UNIVERSITY OF NAIROBI

CENTRE FOR ADVANCED STUDIES IN ENVIRONMENTAL LAW AND POLICY

(CASELAP)

ENHANCING GOVERNANCE OF WATER RESOURCES FOR IMPROVED UPTAKE OF ON-FARM WATER STORAGE TECHNOLOGY AMONG SMALLHOLDER IRRIGATORS IN TSAVO SUB-CATCHMENT, KENYA

By

FRANCIS OKUMU OREMO

REGISTRATION NUMBER: Z81/50013/2015

Thesis submitted in partial fulfillment of the requirements for the award of the Degree of Doctor of Philosophy in Environmental Policy

November 2020

DECLARATION

This thesis is my original work and has not been submitted or presented in any university for examination either in part or as a whole for the award of any degree.

Signature: Date…………………………………………

Oremo Francis Okumu

Supervisors Declaration

This thesis has been submitted for examination with our approval as university supervisors.

Signature: Date……………………………………………

Prof. Nicholas Oguge – Ph.D.

Centre for Advanced Studies in Environmental Law and Policy (CASELAP), University of Nairobi.

Signature: Date…………………………………………...….

Prof. Richard Mulwa – Ph.D.

Centre for Advanced Studies in Environmental Law and Policy (CASELAP), University of Nairobi.

DISCLAIMER

This thesis describes work undertaken as part of a PhD programme at the Centre for Advanced Studies in Environmental Law and Policy (CASELAP), University of Nairobi. All views and opinions expressed therein remain the sole responsibility of the author, and do not necessarily represent those of the University of Nairobi.

ACKNOWLEDGEMENT

Completing this PhD thesis has been an eventful experience for me. I am most grateful to individuals and institutions who have worked with, or assisted me in this journey. My first gratitude goes to Almighty God for amazing grace! Second, I am particularly grateful to my supervisors, Prof. Nicholas Oguge, and Prof. Richard Mulwa for relentless support, guidance and encouragement that helped me to keep the momentum. Their mentorship and advice, particularly from the first supervisor, Prof. Nicholas Oguge, guided me to discover and explore my strengths.

I am indebted to the faculty at CASELAP for their insights and advice during the preparation of the thesis. In addition, I acknowledge colleagues at CASELAP for their motivation and encouragement.

I would like to express my gratitude to the Federal Government of Germany for funding my study through the *Deutscher Akademischer Austauschdienst* (DAAD) scholarship. I am equally grateful to all my interviewees and everyone who participated in this study for their time and contribution.

Finally, I indebted to my wife Nancy, and sons Norbert and Caroli, for their understanding and patience during this study. Special thanks are due to my late parents, Norah and Norbertus Oremo for planting in me the seeds of hard work and dedication that inspired me during this journey.

ABSTRACT

Innovations are vital to achieving sustainable water futures. However, the extent to which they can be adopted is subject to actions and interactions among institutions and stakeholders across governing levels. This study set out to (i) assess farmers' knowledge, attitudes and practices in water resources management; (ii) analyze farmers' willingness to pay for the attributes of on-farm water storage technology; (iii) appraise the implications of water governance on sustainable utilization on water resources; and (iv) develop a governance framework for uptake of on-farm water storage technology. The study used a mixed methods approach where both qualitative and quantitative data were derived. Predictors of farmers' knowledge, attitudes and practices in water management were estimated using ordered and logistic regression models. Farmers' preferences and willingness to pay for the attributes of on-farm water storage technology was assessed by choice experiments. Governance Assessment Tool was used to evaluate micro-level water governance. Results show that knowledge of water issues inform attitudes and practices in water management. Educational attainment, level of income, access to extension, participation in local networks and land tenure were the main predictors of knowledge, attitudes and practices in water management. Farmers expressed high preferences and willingness to pay for on-farm water storage technology. A reduction of water resource conflicts, year-round water availability for irrigation and improved water quality for domestic use and ecosystems were the main attributes of on-farm water storage technology. Polycentricity was a key feature of the sub-catchment water governance. However, multi-level institutions and stakeholders had diverging perspectives and ambitions on water resources management. A framework for uptake of on-farm water storage technology emphasized actors' relations and interactions in defining technology design and diffusion to farmers. The framework highlights the importance of research-extension-farmer linkages and financing mechanisms in innovation uptake. Water governance arrangements in the Tsavo sub-catchment are not sufficient to support water policy implementation and realization of on-farm water storage goal. The technology adoption initiatives have not benefited from institutional support. These findings are important in policy development that intensify awareness and target a range of extension, communication and financial support to enable the uptake of on-farm water storage technology. The integration of the technology into water and agriculture development strategies, and strengthening of local water governance capabilities for sustainable practices are recommended.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMS

ACE	Agricultural and Consumer Economics
ANOVA	Analysis of Variance
ASALs	Arid and Semi-Arid Lands
ASTGS	Agricultural Sector Transformation and Growth Strategy
ATPS	African Technology and Policy Studies
AU	African Union
CAADP	Comprehensive African Agriculture Development Programme
CBOs	Community-based organizations
CESPAD	Centre for Social Planning and Administrative Development
CGs	Conservation Groups
CIMC	Caribbean Institute of Media and Communication
CMCs	Canal Management Committees
CPR	Common Pool Resources’
CV	Contingent Valuation
ERS	Economic Recovery Strategy for Wealth and Employment Creation
EU	European Union
FAO	Food and Agriculture Organisation of United Nations
FGDs	Focus Group Discussions
GWP	Global Water Partnerships
ICWE	International Conference on Water and Environment
IPCC	Intergovernmental Panel on Climate Change
IWA	International Water Association
IWRM	Integrated Water Resources Management
IWUAs	Irrigation Water Users Associations
KAP	Knowledge-Attitude-Practice
KFS	Kenya Forest Service
KWS	Kenya Wildlife Service
KWTA	Kenya Water Towers Agency
MoAL&F	Ministry of Agriculture, Livestock and Fisheries
MoU	Memorandum of Understanding

