Sons, Inc.

Hougaard, P., 1995. Frailty Models for Survival Data. *Lifetime Data Analysis*, 1, pp.255–273.

Huffman, W.E., 1991. Agricultural Household Models: Survey and Critique. In *Multiple Job-Holding Among Farm Families in North America*. Milton Hallberg: Iowa State University Press, pp. 79–111.

IBM Corp., 2012. *IBM SPSS Statistics for Windows, Version 21.0*, Armonk, NY: IMB Corp.

Janssens, W., 2007. *Social Capital and Cooperation: An Impact Evaluation of a Women's Empowerment Programme in Rural India*. Doctoral Thesis. Amsterdam, The Netherlands: Vrije Universiteit.

Jara-Rojas, R., Bravo-Ureta, B.E. & Díaz, J., 2012. Adoption of water conservation practices: A socioeconomic analysis of small-scale farmers in Central Chile. *Agricultural Systems*, 110(0), pp.54–62.

Jenkins, S.P., 2004. *Survival Analysis*, University of Essex, Colchster, UK: Unpublished Manuscript.

De Jong, T., 2011. *Water Abstraction Survey in Lake Naivasha Basin, Kenya*, Wageningen: WRMA, SNV and Wageningen UR. Available at: ftp://ftp.itc.nl/pub/naivasha/DeJong2011.pdf [Accessed October 15, 2011].

Kabubo-Mariara, J. et al., 2006. *Household Welfare, Investment in Soil and Water Conservation and Tenure Security: Evidence From Kenya*, PREM 06/06: Institute for Environmental Studies Vrije Universiteit.

Kabubo-Mariara, J., 2012. Institutional Isolation, Soil Conservation and Crop Productivity: Evidence from Machakos and Mbeere Districts in Kenya. *African Journal of Social Sciences*, 2(3), pp.1–26.

Kabubo-Mariara, J., 2007. Land conservation and tenure security in Kenya: Boserup's hypothesis revisited. *Ecological Economics*, 64, pp.25–35.

Kabubo-Mariara, J., Linderhof, V. & Kruseman, G., 2010. Does land tenure security matter for investment in soil and water conservation? Evidence from Kenya. *African Journal of Agricultural Research*, 4(2), pp.123–139.

Kahinda, J.M. & Taigbenu, A.E., 2011. Rainwater harvesting in South Africa: Challenges and opportunities. *11th WaterNet/WARFSA/GWP-SA Symposium: IWRM for National and Regional Integration through Science, Policy and Practice*, 36(14–15), pp.968–976.

Kahinda, J.M., Taigbenu, A.E. & Boroto, J.R., 2007. Domestic rainwater harvesting to improve water supply in rural South Africa. *Mainstreaming Integrated Water Resources Management in the Development Process*, 32(15–18), pp.1050–1057.

Kahinda, J.M., Taigbenu, A.E. & Boroto, R.J., 2010. Domestic rainwater harvesting as an adaptation measure to climate change in South Africa. *Physics and Chemistry of the Earth*, 35(13–14), pp.742–751.

Karshenas, M. & Stoneman, P.L., 1993. Rank, Stock, Order, and Epidemic Effects in the Diffusion of New Process Technologies: An Empirical Model. *The RAND Journal of Economics*, 24(4), pp.503–528.

Kassie, M. et al., 2011. Are soil conservation technologies “win-win?” A case study of Anjeni in the north-western Ethiopian highlands. *Natural Resources Forum*, 35(2), pp.89–99.

Kassie, M. et al., 2008. Estimating returns to soil conservation adoption in the northern Ethiopian highlands. *Agricultural Economics*, 38(2), pp.213–232.

KFS, 2010. *GETA Participatory Forest Management Plan*, NAirobi, Kenya: Kenya Forest Service.

Khisa, P. et al., 2007. The effect of post harvest crop cover on soil erosion in a maize-legume based cropping system in Gatanga, Kenya. *Journal of Agriculture in the Tropics and Subtropics*, 103, pp.17–28.

Kim, S.-H. & Park, H.J., 2011. Effects of social influence on consumers’ voluntary adoption of innovations prompted by others. *Journal of Business Research*, 64(11), pp.1190–1194.

King, D.C. & Walker, J.L., 1992. The Provision of Benefits by Interest Groups in the United States. *The Journal of Politics*, 54(2), pp.394–426.

Kitaka, N., Harper, D. & Mavuti, K., 2002. Phosphorus inputs to Lake Naivasha, Kenya, from its catchment and the Trophic state of the Lake. *Hydrobiologia*, 488, pp.73–80.

KNBS, 2010. Kenya 2009 Population and Housing Census Highlights. Available at: http://www.knbs.or.ke/Census%20Results/KNBS%20Brochure.pdf [Accessed March 15, 2012].

Lankoski, J. & Ollikainen, M., 2003. Agri-environmental externalities: a framework for designing targeted policies. *European Review of Agricultural Economics*, 30(1), pp.51–75.

Latacz-Lohmann, U. & Hodge, I., 2003. European agri-environmental policy for the 21st century. *The Australian Journal of Agricultural and Resource Economics*, 47(1), pp.123–139.

Leuven, E. & Sianesi, B., 2003. *PSMATCH2: Stata module to perform full Mahalanobis and propensity score matching, common support graphing, and covariate imbalance testing*, Boston: Boston College Department of Economics.

Lubell, M. et al., 2002. Watershed Partnerships and the Emergence of Collective Action Institutions. *American Journal of Political Science*, 46(1), pp.148–163.

Lutz, E., Pagiola, S. & Reiche, C., 1994. The Costs and Benefits of Soil Conservation: The Farmers' Viewpoint. *The World Bank Research Observer*, 9(2), pp.273–295.

Lynne, G.D. et al., 1995. Conservation technology adoption decisions and the theory of planned behavior. *Journal of Economic Psychology*, 16(4), pp.581–598.

Lynne, G.D. & Rola, L.., 1988. Improving Attitude-Behavior Prediction Models with Economic Variables: Farmer Actions toward Soil Conservation. *Journal of Social Psychology*, 128(1), pp.19–28.

Lynne, G.D., Shonkwiler, J.. & Rola, L.., 1988. Attitudes and farmer conservation behaviour. *American Journal of Agricultural Economics*, 12, pp.12–19.

Marenya, P.P. & Barrett, C.B., 2007. Household-Level Determinants of Adoption of Improved Natural Resources Management Practices Among Smallholder Farmers in Western Kenya. *Food Policy*, 32(4), pp.515–536.

Mavuti, K. & Harper, D., 2006. The ecological state of Lake Naivasha, Kenya, 2005: Turning 25 years research into an effective Ramsar monitoring programme. In *Proceedings of the 11th World Lakes Conference*. 11th World Lakes Conference. pp. 30–34.

Mazvimavi, K. & Twomlow, S., 2009. Socioeconomic and institutional factors influencing adoption of conservation farming by vulnerable households in Zimbabwe. *Agricultural Systems*, 101(1–2), pp.20–29.

Mbaga-Semgalawe, Z. & Folmer, H., 2000. Household adoption behaviour of improved soil conservation: the case of the North Pare and West Usambara Mountains of Tanzania. *Land Use Policy*, 17(4), pp.321–336.

Meins, F.., 2013. *Evaluation of spatial scale alternatives for hydrological modelling in SWAT of the Malewa Basin, Kenya*. Master Thesis. Encshede, The Netherlands: International Institute for Geoinformation Science and Earth Observation.

Meinzen-Dick, R., 2007. Beyond Panaceas in Water Institutions. *Proceedings of the National Academy of Sciences*, 104(39), pp.15200 –15205.

Meinzen-Dick, R. & Di Gregorio, M., 2004. *Collective Action and Property Rights for Sustainable Development*, International Food Policy Institute (IFPRI).

Meinzen-Dick, R., Raju, K.. & Gulati, A., 2002. What Affects Organization and Collective Action for Managing Resources? Evidence from Canal Irrigation Systems in India. *World Development*, 30(4), pp.649–666.

Mekonnen, M.. & Hoekstra, A.., 2010. *Mitigating the Water Footprint of Export Cut Flowers from the Lake Naivasha Basin, Kenya*, Delft, The Netherlands: UNESCO-IHE.

Mendola, M., 2007. Agricultural technology adoption and poverty reduction: A propensity-score matching analysis for rural Bangladesh. *Food Policy*, 32(3), pp.372–393.

Merlo, M. & Briales, E.R., 2000. Public goods and externalities linked to Mediterranean forests: economic nature and policy. *Land Use Policy*, 17(3), pp.197–208.