MTP	Medium Term Plan
MWTP	Marginal Willingness to Pay
NEMA	National Environment Management Authority
NGA	National Government Administration
NGOs	Non-Governmental Organizations
NIA	Neighbours Initiative Alliance
NIDA	National Irrigation Development Authority
NWHSA	National Water Harvesting and Storage Authority
OECD	Organization of Economic Cooperation and Development
RoK	Republic of Kenya
RWH	Rainwater Harvesting
SCMPs	Sub-Catchment Management Plans
SDG	Sustainable Development Goal
SRA	Strategy for Revitalizing Agriculture
UN	United Nations
WCD	World Commission on Dams
WEF	World Economic Forum
WHO	World Health Organization
WI	Wetlands International
WRA	Water Resources Authority
WRMA	Water Resources Management Authority
WRUAs	Water Resource Users Association
WSB	Water Services Board
WSP	Water Service Providers
WSSD	World Summit on Sustainable Development
WTP	Willingness to Pay
WWAP	World Water Assessment Programme
WWC	World Water Council

CHAPTER ONE: INTRODUCTION

1.0 Overview

Chapter one presents the general introduction of the study. It describes the background of the study, statement of the research problem, research questions and objectives, justification and scope and limitations of the study. It concludes with operationalization of key concepts related to the study and an outline of the thesis structure.

1.1 Background to the Study

Global human food demand has surged over time and it was estimated that 70% - 120% increase in world food supply will be required by mid-century to keep pace with a burgeoning population and dietary shifts (FAO, 2016; 2017). The rising food demand in a changing climate impacts water resources negatively (IPCC, 2012). An outcome is water scarcity, increased demand for water resources among competing claims, ecological degradation and limited crop productivity (FAO 2017; IPCC, 2014; Vorosmarty, et al., 2010). This situation portends dire consequences for food security and environmental sustainability particularly in semi-arid agro-ecosystems. For the sub-Saharan region where about one-fifth of the population faces severe water scarcity (FAO, 2015) and one-quarter is undernourished (FAO, 2018; World Bank, 2018), water scarcity presents a serious challenge to sustainable development. However, with increased knowledge of water management practices, sub-Saharan region has the highest prospects for sustainable and productive agriculture (Mekdaschi & Liniger, 2013). Policies that integrate innovative technologies in water governance are critical if the sub-Saharan region is to navigate uncertainties and risks in water supply (Rockström & Falkenmark, 2015).

Globally, there is a momentum towards enhancing productivity, stability and sustainability of agricultural systems (UN, 2015). This is given impetus by the 2030 Agenda for Sustainable Development that put food security and water resources at the centre of global development agenda. Sustainable Development Goal (SDG) 2 on “zero hunger” and SDG 6 on “water and sanitation" envision productive and resilient agricultural practices that will simultaneously reduce hunger while safeguarding ecosystems (UN, 2015). SDG 2 which seeks to "end hunger, achieve food security and improve nutrition, and promote sustainable agriculture" reiterates the need for resilient and productive agricultural practices (UN, 2015). Under this goal, national governments are required to implement specific policies that would improve food productivity and incomes particularly among smallholder and marginal farmers. SDG 6, on the other hand, is dedicated to sustainable management and development of water resources (UN, 2015). This goal requires countries to inform and reorient national policies towards effective water governance. Aligning this vision with agricultural priorities would require innovative water governance which features innovative water management technologies, social learning for enhancing human capabilities, farmer engagement and institutional improvement (Rouillard et al., 2013).

Currently, regional, national and sub-national agriculture, food security and water resource development policies identify irrigation as a priority area for investment to improve food security, alleviate poverty and improve economic growth (AU, 2003; 2015; NEPAD, 2015; RoK, 2008; 2010c; 2019). In sub-Saharan region, irrigation is considered as key to expanding cropping area, increasing farm productivity, improving diversity of farm produce, reducing climate risks and enhancing competitiveness of agricultural enterprise (AU, 2003, 2015). Although opportunities exist for actualizing the envisaged outcomes, little has been achieved in terms of developing alternative water supply sources for irrigation. Many countries in the sub-Saharan region still lag in water harvesting and storage investment for irrigation (de Fraiture et al., 2007; Molden et al., 2010). This leaves food production in the region highly exposed to climate risks. Unpredictable and sparse rainfall interlocks with arid conditions to provide uncertain environment for food production.

The regional picture however, disguises mixed agricultural development occurring in many countries. The investment in water storage for agriculture through large-scale centralized infrastructure has led to expansion of acreage under irrigation and extended the benefits of food security and poverty alleviation (AU, 2003; 2015; RoK, 2010c; 2013b). Despite positive economic and social outcomes, irrigation expansion has brought up new challenges in water resource governance (de Fraiture et al., 2007; Fisher & Christie, 2010; Mutabazi et al., 2005) and impacted riparian ecosystems negatively (Villanueva et al., 2018; Jägermeyr et al., 2017). It has led to re-allocation of water resources away from the environment and resultant alterations to aquatic and terrestrial ecosystems. This has led to degradation of soil and water resources and related deterioration of ecosystem services.

Addressing water challenges to crop production and ecosystems requires novel approaches to water governance that integrate innovative technologies in water policies (Lacroix, 2016; Ricart et al., 2018). While some policies pay attention to centralized infrastructure such as dams, others call for consideration of decentralized technologies, such as rainwater harvesting (RWH) (de Fraiture et al., 2010). Enhancing knowledge and use of RWH practices such as on-farm water storage technology is widely considered as a viable strategy to alleviate water resource constraint to crop production and ecosystems (Bouma et al., 2016; IWA, 2016; Jägermeyr et al., 2017; Rockström & Falkenmark, 2015). Additionally, uptake of on-farm water storage systems can delay the need for a costly large-scale centralized water infrastructure (Steffen et al., 2013).

Water scarcity is a serious drawback to food production in Kenya’s arid and semi-arid lands (ASALs) and sub-humid areas which occupy over 90% of the country (RoK, 2010b, 2013a, 2016). In these areas, water scarcity is more related to extreme temporal rainfall variability rather than cumulative seasonal and annual rainfall totals (Malesu et al., 2012; Rockström et al., 2010). Unpredictable rainfall patterns and frequent and intense droughts and dry spells lead to depressed crop yield and water-related conflicts (Ngigi et al. 2014). While water scarcity is a serious issue in ASALs and sub-humid agro-ecosystems, the potential of RWH has been acknowledged but remains untapped (Malesu et al., 2012; Mati, 2007). Social limitations such as inadequate knowledge on water resources management interlock with improper policies and weak institutions to provide unfavourable contexts for uptake of RWH practices (McCord et al., 2018; Ngigi 2008). This limits opportunities for food production and integrated landscape restoration in ASALs and sub-humid environments.

The scarcity of water resources is evident in the Tsavo sub-catchment of Southern Kenya. In this region, water resources are under intense pressure to supply irrigation needs. Water abstractions have surged as a result and much of this water is derived from streams and springs (Ali et al., 2014; KWS, 2008; WRMA, 2017). Dry season irrigation demands, illegal abstractions[1] and unregulated expansion of smallholder irrigation systems are posing considerable challenges and risks, related to sustainability, equity and efficiency in water allocation and use. The Tsavo rivers are abstracted by pumps and canals while the springs are tapped directly to supply irrigation needs (Ali et al., 2014; WRA, 2017). The consequences of these activities include reduced downstream-flows, resource conflicts and deterioration of ecosystem services (Ali et al., 2014; KWS, 2008; WRA, 2017). This ultimately affects water quality, primarily through increased pollution and siltation. The impact of abstraction is felt even during normal flow seasons when downstream sections of the Tsavo rivers dry up (WRMA, 2017).

Although irrigation is the leading cause of pressure on water resources in the Tsavo sub-catchment, increased competition from major water users, such as livestock and wildlife; and water exports for public use, notably from Nol Turesh river (10,000m^3/day) to Machakos, and

[1] Illegal abstraction refers to surface or underground water withdrawals without a permit or above the permitted limits

from Mzima Springs (40,000 m^3/day) to Mombasa (Ali et al., 2014) exacerbate water situation in the region. The growing pressure on water resources in the Tsavo sub-catchment has attracted the attention of Water Resources Authority (WRA). The area of attention is the quest for sustainable and innovative technologies that will simultaneously improve water availability without depleting environmental flows. Subsequently, the Water Resource Management Rules (2007) have incorporated on-farm water storage to improve water availability for irrigation while safeguarding natural flows (WRMA, 2007). Under this Rule, irrigators are required to adopt on-farm water storage technology to improve and stabilize crop yield and relieve pressure on rivers and natural springs particularly during periods of low stream-flows.

On-farm water storage is a farm pond or excavated subsurface run-off storage reservoir for supplemental irrigation (Ngigi et al., 2015; De Trincheria et al., 2017). The ground rainfall run-off is harvested from outlying areas and conveyed through demarcated channels into the farm pond. On-farm water storage technology, therefore has three components: a run-off collection catchment, runoff storage structure and low-cost drip irrigation system. For the proposed on-farm water storage technology to be adopted, there is a need for improved water governance and integrated catchment management across multiple levels of authority and stakeholders. Although the regulatory frameworks on water resources management have incorporated innovative technologies, the adoption of on-farm water storage technology is low among irrigators in the Tsavo sub-catchment. This situation presents a governance challenge that needs to be investigated to guide water resource planning and decision making.

1.2 Statement of the Research Problem

Water stress is a critical issue affecting utilization of water resources in the Tsavo sub-catchment (Ali et al., 2014; KWS, 2008). This is compounded by a surging population, expansion of cropping as a land use, and lack of coordinated management (WRMA, 2017). Thus, there is a recognition that more sustainable forms of water management and innovative technologies are required to improve water availability for human needs and ecosystems (Lacroix, 2016; Ricart et al., 2018). Regulatory frameworks on water resources management in Kenya have incorporated innovative water management practices, such as on-farm water storage (WRMA, 2007), and established governance structures to improve water availability and safeguard environmental flows (RoK, 2016). Despite these efforts, there is low uptake of the innovative on-farm water storage technology among smallholder irrigators in the Tsavo sub-catchment. Empirical studies have focused on the role of governance in the diffusion of innovative water management technologies (Pahl-Wostl et al., 2012; Daniell et al., 2014). However, in Tsavo sub-catchment, little is known on how water governance context enables the adoption of on-farm water storage technology. Thus, there is need to examine water governance context with the aim of improving sustainable utilization of water resources and uptake of on-farm water storage technology among irrigators in the Tsavo sub-catchment. It is also imperative to look at the best practices and develop appropriate framework for the uptake of on-farm water storage technology. This study set out to address this gap in the Tsavo sub-catchment in Southern Kenya as a case

1.3 Research Questions

Main research question:

How does water governance context affect utilization of water resources and uptake of on-farm water storage technology among irrigators in the Tsavo sub-catchment?

Sub-questions:

i. How does knowledge on water resource management relate to sustainable practices?
ii. To what extent are farmers willing to pay for on-farm water storage technology?
iii. How effective is the current water governance in improving sustainable utilization of water resources in the Tsavo sub-catchment?

iv. What is the effective governance framework for improving uptake of on-farm water storage technology among smallholder irrigators in the Tsavo sub-catchment?

1.4 Study Objectives

The main objective of this thesis was to assess the governance of water resources and uptake on-farm water storage technology among smallholder irrigators in the Tsavo sub-catchment. This is operationalized into the following specific objectives;

i. To assess knowledge, attitudes and practices of irrigators in Tsavo sub-catchment in relation to water resources management;

ii. To analyze willingness to pay (WTP) for the attributes of on-farm water storage technology among smallholder irrigators in the Tsavo sub-catchment;

iii. To appraise the implications of water governance on sustainable utilization of water resources in the Tsavo sub-catchment;

iv. To develop a model governance framework for improved uptake of on-farm water storage technology.