Migot-Adholla, S.. et al., 1991. Indigenous Land Right Systems in Sub-Saharan Africa: A Constraint on Productivity? *The World Bank Economic Review*, 5(1), pp.155–175.

Millennium Ecosystem Assessment, 2005. *Ecosystems and Human Well-Being: Synthesis*, Washington, DC: Island Publisher.

Miller, M.J., Mariola, M.J. & Hansen, D.O., 2008. EARTH to farmers: Extension and the adoption of environmental technologies in the humid tropics of Costa Rica. *Ecological management and sustainable development in the humid tropics of Costa Rica*, 34(4), pp.349–357.

Milu, M. & Jayne, T.S., 2006. *Agricultural Extension in Kenya:Practice and Policy Lessons*, Nairobi, Kenya: Egerton University, Tegemeo Institute.

Mooi, E. & Sarstedt, M., 2011. *A Concise Guide to Market Research*, Berlin- Heildelberg: Springer-Verlag.

Mpusia, P.T.O., 2006. *Comparison of Water Consumption between Greenhouse and Out-door Cultivation*. Master Thesis. Encshede, The Netherlands: International Institute for Geoinformation Science and Earth Observation.

Mumma, A., 2007. Kenya's New Water Law: an Analysis of the Implications of Kenya's Water Act, 2002, for the Rural Poor. In *Community-based Water Law and Water Resource Management Reform in Developing Countries*. Oxfordshire, UK: CAB International.

Mutegi, J.K. et al., 2008. Combining napier grass with leguminous shrubs in contour hedgerows controls soil erosion without competing with crops. *Agroforestry Systems*, 74(1), pp.37–49.

Napier, T.L. et al., 1984. Factors affecting adoption of conventional and conservation tillage practices in Ohio. *Journal of Soil and Water Conservation*, 39, pp.205–509.

Ngigi, S.N., 2003. What is the limit of up-scaling rainwater harvesting in a river basin? *Physics and Chemistry of the Earth, Parts A/B/C*, 28(20–27), pp.943–956.

Nkonya, E. et al., 2008. *Linkages between Land Management, Land Degradation, and Poverty in Sub-Saharan Africa: The Case of Uganda*, Washington, D.C: IFPRI.

North, D., 1990. *Institutions, Institutional Change and Economic Performance*, Cambridge: Cambridge University Press.

Nyangena, W., 2006. *Essays on Soil Conservation, Social Capital and Technology Adoption*. Doctoral Thesis. Göteborg, Sweden: Göteborg University. School of Business, Economics and Law.

Nyangena, W. & Köhlin, G., 2009. *Estimating Returns to Soil and Water Conservation Investments - An Application to Crop Yield in Kenya*, Göteborg , Sweden: School of Business, Economics and Law at University of Gothenburg.

OECD, 2012. Glosary of Statistical Terms. Available at: http://stats.oecd.org/glossary/download.asp [Accessed August 31, 2012].

OECD & FAO, 2012. *Sustainable Agricultural Productivity Growth and Bridging the Gap for Small Family Farms*, Washington, D.C and Paris: Organization for Economic Cooperation and Development (OECD) and Food and Agriculture Organization of the United Nations (FAO).

Van Oel, P.R., Krol, M.S. & Hoekstra, A.., 2009. A river basin as a common-pool resource: A case study of the Jaguaribe basin in the semi-arid Northeast of Brazil. *International Journal of River Basin Management*, 7(4), pp.345–353.

Oliver, P., 1984. If You dont Do it, Nobody Else Will: Active and Token Contributions to Local Collective Action. *American Sociological Review*, 49, pp.601–610.

Olson, M., 1965. *The Logic of Collective Action: Public Goods and the Theory of Groups*, Cambridge: Harvard University Press.

Onywere, S.M., Miroga, J.. & Simiyu, I., 2012. Use of Remote Sensing Data in Evaluating the Extent of Anthropogenic Activities and their Impact on Lake Naivasha, Kenya. *The Open Environmental Engineering Journal*, 5, pp.9–18.

Orr, P. & Colby, B., 2004. Groundwater Management Institutions to Protect Riparian Habitat. *Water Resources Research*, 40(12), p.W12S03.

Ostrom, E., 1990. *Governing the Commons: The Evolution of Institutions of Collective Action*, New York, USA: Cambridge University Press.

Ostrom, E. & Ahn, T.., 2009. The Meaning of Social Capital and its Link to Collective Action. In *Svendsen, G.T. and Gunnar, L.S (eds) Handbook of Social Capital*. Northampton, MA: Edward Elgar Publishing.

Otsuki, T., 2010. *Estimating Agroforestry's Effect on Productivity in Kenya: An Application of a Treatment Effects Model*, Osaka, Japan: The Osaka School of International Public Policy, Osaka University.

Pagiola, S., 1998. Economic Analysis of Incentives for Soil Conservation. In *D.W. Sanders, P.C. Huszar, S. Sombatpanit, and T. Enters (eds.) Using Incentives for Soil Conservation*. Washington, D.C: World Bank.

Pagiola, S., 1994. Soil Conservation in a Semi-Arid Region of Kenya: Rates of Return and Adoption by Farmers. In *T.L.Napier, Camboni, S.M, A. El-Swaify,(eds.) Adopting Conservation on the Farm: An International Perspective on the Socioeconomics of Soil and Water Conservation*. Iowa: Soil and Water Conservation Society, pp. 171–188.

Pagiola, S. & Dixon, J.., 1998. Land Degradation in El Salvador. In *A. Valdés and C. Shaw ,eds, El Salvador Rural Development Study*. Washington, D.C: World Bank.

Pandey, S., 1991. The economics of water harvesting and supplementary irrigation in the semi-arid tropics of India. *Agricultural Systems*, 36(2), pp.207–220.

Pender, J. & Gebremedhin, B., 2007. Determinants of Agricultural and Land Management Practices and Impacts on Crop Production and Household Income in the Highlands of Tigray, Ethiopia. *Journal of African Economies*, 17(3), pp.395–450.

Pigou, A.., 1920. *The Economics of Welfare*, London: Macimillan.

Pimentel, D., 1997. *Conservation of Fertilizers and Livestock Manure: Pollution Prevention*, Michigan: National Pollution Prevention Center for Higher Education.

Place, F. & Swallow, B.., 2000. *Assessing the Relationship Between Property Rights and Technology Adoption in Smallholder Agriculture: A Review of Issues and Empirical Methods*, Washington, D.C: International Food Policy Research Institute.

Polman, N.B.P. & Slagen, L.H.., 2002. Self-Organizing and Self-Governing of Environmental Co-operatives: Design Principles. In *Hagedorn (ed). Environmental Co-operation and Institutional Change*. Cheltenham, UK: Edward Elgar Publishing Ltd, pp. 91–111.

Posthumus, H. & De Graaff, J., 2005. Cost-benefit analysis of bench terraces, a case study in Peru. *Land Degradation & Development*, 16(1), pp.1–11.

Poteete, A.R. & Ostrom, E., 2004. Heterogeneity, Group Size and Collective Action: The Role of Institutions in Forest Management. *Development and Change*, 35(3), pp.435–461.

Power, A.G., 2010. Ecosystem services and agriculture: tradeoffs and synergies. *Philosophical Transactions of the Royal Society B*, 365, pp.2959–2971.

Pregibon, D., 1980. Goodness of link tests for generalized linear models. *Appl Stat*, 29, pp.15–24.

Pretty, J.N., Thompson, J. & Kiara, J.., 1995. Agricultural regeneration in Kenya: The catchment approach to soil and water conservation. *Ambio. Stockholm*, 24(1), pp.7–15.

Pretty, J.N. & Ward, H., 2001. Social Capital and the Environment. *World Development*, 29(2), pp.209–227.

Putnam, R., 2000. *Bowling Alone: The Collapse and Revival of American Community*, New York, USA: Simon & Schuster.

Quiggin, J., 2001. Environmental economics and the Murray–Darling river system. *Australian Journal of Agricultural and Resource Economics*, 45(1), pp.67–94.

RAMSAR convention, 2011. The Annotated Ramsar List: Kenya. *The Annotated Ramsar List: Kenya*. Available at: The Annotated Ramsar List: Kenya.

Ravnborg, H.., Guerrero, M. del P. & Westermann, O., 2000. *Collective action for Managing Natural Resources: A manual for Identifying Stakeholders*, Cali, Columbia: CIAT.

Reta, G.L., 2011. *Ground Water and Lake Water Balance of Lake Naivasha Using 3-D Transient Ground Water Model*. Encshede, The Netherlands: International Institute for Geoinformation Science and Earth Observation.

Reuben, E., 2003. *The Evolution of Theories of Collective Action*. Master Thesis. Amsterdam, The Netherlands: Tinbergen Institute.

Van Rijn, F., Bulte, E. & Adekunle, A., 2012. Social capital and agricultural innovation in Sub-Saharan Africa. *Agricultural Systems*, 108(2012), pp.112–122.

Rogers, E.., 1995. *Diffusion of Innovations* Fourth edition., New York: Free Press.

Rogers, E.M., 1962. *Diffusion of Innovations.* First edition., Glencoe, Illinois: Free Press.

Van Rooy, M.., 1965. A Rainfall anomaly index (RAI) independent of time and space. *Notos*, 14, pp.43–48.

Rosenbaum, P.R., 2002. *Observational Studies* Second Edition., New York, USA: Springer.

Rosenbaum, P.R. & Rubin, D.B., 1983. The central role of the propensity score in observational studies for causal effects. *Biometrika*, 70(1), pp.41–55.

Ryan, B. & Gross, N., 1943. The diffusion of hybrid seed corn in two Iowa communities. *Rural Sociology*, 8(1), pp.15–24.

Serrat, O., 2010. *Social Network Analysis*, Washington, D.C: Asian Development Bank.

Shepard, D., 1968. A two-dimensional interpolation function for irregularly-spaced data. In *ACM '68 Proceedings of the 1968 23rd ACM national conference*. 23rd ACM national conference. New York, USA: Association of Computing Machinery, pp. 517–524.

Shiferaw, B. & Holden, S., 2001. Farm-level benefits to investments for mitigating land degradation: empirical evidence from Ethiopia. *Environment and Development Economics*, 6(3), pp.335–358.

Shiferaw, B. & Holden, S., 1998. Resource degradation and adoption of land conservation technologies in the highlands of Ethiopia: a case study of Andit Tid, North Sheawa. *Agricultural Economics*, 18, pp.233–247.

Shively, G.E., 1998. Modeling Impacts of Soil Conservation on Productivity and Yield Variability: Evidence from a Heteroskedastic Switching Regression. In *American Proceedings of the annual meeting of the Agricultural Economics Association annual*. Annual meeting of the American Agricultural Economics Association. 2-5 August, Salt Lake City, Utah.

Sidibé, A., 2005. Farm-level adoption of soil and water conservation techniques in northern Burkina Faso. *Agricultural Water Management*, 71(3), pp.211–224.

Singh, I., Lyn, S. & John, S., 1986. *Agricultural Household Models—Extensions, Applications and Policy*, Baltimore: The Johns Hopkins University Press.

Slagen, L.H.. & Polman, N.B.P., 2002. Environmental Cooperatives: a New Institutional Arrangement of Farmers. In *Hagedorn (ed). Environmental Co-operation and Institutional Change*. Cheltenham, UK: Edward Elgar Publishing Ltd, pp. 69–90.

Stavins, R.., 2000. Experience with Market-Based Environmental Policy Instruments. In *K.G Mäller & J.R Vinvent (ed.) Handbook of Environmental Economics*. Elsevier, pp. 355–435.

Stoof-Leichsenring, K. et al., 2011. Environmental variability in Lake Naivasha, Kenya, over the last two centuries. *J Paleolimnol*, 45, pp.353–367.

Swallow, B.M., Garrity, D.P. & van Noordwijk, M., 2002. The effects of scales, flows and filters on property rights and collective action in watershed management. *Water Policy*, 3(6), pp.457–474.

Tang, Y., 1998. *Bioterracing and soil conservation: experience with contour hedgerow planting in parts of the Hindu Kush-Himalayan region*, Kathmandu, Nepal: Mountain Farming Systems, ICIMOD.

Tenge, A., 2005. *Participatory appraisal for farm-level soil and water conservation planning in West Usambara highlands, Tanzania*. [S.l.]: [s.n.]. Available at: http://edepot.wur.nl/19924.

Tisdell, C., 2009. Policy Choices about Agricultural Externalities and Sustainability: Diverse Approaches,Options and Issue. In *Bechmann, V. and Padmanabhan, M (eds.) Instituions and Sustainability: Political Economy of Agriculture and The Environment-Essays in Honour of Konrad Hagedorn*. New York: Springer.

UN-WWAP, 2006. *The United Nations World Water Development Report 2: Water a Shared Responsibility*, PAris and New York: UNESCO and Berghahn Books.

Uphoff, N., 1999. Understanding social capital: Learning from the analysis and experience of participation. In *Ismail Serageldin (ed,) Social Capital: A multifaceted perspective*. Washington, D.C: World Bank, pp. 215–253.

Vakis, R., Sadoulet, E. & de Janvry, A., 2003. *Measurng Transaction Costs from Observed Behaviour: Market Choices in Peru*, Califonia, Berkeley: University of California, Berkeley, Department of Agricultural and Resource Economics.

Vancampenhout, K. et al., 2006. Stone bunds for soil conservation in the northern Ethiopian highlands: Impacts on soil fertility and crop yield. *Soil and Tillage Research*, 90(1–2), pp.1–15.

Verbeek, M., 2012. *A Guide to Modern Econometrics* 4th Edition., Chichester: John Wiley & Sons.

Verbeek, M., 2008. *A Guide to Modern Econometrics* 3rd Edition., Chichester: John Wiley & Sons.

Verschuren, D., Laird, K.R. & Cumming, B.F., 2000. Rainfall and drought in equatorial east Africa during the past 1,100 years. *Nature*, 403, pp.410–414.

Welderufael, W.A., Woyessa, Y.E. & Edossa, D.C., 2013. Impact of rainwater harvesting on water resources of the modder river basin, central region of South Africa. *Agricultural Water Management*, 116(0), pp.218–227.

White, T.. & Runge, C.F., 1994. Common Property and Collective Action: Lessons from Cooperative Watershed Management in Haiti. *Economic Development and Cultural Change*, 43(1), pp.1–41.

Willy, D.K. & Holm-Mueller, K., 2013. Social influence and collective action effects on farm level soil conservation effort in rural Kenya. *Ecological Economics*, 90, pp.94–103.

Willy, D.K., Kuhn, A. & Holm-Mueller, K., 2011. Options for Improving the Design and Enforcement of Water Institutions in Lake Naivasha Basin, Kenya. In *International Research on Food Security, Natural Resource Management and Rural Development*. Tropentag 2011. Bonn, Germany: Cuvillier Verlag, p. 576.

Willy, D.K., Kuhn, A. & Holm-Mueller, K., 2012. *Payments for Environmental Services and the Characteristics of Socioecological Systems: The Case of Lake Naivasha Basin*, Bonn, Germany: Institute for Food and Resource Economics Discussion Paper.

Wimalasuriya, R. et al., 2008. Rainfall Variability and its Impact on Dryland Cropping in Victoria. In 52nd Annual Conference of the Australian Agricultural and Resource Economics Society (AARES). Canberra, Australia, p. 29.

World Bank, 2013. Data: Renewable internal freshwater resources per capita (cubic meters). Available at: http://data.worldbank.org/indicator/ER.H2O.INTR.PC [Accessed January 21, 2013].

World Bank, 2008. *World Development Report 2008: Agriculture for Development*, Washington, D.C.: World Bank.

WRMA, 2010. *Lake Naivasha Water Abstraction Survey*, Unpublished.

WRMA, 2009. *Rift Valley Catchment Area Management Strategy*, Nairobi, Kenya: Government Printers.

WWF, 2012. *Living Planet Report 2012: Biodiversity, biocapacity and better choices*, Gland, Switzerland: World Wide Fund For Nature.

WWF, 2011. *Shared Risk and Opportunity in Water Resources: Seeking Sustainable Future for Lake Naivasha*, WWF.

Yaffee, S.., 1998. Cooperation: A Strategy for Achieving Stewardship Across Boundaries. In *Knight RL and Landres P (Eds). Stewardship across boundaries*. Washington, DC:: Island Press.

Yihdego, Y., 2005. *A Three Dimensional Ground Water Model of the Aquifers around Lake Naivasha area, Kenya*. Master Thesis. Encshede, The Netherlands: International Institute for Geoinformation Science and Earth Observation.

Zhunusova, E., 2012. *Marginal Benefits and Opportunity Costs of Environmentally Friendly Technologies Employed by Small-Holder Farmers in the Lake Naivasha Basin, Kenya*. Master Thesis. Bonn, Germany: University of Bonn.

Abu-Zreig, M., Attom, M. & Hamasha, N., 2000. Rainfall harvesting using sand ditches in Jordan. *Agricultural Water Management*, 46(2), pp.183–192.