1.5 Justification of the Study

Sustainable agricultural development critically depends on utilization of improved, context-specific and eco-friendly innovations (Mottaleb, 2018). The use of agricultural innovations is at the heart of efforts to attain food self-sufficiency while protecting the ecosystems. Studies show that RWH practices, such as on-farm water storage technology can bridge water gap in agriculture without depleting environmental flows (Giordano & Fraiture 2014; Jägermeyr et al., 2017; Lasage & Verburg, 2015; Rockström & Falkenmark 2015). Despite the observed benefits of on-farm water storage technology, farmers in water stressed environments, such as the Tsavo sub-catchment, have not adopted the technology. This study, therefore, examined the governance context for uptake of on-farm water storage technology among smallholder irrigators in the Tsavo sub-catchment. It also developed a governance framework to improve uptake of the technology. Scaling up the proposed technology in the sub-catchment will strengthen resilience of smallholder irrigation while safeguarding ecosystems in the context of growing population and climate change. This study is in tandem with Kenya's long-term development blueprint, the Kenya Vision 2030, which identifies agriculture as a key sector through which to deliver ten percent annual economic growth rate. It also provides an avenue for a practical response to the 2030 Agenda for Sustainable Development, African Union Agenda 2063, Kenya's Agriculture Sector Transformation and Growth Strategy (ASTGS) 2018 – 2030 and National Water Resources Management Strategy.

The choice of smallholder irrigators for this study is strategic. The major water uses and users in the Tsavo sub-catchment are irrigation, wildlife, livestock, and urban and rural population. However, community-based irrigation development is the leading cause of pressure on water resources (WRMA, 2017). The sub-catchment surface water resources are over-abstracted to supply irrigation needs. This is visually manifest in dry river-beds especially in the downstream parts of the river even during periods of normal flows.

Tsavo sub-catchment is an interesting area for this study. First the region has many wetlands and riparian reserves that have been encroached by smallholder community-based irrigation schemes. Second, irrigation expansion is happening in the context of highly variable rainfall resulting into increased competition for water resources. Third, despite a legal requirement for investment in on-farm water storage to improve water availability for irrigation while safeguarding environmental flows, it is not clear whether governance structures are adequate to promote the uptake of the technology. Fourth, a considerable number of farmers rent agricultural land under unclear farm rental agreements that can impact negatively on land and water resources. Finally, a surging population is aggravating water situation in the sub-catchment. Rapid population growth is mainly attributed to migration from neighbouring areas (WRMA, 2017). Given the growing pressure on water resources, it is critical to facilitate the uptake of on-farm water storage technology among smallholder irrigators in order to secure water supply for food production and ecosystems.

1.6 Scope and Limitations of the Study

The study explored governance context for sustainable utilization of water resources and uptake of on-farm water storage technology among smallholder irrigators in the Tsavo sub-catchment. Thus, it assessed how farmers' knowledge relates to practices in water resources management; estimated farmers' capacity to pay for on-farm water storage technology; analyzed whether the sub-catchment water resource governance context is supportive to sustainable utilization of water resources; and model a governance framework for uptake of on-farm water storage technology. Due to resource constraints, the study was limited to three community-based irrigation schemes in the Tsavo sub-catchment: Kimana, Rombo and Njukini. However, it would be ideal to target all irrigation schemes in the Tsavo sub-catchment. The household survey was limited to smallholder irrigators within the sampled areas. The study findings were generalized to other community-based irrigation schemes in the entire sub-catchment.

The scope of stakeholders interviewed was limited to Water Resources Authority (WRA), National Environment Management Authority, Kenya Wildlife Services (KWS), Kenya Forest Services (KFS), Ministry of Water and Irrigation, Ministry of Agriculture, County Governments of Kajiado and Taita Taveta, Civil Society Organisations (CSOs), Water Resource Users Associations (WRUAs) and Kajiado WRUA Council. It would be ideal to interview more stakeholders including National Irrigation Development Authority (NIDA), research organizations and wildlife conservancies to obtain further insights on micro-level water governance.

The study anticipated various limitations during the fieldwork that could affect the conclusions and generalizations from the findings. Knowledge, Attitudes and Practices (KAP) survey used a single measure to test farmers' knowledge in water resources management and a limited set of dependent variables for attitudes and practices in water management. Possible consideration of a wide range of indicators could have provided additional richness to this study. Moreover, the KAP and choice experiment surveys relied on self-reported practices and preferences, respectively. This, however, did not affect the study outcomes because data collection methods and data sources were triangulated to verify the authenticity of responses. For choice experiments, debriefing questions were administered to establish possible reasons behind respondent's choices.

1.7 Key Concepts Relevant to the Study

1.7.1 Rainwater Harvesting

Rainwater harvesting (RWH) encompasses a set of technology and practices for collecting, concentrating and storing rainwater for various uses (Ngigi et al., 2006; Malesu et al., 2012; De Trincheria et al., 2017). RWH can be distinguished into several techniques – such as earth dams, farm ponds, tanks, percolation ditches, terracing, furrowing and conservation tillage – on the basis of where the rainwater is collected or how it is stored (Critchley & Siegert, 1991; Ngigi, 2003). Rainwater can be collected from roofs, fields, rock outcrops and roads or ephemeral streams and gullies, and stored in the soil profile of the cropped area or in a storage facility such as tanks or farm ponds. In this regard, RWH technology can supplement conventional water supplies to meet rising demands amidst challenges of climate change and land use change (Ngigi et al., 2006; Rockström & Falkenmark, 2015; Velasco-Muñoz et al., 2019).

Rainwater harvesting is a viable strategy for improving productivity and resilience of cropping systems. In this study, the concept RWH is used to encompass the collection, storage and utilization of rainfall run-off for supplemental irrigation in smallholder irrigation systems to increase and stabilize yields while safeguarding environmental flows. The ground run-off is collected from neighbouring areas, stored in on-farm water reservoirs and used during periods of water stress or scarcity.

1.7.2 Willingness to Pay

Willingness to pay (WTP) reflects the maximum sum of money that an individual is willing to pay for a good or service based on personal preferences or budget constraints (Roy, 2004; Hanley et al., 2007). The WTP can be used as a methodological tool to estimate the capacity of a social group to pay for a specific programme or intervention either directly or through "hypothetical" markets (Bockstael et al., 2007). The WTP reflect individuals' preferences for a good, service or technology. Economists use WTP as the standard measuring stick of benefit.

The concept of WTP is grounded in the standard micro-economic theory which assumes that individual decisions are based on ideals of rationality (Freeman, 1993). For example, if a change in environmental or social good or service is in prospect, such as improvement in water availability and quality in a river catchment or a reduction in water conflict, and water users believe they will be better off in some way, they may be willing to pay money to secure such benefits. In this case, WTP reflects water users view of the economic value of improved environmental goods and services.

Economic valuation provides various approaches and tools for estimating external benefits of proposed programmes or interventions by assigning monetary values to a range of environmental and social attributes (Streimikiene et al., 2019). In this study, WTP reflects smallholder irrigators' view of economic value of environmental and social attributes associated with on-farm water storage technology. The economic valuation reveals and estimates the monetary value of auxiliary benefits of on-farm water storage technology, such as reduced water conflicts and improved water quality for domestic use and for environmental flows.

1.8 Structure of the Study

This thesis comprises five chapters. Chapter 2 reviews relevant literature and set out analytical framework for the study. Chapter 3 describes the geographical context of the area under study and discusses the research methodology. Chapter 4 presents the research findings, discusses the results and relates them to relevant literature. It concludes with a proposed governance framework for uptake of on-farm water storage technology. Chapter 5 presents a summary of key findings, conclusion, recommendations of the study and areas for further research.

CHAPTER TWO: LITERATURE REVIEW

2.0 Overview

The chapter takes a broad view of water governance through actions and interactions of multi-level actors and water user groups. It reviews multi-level water governance and its impacts on adoption of innovation, farmer knowledge and practices in water governance and integrated water resources management (IWRM). The chapter analyzes RWH and places it within the context of IWRM. Using a choice experiment approach, the chapter analyzes farmers' preferences and willingness to pay (WTP) for the attributes of on-farm water storage technology. It sets the policy context for sustainable practices in water management in Kenya with a review of relevant governance frameworks. The chapter concludes with analysis of diffusion of innovation theory and its potential relevance to the uptake of on-farm water storage technology.

2.1 Water governance

2.1.1 Introduction

Water governance is defined as "…set of rules, practices, and processes through which decisions for the management of water resources and services are taken and implemented, and decision-makers are held accountable" (OECD, 2015, p. 5). Water resources management, on the other hand, is elaborated as "…operational activities of monitoring and regulating water resources and their use" (Woodhouse & Muller, 2016, p. 226). It also entails alteration of water systems to support socio-economic development and ecosystems (Boer et al., 2013).

Water scarcity poses serious constraints to sustainable development, especially when set against the backdrop of growing economies and environmental change (IPCC, 2012; 2014; Pahl-Wostl et al., 2012; Porcher & Saussier, 2019). The global freshwater demand is expected to accelerate through the 21st Century (IPCC, 2014), leading to increased groundwater overdraft and excessive abstraction of surface water resources (FAO, 2015). For dryland agro-ecologies, the declining water resource base inflicts serious limitations on availability and adequacy of water resources, ultimately undermining economic development, human health and ecosystems (WWAP, 2016).

Over the past decades, several efforts have sought to unlock water crisis. Initial ones were focused on unlocking the crisis through "infrastructural" solutions, such as construction of dams and reservoirs (Menga, 2016; WCD, 2000). While these efforts have generally been applied to boost water supplies, there is a growing realization that infrastructural solutions alone are not sufficient to address complex water challenges (Hellegers & Lefaive, 2015; Quentin, 2017). The essence of global water crisis is not as much in resource scarcity and poor infrastructure, it is largely a governance crisis (WWAP, 2016; Ochoa-Garcia & Rist, 2017). Many countries are experiencing a number social, economic and environmental challenges in governing water.

Crisis of water governance manifests in many ways, such as inefficient and ineffective institutions, absence of integration, sectoral fragmentation, over-regulation of water sector, weak participatory decision-making processes, resource use conflicts and limited recognition of environment as "legitimate water user" (Baldwin et al., 2018; Cole et al. 2017; Dell'Angelo et al. 2016; McCord et al., 2017; Pahl-Wostl et al., 2012; Pluchinotta, et al., 2018; WEF, 2016). Development policies in many countries tend to place economic interests ahead of environment and social equity, two of the three pillars of sustainable development (Jägermeyr et al., 2017; Ricart et al., 2018). In response to crisis of water governance, many countries have prioritized decentralization of water management and governance (Pahl-Wostl et al., 2012; Sullivana et al., 2019). Decentralization gives impetus to river basins as fundamental units of water governance (Bertule et al. 2018; Buriti et al., 2018; Hidalgo-Toledo et al., 2019). This is particularly important as river basins have recently been "rediscovered" as promising units for integration and coordination of water management functions due to relative uniformity of hydrological and social conditions (Bertule et al. 2018; Buriti et al., 2018).

2.1.2. Multi-level water governance

Water governance is based on interdependent arrangements among multiple levels of authority and stakeholders (Daniell et al., 2014; Wanessa et al., 2020). Such arrangements imply that complex challenges to water management requires collaborative processes between actors operating at multiple inter-linked levels and scales. In a multi-level water governance system, the authority is dispersed vertically between different levels of governance, encompassing national, basin and sub-basin institutions; and horizontally across different sectors of interest and spheres of influence, including non-state actors.