APPENDICES

Appendix 1 : Survey Instrument

RCR Lake Naivasha Basin Survey, 2011
Water Users Interview Schedule

Introduction
I am part of a University research team which consists of researchers from Kenya and Germany. We are currently conducting a survey, seeking to understand different ways of using and managing water in the Lake Naivasha Basin. You have been randomly selected to give views on water management and use in your farm and this area in general. We appreciate your **VOLUNTARY** participation in this survey. The information you disclose will completely be **CONFIDENTIAL** and your opinion will be combined with those of others to give a general view. For more information you can contact Daniel Kyalo through: 0724598988.

SECTION A: GENERAL INFORMATION

Enumerator	____________________	**enumcode**	[_____]
Respondent's Name	____________________	**hmnum***	[_____]
County	____________________	**count**	[_____]
District	____________________	**dist**	[_____]
Division	____________________	**div**	[_____]
Location	____________________	**loc**	[_____]
Sub-Location	____________________	**subloc**	[_____]
Village	____________________	**vill**	[_____]

Insert number from Table K1 after the interview

GPS Readings:

Altitude	[_______________]
UTM	[_______________]
Longitude	[_______________]
Latitude	[_______________]

SECTION B: GENERAL WATER USE TRENDS

We shall start by talking about the water used in your household. We will talk about where you get this water from, and the quantities you use. We will also talk about how the quantity of water has been changing in this area in the last 10 years.

B1. Give me the following details on the specific water uses within your household

Type of water use *(Probe for each use)*	What are the **two main sources** of water for the following purposes and what are the average quantities used per day from each source? *(Use codes below)*						**General water quality for the use** 1=Good 2=Poor	
	1st Source	**Qty/day**	**Qty Units**	**2nd Source**	**Qty/day**	**Qty Units**	**1st Source**	**2nd Source**
Watuse	**wsrc1**	**wsrc1qty**	**qunit**	**wsrc2**	**Wsrc2qty**	**qunit2**	**Src1qlt**	**Src2qlt**
Domestic (Drinking, cooking, washing)								
Irrigation								
Livestock watering								

Sources of water: 1=River/stream 2=Roof catchment 3= Own Borehole 4= Communal Borehole 5= Well 6= Spring 7=Wetland/swamp 8=Tap water (home) 100=other (specify)____________

Units: 1=Litres 2=20 Litre container 3=Cubic metres 100=Other (specify)__________________

B2**.** In your assessment, what has been the general trend in the quantity of water available from **rivers** in this area the last 10 years? r**watertr** [_____]

1=Decreased 2=Increased 3=Remained the same 4= No idea

B3**.** In your assessment, what has been the general trend in the quantity of water available from **boreholes** in this area the last 10 years? **bwatertr** [_____]

1=Decreased 2=Increased 3=Remained the same 4= No idea

B4. If decreased in B2 or B3, what measures have you taken to cope with this change? **(cope1-4)**

....

SECTION C: SOIL AND WATER CONSERVATION

I would now like to ask you about any methods of soil and water conservation that you know and those that you have been using in your farm, or those that you are planning to use or you are reluctant to use. I would also like to know how you benefit from these methods, and the challenges

C1. What methods of **soil erosion control** do you know? **(Seromtd1- 4)**

....

....

C2. What methods of **saving water or using water wisely** do you know? **(Wsavmtd1-4)**

....

....

C3. In your opinion, how can you describe the slope of your **main farm**? 1=Extremely steep 2= Moderately steep 3= Flat **slopefm**[____]

C4. ENUME: Check the actual slope of the farm and record (use codes in C3) **actslope** [______]

C5. Do you experience any form of soil erosion in your **main farm**? 1=Yes 2=No **erosion** [_____]

C6. If Yes, in C5, what is the soil erosion status in your **main farm**? 1=Very little 2=Little 3=Moderate 4=Extreme 5= Very extreme **erofarm** [____]

C7. ENUME: Check the actual soil erosion condition on the farm and record (use codes in C6) **eroeact** [____]

C8. Have you implemented any of the following **soil erosion control measures** on **your farm**?

Soil conservation method		**Status of Implementation** 1=Already using 2=Have desire to use 3= Reluctant to use	**Extend of practice**	When did you start this practice **(year)**	Main source (s) of materials for this practice *(Use codes below)*			Mode(s) of acquisition by source 1=Free 2=Purchased			Main source (s) of information about this practice *(Use codes below)*			Since you started the practice, have you expanded?	If Yes, by what margin *(Use codes below)*	If No expansion, why? *(Use codes below)*		
conmech	**Nr.**	**status**	**extent**	**ystart**	**Matsrc1-3**			**Modacq1-3**			**Infsrc1-3**			**expand**	**mrgexp**	**Rsnnoexp1-3**		
Tree planting	1		$_1$Number[______]															
Napier grass	2		$_2$Acres [______]															
Grass (other) strips	3		$_3$Metres[______]															
Terracing	4		$_3$Metres[______]															
Contour ploughing	5		$_2$Acres [______]															
Contour cropping	6		$_2$Acres[______]															
Crop rotation	7		$_4$Times/year[_____]															
Cover crops	8		$_2$Acres[______]															
Mixed cropping	9		$_2$Acres[______]															

Material sources: 1= Private nursery 2=Own nursery 3=Neighbour 4=NGO 5=Governmental organization 6= Community group 100=Other (specify)________
Margin of expansion: 1= Less than half 2=About half 3= More than half 4=Doubled 5=More than doubled 100=Other (specify)__________________
Information sources: 1=Agricultural extension officers 2=Farmer field schools 3= Local school 4=NGOs 5=Media (Print, Audio and Visual) 6= Other Farmers/Neighbours 7=Community based organisation (CBO) 8=Church 100=Other (Specify)________________________
Reasons for no expansion: 1=Lack of materials 2=Needs too much labour 3=Costly to implement 4=Not beneficial 5=No land for expansion 100=Other______

C9. For the technologies practiced in Table C8 above, make a follow up on the following aspects

Technology (***Transfer from Table C8, using Nr. as the code)***	When did you **start using** this practice after **learning about it**? *(Use codes below)*	How do you **benefit** from this practice? *(Use codes below)*				Do you depend on **external support** on the following things to maintain this practice? 1=Yes 2=No	
Techn	**Adotime**	**benefit1-4**				**Advice**	**External inputs**
						advdep	**inpdep**

Adotime: 1=Immediately (within one season) 2=After a short time (within one –two years) 3=After a long time (More than two years)
Benefit: 1=Improved yield 2=More fodder for livestock 3= Better soil status 4= Conserve water 100=Other (specify)__________

C10. Have you ever **given** planting materials to another farmer /other farmers for **free**?
1=Yes 2=No **matgive**[____]

(**ENUM:** ***If No, Skip to Qn C13***)

C11. If Yes, specify the planting materials **pltmat1** [_____] **pltmat2** [_____] **pltmat3** [_____]
1=Horticultural crop seedlings 2=Seeds (cereals) 3= Napier grass cuttings 4=Other fodder vines 5= Tree seedlings 100=Other (specify______________________

C12. How often have you given planting materials to another farmer? **givefreq** [_____]
1=Rarely 2= Sometimes 3= Very frequently

C13. Have you ever **sold planting** materials to another farmer /other farmers?
1=Yes 2=No **matsell**[____]

(**ENUM:** ***If No, Skip to Qn C16***)

C14. If Yes, specify the planting materials **pltmat1**[_____] **pltmat2**[_____] **pltmat3**[_____]
1=Horticultural crop seedlings 2=Seeds (cereals) 3= Napier grass cuttings 4=Other fodder vines 5= Tree seedlings 100=Other (specify)_________________

C15. How often have you sold planting materials to another farmer? **sellfreq**[_____]
1=Rarely 2= Sometimes 3= Very frequently

DO NOT SKIP

C16. Have you **ever participated** in a Payment for Environmental Services (**PES**) scheme?
1=Yes 2=No **PESyes** [_____]

C17. Have you implemented any of the following **water conservation and storage measures** on your farm?

Water conservation method		**Status of Implementation?** 1=Already using 2=Have desire to use 3= Reluctant to use	**Extend of practice**	When did you start this practice **(year)**	Main source (s) of information about this practice *(Use codes below)*			Since you started the practice, have you expanded?	If Yes, by what margin *(Use codes below)*	If No expansion, why? *(Use codes below)*		
conmech		**status**	**extent**	**ystart**	**Infsrc1-3**			**expand**	**mrgexp**	**Rsnnoexp1-3**		
Roof catchment	**1**		$_1$Capacity of storage (L) [______]									
Check dams	**2**		$_2$Number [____________]									
Runoff harvesting	**3**		$_1$Capacity of storage (L) [_______]									
Drought resistant varieties	**4**		$_3$Names of crops[______________]									
Other______________	**5**											

Margin of expansion: 1= Less than half 2=About half 3= More than half 4=Doubled 5=More than doubled 100=Other (specify)_________________

Information sources: 1=Agricultural extension officers 2=Farmer field schools 3= Local school 4=NGOs 5=Media (Print, Audio and Visual) 6= Other Farmers/Neighbours 7=Community based organisation (CBO) 8=Church 100=Other (Specify)______________________

Reasons for no expansion: 1=Lack of materials 2=Needs too much labour 3=Costly to implement 4=Not beneficial 5=No land for expansion 100=Other______

C18. What **constraints** do you face in implementing **soil conservation technologies**? **soilcon1**[____] **soilcon2** [_____]so**ilcon3**[____]
1= Lack of enough labour 2=High costs of starting 3=Lack of sufficient information 4=Lack of sufficient land 5= High cost of maintenance 100=Other (specify)__________________

C19. What **constraints** do you face in implementing **water conservation technologies**? **wtcon1**[____] **wtcon2**[____] wt**con3**[____]
1= Lack of enough labour 2=High costs of starting 3=Lack of sufficient information 4=Lack of sufficient land 5= High cost of maintenance 100=Other (specify)__________________

C20. Have you or any member of your household **participated in any training** on **soil conservation** in the last 12 Months?
1=Yes 2=No **soilcontr** [_____]

C21. Have you or any member of your household participated in any **training** on **water conservation and efficient use** in the last 12 Months? 1=Yes 2=No **swatcontr** [_____]

C22. Have you been involved with any organization(s) that has been promoting water conservation in this area?
1=Yes 2=No **sconprom** [_____]

(**ENUM:** ***If No, Skip to Qn C24***)

C23. If Yes in C22 provide name(s)
....

C24. Have you been involved with any organization(s) that have been promoting soil conservation in this area?
1=Yes 2=No **wconprom**[_____]

(**ENUM:** ***If No, Skip to Qn C26***)

C25. If Yes in C24 provide the name(s)
....

C26. Have you been involved with any organization that has been promoting efficient water use in this area?
1=Yes 2=No **effwprom**[_____]
(**ENUM:** ***If No, Skip to Qn D1***)

C27. If Yes in C26 provide name(s)
....

SECTION D: LAND USE AND CROP PRODUCTION

We are now going to talk about the crops you produce in your farm, the inputs you use in producing the crops, for example fertilizers. We will also talk about different ways in which you use your land, and the portions of your land that you use for different purposes.

D1. I would like to know some details about the land owned or used by your household

Total land owned in acres	**totland**	
Land **rented in** (within the **basin**) (acres)	**drentin**	
Land **rented out** (within the **basin**) (acres)	**ldrentot**	
Other land **accessed** (gift/public/communal) acres	**othland**	
Land under **crops** (acres)	**cropland**	
Land under **pastures** (acres)	**pastland**	
Land under **homestead**(acres)	**hmeland**	
Land purely occupied by **trees** (woodlot) (acres)	**treeland**	
Land that is not usable (acres)	**lntuse**	
Riparian Land (**if farm next to river**) (acres)	**ripland**	

D2. What is the **mode of ownership** for the main farmland **tenure** [_____]
1= Owned with title deed 2=Owned without title deed 3=Rented 4= Gift 100=Other (specify)___

D3. Which year did you **start farming**? **farmstat** [_____]

D4. What is the **daily wage for** general farm work in this area? **wage**[_____] (Kshs)

D5. Did the household produce any crops during the **Long rains season 2010** (**March-August rains)** (1=Yes 2=No) **cropls**[_____]

D6. If **Yes in D5**, indicate the details below for **all the crops** produced during the season

Crop (*Use codes below*)	**Plot**	**Land Size** (acres)	**Land prep. Cost in Kshs**	**Seeds** (*for Units use codes below*)			**First Fertilizer** (*For type &Units, use codes below)*				**Second Fertilizer** (*For type &Units, use codes below)*				**Third Fertilizer** (*For type &Units, use codes below)*				**Harvest** (*For units, use codes below)*		**Sales** (*For units, use codes below)*		**Av. selling Price Per unit**	**Mode of watering**
				Qty	Unit	Cost/unit	Typ	Qty	unit	Cost/unit	Typ	Qty	Unit	Cost/Unit	Typ	qty	unit	Cost/unit	Qty	Unit	Qty	Unit		

Unit codes		**Crop codes**				**Fertilizer types**	**Watering mode**
1=90 kg bag 2=Kgs 3=Litre 4=Crates 5=Numbers 6=Bunches 7=Gorogoro 8=Tonnes	9=50 kg bag 10=Debe 11=Grams 12=Wheelbarrow 13=Cart 14=Canter 15=Pickup 16=2kg packet(seed)	1= Beans 2= Cow peas 3= Green grams 4= Soya beans 5= Green peas 6= Pigeon peas 7= Dolichos lab lab 8= cowpea leaves 9 = Maize(Dry) 10 = Maize (Green) 11 = Sorghum	12= Finger millet 13=Bulrush millet 14 = Wheat 15= Sukumawiki 16= Arrow root 17= Spinach 18 = Tomatoes 19 = Cabbage 20 =French bean 21= Carrot	22 Cauliflower 23=Traditional vegetables 24= Onions 25= Cassava 26= Sweet potatoes 27= Irish potatoes 28= Bananas 29=Oranges 30= Mangoes 31=Sweet melon	32=Passion fruit 33=Avocado 34= Pumpkin 35= Pawpaw 36= Green pepper 37= Sunflower 38= Sugarcane 39= Cut flowers 40= Barley 41=Baby corn 100=Other(specify) ________	1= CAN 2= DAP 3= NPK (20:20:0) 4= NPK (17:17:0) 5 = Urea 6 = Foliar feed 7= Animal Manure 8=Compost manure 9=Other (specify) ________	1=Rain fed 2= Irrigated 3=Both

D7. Did the household produce any crops during the **short rains season 2010/2011(Oct-Dec. rains**)(1=Yes 2=No) **croppss** [____]

D8. If **Yes in D7**, indicate the details below for all the crops produced during the season

Crop (*Use codes below*)	**Plot**	**Land Size** (acres)	**Land prep. Cost in Kshs**	**Seeds** (*for Units use codes below)*			**First Fertilizer** (*For type &Units, use codes below)*				**Second Fertilizer** (*For type &Units, use codes below)*				**Third Fertilizer** (*For type &Units, use codes below)*				**Harvest** (*For units, use codes below)*		**Sales** (*For units, use codes below)*		**Av. selling Price Per unit**	**Mode of watering**
				Qty	Unit	Cost/unit	Typ	Qty	unit	Cost/unit	Typ	Qty	Unit	Cost/Unit	Typ	qty	unit	Cost/unit	Qty	Unit	Qty	Unit		

Unit codes		**Crop codes**				**Fertilizer types**	**Watering mode**
1=90 kg bag 2=Kgs 3=Litre 4=Crates 5=Numbers 6=Bunches 7=Gorogoro 8=Tonnes	9=50 kg bag 10=Debe 11=Grams 12=Wheelbarrow 13=Cart 14=Canter 15=Pickup 16=2kg packet(seed)	1= Beans 2= Cow peas 3= Green grams 4= Soya beans 5= Green peas 6= Pigeon peas 7= Dolichos lab lab 8= cowpea leaves 9 = Maize(Dry) 10 = Maize (Green) 11 = Sorghum	12= Finger millet 13=Bulrush millet 14 = Wheat 15= Sukumawiki 16= Arrow root 17= Spinach 18 = Tomatoes 19 = Cabbage 20 =French bean 21= Carrot	22 Cauliflower 23=Traditional vegetables 24= Onions 25= Cassava 26= Sweet potatoes 27= Irish potatoes 28= Bananas 29=Oranges 30= Mangoes 31=Sweet melon	32=Passion fruit 33=Avocado 34= Pumpkin 35= Pawpaw 36= Green pepper 37= Sunflower 38= Sugarcane 39= Cut flowers 40= Barley 41=Baby corn 100=Other(specify) ____________	1= CAN 2= DAP 3= NPK (20:20:0) 4= NPK (17:17:0) 5 = Urea 6 = Foliar feed 7= Animal Manure 8=Compost manure 9=Other (specify) ____________	1=Rain fed 2= Irrigated 3=Both

D9. For the first **four crops** in **Table D6** above, what is the maximum yield you have ever achieved?