Recent water sector reforms highlight the importance of basin and sub-basin institutions in water governance. This realism is now well captured in national and global policies that promote participatory decision-making processes. Such important instruments, such as the 2030 Agenda for sustainable development, the EU Water Framework Directive, and the OECD Principles on Water Governance bear testimony to the call at the international plane. Similarly, the Constitution of Kenya (2010), the National Water Policy (1999) and the Water Act (2016) provides for collaboration and integrated water resources management. The OECD highlights critical role of water reforms and recommends a three-pronged strategy to attaining the reforms. The three prongs of the strategy are: financing, governance, and improved coordination and coherence between water and sectoral policies (OECD, 2015). These strategic areas call for contextual and tailor-made governance arrangements for river catchments, and endorse active community engagement in water management decision-making processes (OECD, 2015).

Since 2002, Kenya has pursued water reforms that establish a polycentric governance. In this approach, water management decision-making is shared among multiple, independent decision-centres and "overlapping national, basin and sub-basin authorities" (Baldwin et al., 2018; Cole et al., 2017; Dell'Angelo et al., 2016). This arrangement implies local decision-making and multi-level institutions connected by overarching legislation (McCord et al., 2018; Pahl-Wostl et al., 2012). Although water reforms have delegated key responsibilities to decentralized units at the basin and sub-basin levels (RoK, 2002), this does not always lead to a polycentric governance system if frameworks and institutions for coordination among multi-level actors are weak (Pahl-Wostl & Knieper, 2014). Studies on polycentric governance show that in addition to local participatory processes, effective water governance requires coordination between water user groups and between multi-level institutions (Cole, 2011; McCord et al., 2017; Baldwin et al., 2016; Pahl-Wostl et al., 2012). While local institutions are more responsive to local realities, they often lack capacities to regulate and coordinate water use among diverse and competing actors.

A growing body of empirical research has analyzed the suitability of polycentric water governance to local socio-ecological contexts (Baldwin et al., 2018; Cole et al., 2017; Dell'Angelo et al., 2016; McCord et al., 2018). Baldwin et al. (2018) assessed the impact of polycentric governance arrangements on sustainable water practices in Kenya and found that water sector reforms have played an enabling role in facilitating collective bottom-up actions. Their findings stressed the importance of collective institutions in providing incentives for cooperation particularly with regard to sharing knowledge and information and building trusts and new norms for sustainable practices. However, the ability of collective institutions to address complex water governance issues is increasingly challenged by inadequate resources and technical capacities (Dell'Angelo et al. 2016). Pahl-Wostl et al. (2019) compared water governance and management systems in 29 river basins, and found that polycentric governance regimes can promote sustainable practices in water management and improve adoption of innovative water management technologies.

However, the adoption of innovative water management technologies may encounter resistance, especially when water user groups and multi-level institutions are required to commit resources, and if the innovation does not align with the prevailing world views and norms. Such challenges imply that it is important for the proponents of innovation to build networks across levels and scales to support the adoption of new technologies. Daniell et al. (2014) analyzed the interactions and coalitions that occur between multi-level actors to improve the adoption of water innovations. Their findings show that adoption and replication of innovative technologies require multi-level coalitions or networks across at least two governing levels, including one with decision-making power and resources to implement the innovation. Their study highlights the enabling role of the national government in facilitating the adoption of innovations, particularly those in competition with entrenched practices in water management. The higher-level governing authority can enable the innovation through appropriate policy measures and funding mechanisms. The study conclude that a coalition of multi-level actors would benefit from the inclusion of experts on innovation and from other relevant fields.

2.1.3 Governance of common pool water resources

Common pool resources (CPRs) are "natural or man-made resource systems that are sufficiently large and costly to exclude potential beneficiaries from obtaining benefits from its use" (Ostrom, 1990). These resources are used by multiple users or groups, and of "which joint use involves subtractability i.e. use by one user will subtract benefits from another user's enjoyment of the resource system." (Ison et al., 2007). CPRs such as rivers and springs are appropriated by many users (e.g. private irrigators, livestock, household uses, industry and ecological systems) which often results into over-abstraction and free-riding (Baldwin et al., 2018; Pluchinotta et al., 2018; Ostrom, 1990).

However, CPRs can be a source of cooperation. Studies show that under specific conditions, water users can engage collectively to address the challenges associated with the crisis of commons and allocate water resources equitably among competing sectors (Baldwin et al., 2018; Cox et al., 2010; Ostrom, 1990). Conditions, such as shared interests, opportunities for knowledge and information transfers, conflict resolution systems, perceptions of risk with inaction, continuous trust building and incentives for compliance are highlighted by successful collective actions related to the management of CPRs (Baldwin et al 2018; Cody et al., 2015; Ostrom, 1990, 2005).

The challenge of achieving equitable water allocation among farmers in the "head-end and tail-end" of irrigation system has been a mainstay in the CPR literature (Baldwin et al., 2018; Ostrom, 1990; Sarkera et al., 2009). Sustainable irrigation systems are largely dependent on effective coordination and cooperation among farmers (Dell'Angelo et al., 2016; McCord et al., 2017, 2018). As a result, farmers' participation and representation in water management has long been promoted as a strategy to achieve equitable outcomes. Much of CPR literature shows that collective action is influenced by context-specific factors, such as the degree water scarcity, size and heterogeneity of water users, social capital, origin of user groups and levels of income (Agrawal, 2001; Araral, 2009; Fujiie et al., 2005; Hardin 1982; McCord et al., 2018; Olson, 1965; Walker & Ostrom 2009). While water resource abundance can disincentivize cooperation and coordination among water users, perceptions of water scarcity may prompt efforts towards collective action and build support for sustainable practices (Fujiie et al., 2005; Araral, 2009). The size of water users has a bearing on costs of coordination and enforcement of rules, which will increase with additional water users (Hardin, 1982; Janssen et al., 2015). Similarly, a group of heterogeneous users might struggle to build trust and norms of reciprocity among themselves (Janssen et al., 2015). Larger and heterogeneous group and low social capital can limit interactions and communication among members (Walker & Ostrom, 2009).