Crop *(Use codes in Table D4)*	**Maximum yield** (Quantity)	**Units** *(Use codes below)*	**Area to which yield applies** (Acres)
Crop	**maxyld**	**unit**	**area**

Units: 1=90 kg bag bag 2=Kgs 3=Litre 4=Crates 5=Numbers 6=Bunches 7=Gorogoro 8=Tonnes 9=50 kg 10=Debe 13=Cart 14=Canter 15=Pickup

D10. Indicate the following **details on all inputs used on crops (Except Fertilizers and seeds)** during the **last year (April 2010-March 2011)**

Input type *(Use codes below)*	**Season** 1=Main 2= Short	Quantity Used	Quantity units *(Use codes below)*	Source *(Use codes below)*	If source = purchased, price per unit (Kshs)
Inptype	**season**	**qtyused**	**qunits**	**source**	**punit**

Inptype: 9= Pesticides 10=Herbicides 11=Fuel 12= Transport 13= Packaging material 14=Hired Labour 15= Fungicide 100=Other (specify)_________________

Units: 1=90 kg bag 2=Kgs 3=Litre 4=Crates 5=Numbers 6=Bunches 9=Gorogoro 11=50 kg bag 12=Debe 13=Grams 14=Wheelbarrow 15=Cart 16=Canter 17=Pickup 18=2kg packet

Source: 1=Purchased 2=Given by another farmer 3=Government donation 100=Other(specify)_________________

SECTION E: IRRIGATION (APPLICABLE ONLY TO FARMERS WHO IRRIGATE)

You mentioned to me that you irrigated some crops in the past seasons. Therefore, I would like us to talk a little bit about your irrigation activities. That is, how you obtain irrigation water, the methods you use for irrigation, and the challenges you face in your irrigation activities.

E1. What are the legal **requirements** that a farmer must meet if s/he wants to **use water for irrigation?** **irreq1**[_____] **irreq2**[_____] **irreq3**[_____]
1=None 2=Obtain a water permit 3=Install a water meter 4=Obtain verbal permission from community water leaders 5=Make a payment according to the amount of water used 100=Other___________

E2. For all the crops where **mode of watering was irrigation or both irrigation and rain fed,**

(*refer to Tables D6 and D8*) indicate the following details

Irrigated crop *(Transfer from Tables D6 and D8)*	Number of plantings within 2010	For the first planting indicate: (1) **Acreage covered by the crop** (2) **Number of months crop was irrigated** (3) **Number of times irrigation done per week**			For the second planting indicate (1) **Acreage covered by the crop** (2) **Number of months crop was irrigated** (3) **Number of times irrigation done per week**			For the Third planting indicate (1) **Acreage covered by the crop** (2) **Number of months crop was irrigated** (3) **Number of times irrigation done per week**			**Main method of irrigation** *(Use codes below)*	Average time taken per irrigation session**(Hrs)** *(Ask for first planting only)*
irrcrop	**planum**	**acres 1**	**mnts 1**	**irtimes 1**	**acres 2**	**Mnts 2**	**irtimes 2**	**acres 3**	**Mnts 3**	**Irtimes 3**	**irrmtd**	**rsnirrg**

Methods of irrigation: 1= Sprinkler 2= Furrow 3=Basin 4=Drip 5=Flood 6=Watering can
100=Other (specify)___________

E3. What is your **most preferred** irrigation method? (***Use codes in Qn E2 above***) **prefmtd** [_____]

E4. Why do you **prefer** the above mentioned **irrigation method**?
prefwhy1[_____] **prefwhy2**[_____] **prefwhy3**[_____]
1= Uses less water 2=Requires less labour 3=Cheap to install 4=Easy to use/not complex 5=The only one known 100=Other Specify_____________________

E5. Indicate how **the intensity of irrigation** varies **within the year**

Irrigation Intensity	**Months (1=Jan, 2=Feb,...,12=Dec)**	**Number of times irrigated per week**
High *(When irrigation is done many times)*		
Moderate (*When irrigation is done average times*)		
Low (*When irrigation is done fewer times*)		

E6. How do you **obtain your irrigation water**? **irrwtac1**[_____] **irrwtac2**[_____]
1=Flow by gravity 2=Pumping (from river) 3= Pumping (from borehole) 4=Directly from the river (bucket)

5=Directly from a Well (bucket) 6= Directly from the tap 100=Other (specify)_______________

E7. For the **method(s) of water abstraction** that are used by the farmer, make a follow up to estimate the water quantities

ENUME: For water use from unmetered piped water, do the estimation using the guideline provided. Otherwise where there is a meter or abstractions involving a water pump, ask the questions for the relevant abstraction method.

Farmers with Water meter		
Average quantity per month in low irrigation intensity Months (M^3)	**qtylow**	
Average quantity per month in medium irrigation intensity Months (M^3)	**qtymode**	
Average quantity per month in high irrigation intensity Months (M^3)	**qtyhigh**	
From Tap (To do the estimation, get a container from the farmer and fill it at the tap three times and record the following)		
Capacity(size) of container (**Litres**)	**capcont**	
Amount of time taken to fill **first time** (Minutes)	**Time1**	
Amount of time taken to fill **second time**(Minutes)	**Time2**	
Amount of time taken to fill **third time** (Minutes)	**Time3**	
Length of time taken to irrigate **0.25** acre plot	**Timeirr**	
Is the current water pressure.... 1= Normal, 2=Lower or 3=Higher (than Normal)	**presure**	
Farmers Using Water Pumps		
Size of Pump (GPH)	**pumpsze**	
Diameter of pipe from Pump (inches)	**diampipe**	
Type of fuel used (1=Petrol 2=Diesel 3=Electricity 4=Manpower)	**fueltyp**	
Average quantity of fuel used per week	**fuelqty**	
Quantity units 1= Litres 2= Kwh	**qtyunits**	
Time pump runs to irrigate one acre	**timeacre**	
Depth of borehole in Metres (**for farmers with boreholes**)	**depth**	
Farmers drawing water directly from the source using buckets		
Average size (capacity) of bucket used (Litres)	**capbuckt**	
Number of buckets used to irrigate 0.25 Acre of land	**numbukt**	

E8. Is the water that you receive (for irrigation) sufficient for your irrigation needs?
1=Yes 2=No **sufwater**[_____]
(**ENUM:** ***If Yes, Skip to Qn E10***)

E9. If No in E8 above, if you needed more water what options do you have? (**Waterad1-4**)
....
....

E10. What constraints do you **face** when undertaking day to day irrigation **activities? irrcon 1-4**
....
....

E11 Are there any traditional believes or taboos about water in your community? **tradbel**[_____]
1=Yes 2=No

(**ENUM:** ***If No, Skip to Qn E13***)

E12. If yes in E11, what are the three most important ones according to you? **tradbel1-5**

....

....

....

E13. Do you have a water permit from WRMA? 1=Yes 2=No **permown** [_____]

(ENUM : If No Skip to QN E17)

E14. If yes, in E13 what is the class of the Permit? **permclass** [_____]
1=A 2=B 3=C 4=D 5=E

E15. How much did you pay for the permit (Kshs) **permamt** [_____]

E16. Which year did you acquire the permit (Year) **permyr** [_____]

E17. How long did it take you from the time you applied for the permit to the time you received it?(Months) **perdpmt**[_____]

E18. Indicate the following details on **payments for irrigation water**

Amount paid for water (Kshs)	**Units for which payment applies**

Units: 1=M^3 2=Litre 3= Month (flat rate) 100=Other (specify)_______________

SECTION F: LIVESTOCK OWNERSHIP AND PRODUCTS

In most cases, livestock production is done together with crop production activities. I would like to know whether you have any livestock in your farm, and the types of livestock products that you have produced in the past 12 months.

F1. Did the household have any **livestock in** the **last one year** (**April 2010- March 2011)**
1=Yes 2=No **liveown**[_____]
(**ENUM:** ***If No, Skip to Section G***)

F2. If Yes, in QN F1, fill in the following details

Livestock		Number owned April 2011	**Number sold within 2010**	Unit selling price(Kshs)
livetype		**numm11**	**numsale**	**selprc**
Cattle	**1**			
Calves	**2**			
Goats	**3**			
Sheep	**4**			
Donkeys	**5**			

F3. For all the **livestock products** within the reference period (**April 2010-March 2011**) record the following details

Livestock Product		Number of **months** of **production** within the year	**Average** production per month	**Unit** of Production (*Use codes below*).	Number of **months** of **sales** per year	Average Amount **sold** /month	**Price** received **per Unit (Kshs) on the largest sale**
liveprod		**mprod**	**avpmon**	**untprod**	**mnsal**	**avsld**	**price**
Milk	**1**						
Eggs	**2**						
Manure	**3**						
Other (specify)	**4**						

Unit codes : 1 = 90 Kg bag 3= Litres 2= Kgs 5=300 ml bottle 14= Wheelbarrow 15 = Hand carts 21=750ml bottle 22=Big cup 23=Small cup 20=Trays 24=500 ml bottle 27 = 90 Kg bag 28 = Pick- up 100= Other (specify)________________________

F4. How do you utilize or dispose manure from your livestock? **mandisp1**[___] **mandisp2**[___]
1=Sell 2=Apply on my farm 3= Dump by the roadside 4=Give to neighbours 5=Heap somewhere on my farm 6= Leave on the cattle Boma 100=Other (specify)_______________

SECTION G: CREDIT ACCESS , TRUST, MEMBERSHIP AND PARTICIPATION IN

We will now talk about participation in any community group by any member of your household and how your household benefits from participating in the groups. We will also talk about how people in your village cooperate, help each other and trust each other. We will also talk about where people in this area can obtain credit.

G1. Are **you or any member of your household** a member of any **Water Resource Users Association (WRUA)**? 1=Yes 2=No **WRUAmem** [_____]

(**ENUM:** ***If No, Skip to Qn G5***)

G2. If yes in G1 what is the **name of the WRUA**? **WRUAname**[________________________]

G3. Do you feel that you benefit by being a member of the WRUA? 1=Yes 2=No **WRUAben**[___]

G4. If Yes, what are the benefits? **(WRUAben1- 4)**

....

....

G5. Are **you or any member of your household** a member of any **Community water project**? 1=Yes 2=No **wpromem** [_____]

(**ENUM:** ***If No, Skip to Qn G9***)

G6. If yes, what is the **name of the Community water project**? **Wproname** [______________]

G7. Do you feel that you benefit by being a member of the CWP ? 1=Yes 2=No **Wproben** [___]

G8. If Yes, what are the benefits? **(Wproben1-4)**

....

....

G9. Have you or has any member of your household participated in any **activity that required the participation of community members** in the last 12 Months 1=Yes 2=No **parcom**[_____]

G10.If Yes in G9, indicate the following (***PROBE for specific water and soil conservation activities***)

Household member who participated (Name)	**First** activity participated in			**Second** activity participated in			**Third** activity participated		
	Activity Name	Times in last year	Average Hours per time	Activity Name	Times in last year	Average Hours per time	Activity Name	Times in last year	Average Hours per time
mempart	**act1nam**	**act1freq**	**avhrs1**	**Act2nam**	**Act2freq**	**Avhrs2**	**Act3nam**	**Act3freq**	**Avhrs3**

Activity: 1=Communal tree planting 2=Maintenance of community water system 3=Communal soil erosion control activity 100=Other (specify)___________

G11. How likely is it that those who **do not participate** in communal activities will be criticized? **crttlike**[_____]

1=Very likely 2=Somehow likely 3=Unlikely 4=Very unlikely

G12.Have you made any **financial contribution** towards communal water management in the last 12 months? **fincont** [_____]

G13. If Yes in G12, how much **contamt Kshs.**[_____]

G14. Other than the WRUA, are you or any member of your household a member of any voluntary communal or religious group: organization, network or association? 1=Yes 2=No **grpmem** [___]

G15. If yes in Qn G14 fill in the following details

Name of household member	Name of organization/ group	When did the person join (**Year**)	Type of group *(Use codes below)*	Number of members in the group	Role in group (*Use codes below*)	Number of times group holds meetings		Requirements for membership	What benefit (s) do you draw from the group?			Ranking of group (1=Most important to household)
hhmname	**orgname**	**yrjoin**	**grptype**	**memsnum**	**grprole**	**Num**	**freq**	**memreq**	**benefit**			**grank**

Types of groups: 1= Welfare group 2=Farmers group 3=Water users group 4= Church 5= Youth group 6=Women group 7=Cultural association 8=Merry-go-round 9=Village Association 10=Professional Association 100= Other (specify)___________________________

Role in group : 1=Member 2=Chairperson 3=Other official/Committee member

Frequency : 1=Week 2=Month 3=Year 100=Other (specify)____________________

Membership requirements: 1= Voluntary joining 2=Mandatory to join 3= Invited membership 4=Based on engagement in certain activity 5=Payment of membership fee 100=Other(specify)_____________________

Benefits: 1= None 2= Access to natural resources 3=Benefit our community 4= Recreation 5=Spiritual benefits 6= Access to markets 7=Help in times of problems 100=Other (specify)__________________

G16. Suppose **your neighbour suffers a misfortune**, **who** do you think should help him/her **financially**? (*Circle the first four mentioned*)

	help1-4				
1	No one should help	6	Village elder	11	Mutual support group to which s/he belongs
2	Family	7	Business people	12	Assistance group to which s/he belongs
3	Friends	8	Police	13	Don't know/not sure
4	Neighbors	9	Social authorities	14	Non Governmental Organizations
5	Religious leader or group	10	Political leader	15	Fellow men/women (If Man/Woman)

G17. How many of your neighbours would you trust with a loan? **loantr**[_____]

1=All 2=Most of them 3= Just a few 4=None

G18. When did you start living in this community? (Year) **comlivyr**[_____]

G19. If you **need a loan today**, what are the **possible sources available** to you?

lnsorc1[_____] **lnsorc2**[_____] **lnsorc3**[_____]

0=None 1= Equity bank 2=KCB bank 3=Cooperative Bank 4=Employer 3=Farmers Union 4=Community group 5= Local money lender 6= Faulu Kenya 7=KWFT 8=K-REP 9=SACCO 10=AFC 11=Neighbour 100= other (specify)________________________

G20. Have you **requested for a loan** in the last one year 1=Yes 2=No **loareq** [_____]
(**ENUM:** ***If No, Skip to Qn G26***)

G21. If yes in G20 from **which source(s)**? **loasrce1** [_____] **loasrce2** [_____]
0=None 1= Equity bank 2=KCB bank 3=Cooperative Bank 4=Employer 3=Farmers Union 4=Community group 5= Local money lender 6= Faulu Kenya 7=KWFT 8=K-REP 9=SACCO 10=AFC 11=Neighbour 100= other (specify)________________________

G22. Were you granted the loan? 1=Yes 2=No **loagrant** [_____]

G24. Loan granted by which lender (s) (Use codes in G21) **lendok1**[_____] **lendok2**[_____]

G25. If No in G22, why were you not granted the loan? **loanowhy** [_____]
1= No security for loan 2=previously defaulted 3=No guarantors 4=Group member defaulted
100= Other (Specify)__________________________

G26. How many times have you had a contact with the following people in the last one year?

Type of officer		**Number of times visited**	**The main 3 purposes of visit**
Government extension officer	1		
NGO officers	2		
Government water management officer	3		
Community water management officer	4		

Purposes: 1=Advice on crop production 2=Advice on livestock production 3=Advice on water conservation 5=Collection of water fees 6=Advice on water conservation 100= Other specify_____________

SECTION I: PERCEPTIONS AND WATER RULES

I would like to know your opinion and perceptions on a number of things related to water management efforts by the government and community organizations in this area. We will also talk about both government and communal water rules that exist in this area, and any traditional or cultural believes about water that are in your community.

I1. I am now going to read to you some **statements**, and then you will tell me the extent to which you agree or disagree with them.