2.2 Farmer Knowledge and Practices in Water Resources Management

Broad understanding and support for water policies is central in the transition towards more sustainable water management practices (Dean, fielding et al., 2016; Dean, Lindsay et al., 2016). However, the process towards accepting new policies is complex and depends on knowledge of water issues and attitudes that may arise when users acquire conservation-focused knowledge (Dean, Lindsay et al., 2016; Thomas et al., 2020). Recent water policies give impetus to participatory approaches as a means to incorporate user perspectives and improve social acceptance of policy measures (Ogada et al., 2017; Mwihaki, 2018; D'Agostino et al., 2019). Active engagement of resource users in policy development and implementation can engender high levels inclusion and trust and build support for policy measures.

A growing body of research shows various determinants of knowledge, attitudes and practices in water management. These determinants include: geographical experiences such as climatic conditions (Dean, Fielding, et al., 2016), farm characteristics such as farm location relative to a water source (Rolston et al., 2017), and social relations such as membership to a network (Shikuku et al., 2017). Other predictors include residency status (Bo et al., 2014) and psychological factors such as environmental identity and values (Dean, Fielding, et al., 2016; Dean, Lindsay, et al., 2016). For this reason, long-term residents demonstrate a better understanding of water-related issues than new immigrants and non-native speakers (Bo et al., 2014). Dean, Fielding, et al. (2016) showed that knowledge of water issues is connected to pro-environment values and adoption of sustainable practices. Rolston et al. (2017) showed that despite an appreciation of water resource management challenges, water users have limited understanding of IWRM principles.

Much of literature review on sustainable agricultural practices has drawn attention to range of factors influencing farmers' knowledge and practices in soil and water management. Thomas et al. (2020), for instance, assessed how farmers engage, utilize and share knowledge within group settings, and found that social networks are crucial to acquisition and dissemination of knowledge on sustainable practices. D'Agostino et al. (2019) analyzed stakeholders' perceptions on water issues in Malta. The study which was prompted by unsustainable agricultural water use found that irrigation challenges were tied to crisis of water governance, particularly an absence of socially and environmentally acceptable policies. Hilimire & Greenberg (2019) assessed how beginning farmers in the United States practiced water conservation during dry seasons. The findings showed that soil conservation practices were prioritized as a means to water conservation. Additionally, educational attainment and sense of stewardship were significant influencing variables.

Mills et al. (2016) analyzed farmers' willingness and ability to adopt environmental management practices, and level of engagement with extension and support services. The findings showed considerable heterogeneity with regard to influencing variables. While farmers had expressed willingness to adopt sustainable practices in soil and water management, they were constrained by biophysical, economic and technological factors. Valizadeh et al. (2019) examined farmers' water conservation practices in Iran and found that, to a large extent, such practices were influenced by social-structural factors. Shikuku et al. (2017) assessed farmers' attitudes and factors influencing agricultural adaptation in East Africa. They found that farmers were less willing to adopt sustainable practices in soil and water management. Adaptation to climate risks were mainly influenced by social networks and size of household. While a vast body of literature is focused on explaining the relationship between knowledge and sustainable practices in soil and water management, there is limited empirical evidence about how knowledge of water resources management among irrigators affects their attitudes and practices, and how policies can address existing gaps in knowledge and practice.

2.3 Integrated Water Resources Management

2.3.1 Genesis and evolution of IWRM

Over the past decades, IWRM has become a global discourse, driving water policy reforms at all levels of governance (Anderson et al., 2008; Bertule et al., 2018; Biswas, 2004; Hooper 2005; IWA, 2018; UN, 2012). The IWRM is defined as:

> *"… a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (GWP, 2000, p.22).*

The IWRM places emphasis not only on "coordinated development and management of water and land resources", but also on surface and groundwater resources and upstream and downstream interests. At the heart of IWRM approach is the management of water resources at the basin level in conformity with hydrographic boundaries (Bertule et al. 2018; UN, 2012).

For decades, many countries have made various efforts to institutionalize water resources management (Dellapenna & Gupta, 2009). These efforts were driven by the desire to unlock complex challenges in water governance (Anderson et al, 2008; Rahaman & Olli, 2005). The Mar del Plata Water Conference, 1977, was the turning point in the institutionalization of water management (Bertule et al., 2018; Rahaman, 2009). It adopted general principles for water governance which prompted a momentous turnaround in policy reforms. However, it was the Dublin Conference on Water, Environment and Development, 1992, which crystallized the principles, scope and strategic actions required to aid the transition to IWRM. The "Dublin statement on Water and Sustainable Development" committed the world to IWRM paradigm which underlined the need to keep in sight the connections between water resources and land management (ICWE, 1992). The Dublin principles were endorsed by the United Nations Conference on Environment and Development, 1992 in Rio, and subsequently incorporated in the Agenda 21. The Rio Conference acknowledged the multi-sectoral and integrated approaches to water governance and proposed strategic actions to tackle water resource scarcity, climate change and deteriorating water quality (Biswas, 2001; UNCED, 1992). Other influential international events, such as, the "World Summit on Sustainable Development", 2002 in Johannesburg; the "UN Conference on Sustainable Development", 2012 in Rio; and the "UN Sustainable Development Summit", 2015 in New York (Table 2.1), have refined and thrust the IWRM into the global development agenda.

Table 2.1: Key international events and agreements on implementation of IWRM principles

Mar del Plata, UN Water Conference, 1977	**Dublin,** International Conference on Water, Environment and Development, 1992	**Rio,** United Nations Conference on Environment and Development, 1992	**Johannesburg,** World Summit on Sustainable Development, 2002	**Rio,** The United Nations Conference on Sustainable Development 2012	**New York,** The United Nations Summit on Sustainable Development 2015
Foundation laid for the principles of IWRM	Crystallized the principles of IWRM	Call for integrated water resource development and management formalized	Call to develop National IWRM policies	Reaffirmed commitments to develop IWRM	Committed to monitor implementation of IWRM

Source: Bertule et al., 2018

The 2030 Agenda acknowledged the significance of IWRM in sustainable development and commits to monitor its implementation (UN, 2015). SDG 6 seeks to "ensure availability and sustainable management of water and sanitation for all". Target 6.5 envisions the implementation of IWRM at all levels, "including through transboundary cooperation" by 2030 (UN, 2015).