Statement		Strongly agree	Agree	Disagree	Strongly disagree
My farming activities affect the people who are located downstream from my farm	**fameff**				
Compared to 10 years ago, water in our village is getting more scarce	**wscarse**				
I am satisfied with the communal rules governing water use for irrigation in this area	**Comsat**				
There is no r/ship between my individual farming activities and the status of water resources in my area	**Famwat**				
I would be willing to protect water resources in my area for the sake of everybody	**Prowill**				
The communal methods of punishing those who break rules on water are fair to all	**Comfair**				
Government water administrators are more efficient than the communal water administrators	**Goveff**				
I am satisfied with the system used currently to collect water fees	**Feesat**				
Water management in my area improved after 2005	**Impr05**				
I don't benefit by participating in communal activities	**Noben**				
The government ways of punishing those who break rules on water are fair to all	**Govfair**				
I am satisfied with the method used in this area to allow people to use water for irrigation	**Righsat**				
The government has played an important role in water management issues	**Govrole**				
I am satisfied with the government rules governing water use in this area	**Grulsat**				
I have confidence in the Community water management leadership	**Leadcon**				
Soil erosion has an impact on crop productivity	**Serprod**				
Generally speaking I have confidence in government officials managing water issues	**Govcon**				
People in my village are concerned mainly with the welfare of their own families but not that of others	**Welown**				
I am satisfied with the communal rules governing water use for domestic purposes in this area	**Crulsat**				
People in this area are generally concerned with the use of water efficiently	**Ppleff**				

Statement		**Strongly agree**	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**
In this area, anybody can report another person if they are breaking water rules	**Brekrep**					
If I drop my purse or wallet in the neighborhood whoever will see it will return it to me	**Purse**					
Members in this village/neighborhood are always more trustworthy than those in another village within this area	**Trust**					
The quality of the water I get is affected by the activities of the people who are upstream	**Upaffe**					
Most water conservation technologies are very difficult to implement	**Techdiff**					
Soil erosion is a major environmental problem in our area	**eroprob**					
Water scarcity is not a major problem affecting crop production in this area	**wscacrop**					
People in this area would not contribute money or dedicate their time in punishing law breakers in case they are required to do so	**conpun**					
I would start using a new technology (e.g. planting a new seed) just because my neighbour is planting the same	**techneib**					

I2. What **government, communal and traditional rules** on water use for different purposes are you aware of? List as many as possible

	Government rules	Communal rules	Traditional (cultural)
Domestic water use			
Livestock watering			
Irrigation water use			

I3. In your opinion what is the **likelihood that people** in this area will break existing **government water rules**? **govobey**[_____]

1= Very unlikely 2=Unlikely 3=Likely 4=Very likely

I4. What kind of action is usually taken against people who break **government** water rules? **(govsanc1-4)**

....

....

I5. In your opinion do **people stop breaking** the rules after they or someone else has faced the actions you mentioned? 1=Yes 2=No **gvpunef**[_____]

I6. In your opinion what is the **likelihood that people** in this area will break existing **communal water rules**? **combrek**[_____]

1= Very unlikely 2=Unlikely 3=Neutral 4=Likely 5=Very likely

I7. What kind of **action is usually taken** against people who break **communal** water rules?

....

....

I8. In your opinion is **do people stop breaking** the rules after they or someone else has faced the actions you mentioned in I7? 1=Yes 2=No **cmpunef**[_____]

I9. Do you think **action should be taken on people** for taking more water than **what is allowed**?

1=Yes 2=No **wtpun**[_____]

I10. For either yes or No answer please tell me more on the reason why you think so.

....

....

I11. How would you generally rank the performance of the following?

		Very satisfactory	Satisfactory	Unsatisfactory	Very Unsatisfactory
Government water management system	**govrank**				
Local water management systems	**comrank**				
The prices of water we are paying	**pricrank**				
Government rules on water access and use	**grlerank**				
Community rules on water access and use	**crlerank**				
Performance of the WRUAs in managing water	**wruarank**				

I12. In your opinion does anybody who participates in communal water management activities **benefit** in any way? 1=Yes 2=No **comben**[_____]

I13. If yes, what are the benefits somebody can get? **(Partben1-4)**

....

....

....

SECTION H: HOUSEHOLD ASSET OWNERSHIP AS A WELFARE INDICATOR

As we near completion of our discussion, I would like us now to talk about the value of assets that you own within the household.

H1. Please tell us about the **ASSETS** that you own **at the moment**

Item		Number	Current* Unit value	Total current value	Item		Number	Current* Unit value	Total current value
item		**cnum**	**Untval**	**totval**	**item**		**cnum**	**Untval**	**totval**
1.	Cow shed (s)				19	Farm house(s)			
2.	Ox plough				20	Furniture			
3.	Food store				21	Panga			
4.	Water trough				22	Jembe			
5.	Milking shed				23	Vehicle(s)			
6.	Fence for paddocks				24	Tractor			
7.	Chuff cutter				25	Tractor trailer			
8.	Wheel barrow				26	Motorbike			
9.	Sprayer				27	Water tank			
10.	Donkey/ox cart				28	Posho mill			
11.	Feed troughs				29	Cereals Sieve			
12.	Milk Buckets				30	Well			
13.	Bicycle				31	Power saw			
14.	Television				32	Mobile phone			
15.	Radio				33	Fixed land line			
16.	Spade/shovel				34	Borehole			
17.	Solar panel				35	Water pump			
18.	Irrigation equipment Name:				100	Other (specify)			

Note: * This is the value of the asset as it is, in its depreciated state.

SECTION K: HOUSEHOLD DEMOGRAPHIC INFORMATION

Finally, let us talk about the members of your household. These are the people with whom you live together, share food from the same pot, make decisions as one unit, and work in your farm together. Particularly, we shall talk about those who have lived here with you for a period not less that one Month within the last one year, that is from April 2010 to March 2011. We will talk about their age, education, and if they are involved in any income generating activity outside the farm.

SECTION K: HOUSEHOLD DEMOGRAPHIC INFORMATION

K1. Indicate the following details for **all the household members** who **were home** for **atleast one month** within the **last one year** (**April 2010- March 2011)**

House hold member number	First Name	**Gender** 1=Male 2=Female	**Year of birth**	**Relationship to head** 1=head 2=spouse 3=Child 4= Parent 5= Niece 6= Nephew 7= Worker 8= Grand child 9=Bro/Sis inlaw 10=Bro./Sis 100=Other	Number of months living at home in the last 12 months	Marital status 1=Single 2= Married 3=Divorced 4=Widowed 5=Separated 100=Other ___________	**Level of education completed** 0= none 1= Primary 2=Secondary 3= Tertiary college 4= University 5= Adult education	Was this person involved in any **OFFFARM Income generating activity** in the past **12 months** ***1 = Yes*** ***2 = No (got to next member)***	If yes, What are the **main 2 Income generating activities?** ***(See Activity Code below)***		Months involved in the activity in the last 12 months		**Monthly** estimate of income from this activity (KShs)	
									IGA1	**IGA2**	**IGA1**	**IGA2**	**IGA1**	**IGA2**
hmnum	**fname**	**Gender**		**relhead**		**mstat**	**educlev**	**incgen**	**Igact1**	**Igact2**	**Iga1mon**	**Iga2mon**	**Iga1inc**	**Iga2inc**
1														
2														
3														
4														
5														

Income generating activities

1 =Charcoal burning
2=Selling firewood
3=Timber /poles trading
4 =Brick making
5=Boat making
6 =Carpentry
7=Industrial worker
8=Pension
10 10=Subordinate staff
11=Curio trader
12=Lumbering/wood cutting
13=Pit sawing
14=Mining
15=Tree seller, commercial
16=Selling tree seedlings/seeds
17=Manager
18=Mechanic
19=Messenger
20 =Nurse
21=Pastor/religious services
22 =Driver
23= Doctor
24=Tea picker
25=Teacher
26=Veterinary doctor
27=Waiter/cook
28=Watchman
29=Building/Mason
30=Chain Sawing (power saw
31=Tailor
32=Electrician
33=Engineer
34 =General farm worker
35 =House help
37=Lab attendant
38=Lecturer/tutor
39=Herbalists
40=Policeman/woman
41=Road constructor
42=Sales person
43=Secretary
44=Shop keeper/attendant
45=Subordinate civil services
46=Surveyor
47=Trading in agric produce
48=Income from sale of agric produce from another farm
100=Other (specify)____________

K2. Indicate the **estimated household income** from other sources in the last one year (include in-kind receipts to the household)

Income source		**Amount (Kshs)**	**Number of Months income received within between April 2010 and March 2011**
Remittances (*Includes Money send home by people working in towns*)	**Reminc**		
Rental income (Land)	**renincl**		
Rental income (Buildings)	**renincb**		
Income from Farm outside the basin	**farinc**		
Donations/Gifts	**doninc**		
Other(specify)			
Other(specify)			

INFRASTRUCTURE (DISTANCES IN KILOMETERS)

K3. What is the **distance** from your home to the nearest **shopping centre?** **distshop**[_____]

K4. What is the **distance** from your home to the nearest **tarmac road?** **disttmk**[_____]

K5. What is the **distance** from your home to the nearest **health centre?** **disthc** [_____]

K6. What is the **distance** from your home to where you can **tap electricity?** **dstelec** [_____]

K7. What is the **distance** from your home to where you can get **piped water?** **dstpipe**[_____]

K8. What is the **distance** from your home to **public/private extension services**? **dstext**[_____]

K9. What is the **distance** from your home to **the nearest river/stream**? **dsrver**[_____]

K10. What is the **distance** from your home to **the intake point for the community water**? **dscomwat**[_____]

General Comments from the respondent

....

....

....

********************************** *THE END* ***********************************