2.3.2 Operationalizing IWRM principles

The water resource governance principles embedded in the IWRM framework include cost efficiency, social equity and environmental sustainability (ICWE, 1992). These principles are elaborated through a recognition "that freshwater is finite and vulnerable resource essential for sustaining human and ecological systems; water resource management needs to be grounded on a collaborative platform – involving multiple actors, including women; and that, water has economic value in all its competing uses and should be regarded as economic good." (GWP, 2005, p.22). Since 1992, many countries have responded to water crises by incorporating IWRM principles into water policies (Bertule et al., 2018; Mersha et al., 2019; UN, 2002).

Despite global recognition, IWRM has been the target of criticisms, mainly because of its wide scope and the mismatch between principles and implementation (Beveridge & Monsees, 2012; Biswas, 2008; Rahaman, 2009). Specifically, its *"one size fits all mentality"* and *"contextual insensitivity"* have been the main subject of criticism. The IWRM underestimates trade-offs and conflicts between environmental sustainability, social equity and economic efficiency targets (Mehta & Movik, 2014). Van Oel et al. (2014) investigated the mismatch between IWRM principles and stakeholder' practices in Lake Naivasha basin, and found that existing knowledge base among stakeholders is inadequate to support the implementation of integrated approaches to water resources management. Obando et al. (2018) assessed IWRM implementation gap and established that the integrated framework does not facilitate better understanding of needs of other water-related sectors in water policy development and implementation. Although, IWRM is premised on stakeholder communication and consensus on water management issues (Saravanan, 2009), its implementation is constrained by diverse and conflicting interests and power imbalance among actors in water governance (Van Kopper, 2007). A study in Brazil (Barbosa et al., 2016) explored factors hindering implementation of IWRM, and established that governance and institutional challenges are more constraining to the realization of the IWRM outcomes than technical and financial factors. It also acknowledges the critical role of external stakeholders to water sector in effective implementation of water policies. Mehta et al. (2016) analyzed IWRM policies in Southern Africa and found that the policies have entrenched inequalities in water allocations due to undeserved focus on water demand management strategies. However, IWRM has recently been redefined as "*a means to and end"*, iterative and adaptive process. This suggests that it is scale-appropriate and accommodative to emerging challenges, local constraints and evolving socio-economic priorities (OECD, 2015; UN, 2015; Woodhouse & Muller; 2016).

The operationalization of IWRM paradigm necessitates a shift towards enabling institutional and regulatory frameworks (Hussain & Giordano, 2004; IWA, 2018; GWP; Hidalgo-Toledo et al., 2019). Subsequently, many countries have instituted reforms in the water sector and delegated key responsibilities to decentralized units at the basin and sub-basin levels (Hidalgo-Toledo et al 2019). IWRM principles are operationalized at these levels, largely through governance and institutional development. However, the integration of governance, and appropriate technology is critical in bridging the gap between IWRM principles and implementation (IWA, 2018).

Kenya has set a legal and policy regime for IWRM. However, its implementation is still sparse in many river basins (Van Oel et al., 2014; Obando et al., 2018) where current water use is less optimistic due to environmental degradation and over-allocation of water resources to supply human activities. This realization has intensified efforts towards utilization of technologies that can improve water availability and address environmental degradation. RWH technologies can improve water availability and ensure equity in water allocation while safeguarding the ecosystems.

2.4 Rainwater Harvesting

2.4.1 Rainwater harvesting systems

Rainwater harvesting summarizes numerous technologies, practices and strategies for concentrating and storing rainwater for productive uses (ACE, 2015; De Trincheria et al., 2017). Several co-benefits coupled to drought mitigation, watershed management and water quality improvement are associated with RWH technology and practices (FAO, 2015; Malesu et al., 2012; Nicol et al., 2015).

For centuries, RWH has been widely applied as adaptive strategy to variable and changing climate. Many communities across the world have used diverse RWH techniques to capture and store water for beneficial uses (Critchley & Siegert, 1991). The past two decades, however, has seen a resurgence of interest in scaling up RWH practices to address persistent water crisis in many regions (Kumar et al., 2016; Lasage & Verburg, 2015). Recent water and agriculture policies have recognized RWH as a potential source of water for domestic use and supplemental irrigation (RoK, 2008; 2010a; 2015; 2016). In Sub-Saharan Africa, RWH has received wide recognition as a policy response to pervasive water scarcity (Malesu et al., 2012; Rockström & Falkenmark, 2015).

Rainwater harvesting can be differentiated into *in situ*, micro-catchment and macro-catchment RWH technologies, depending on the size of the catchment and the point of water storage (Critchley & Siegert, 1991; Hatibu & Mahoo, 2000; Ngigi, 2003; Oweis et al., 2012). *In situ* technologies define practices, such as mulching and conservation tillage, that improve infiltration and soil moisture holding capacity by capturing and keeping rainwater when and where it falls (Biazin et al., 2012; Garg et al., 2012; Hatibu & Mahoo, 2000; Rockström & Falkenmark, 2015). Micro-catchment systems, on the other hand, describe practices, such as *zai pits*, bunds and retention ditches, that collect runoff from small catchments ($10m^2$ to $500m^2$) and hold it to allow soil moisture infiltration and retention (Biazin et al., 2012; Malesu et al., 2012). Macro-scale systems capture storm runoff from external catchments for storage in reservoir structures, such as on-farm water storage (Malesu et al., 2012; De Trincheria et al., 2017). *In situ* and micro-catchment RWH technologies are widely applied in semi-arid environments, partly due to past policies that were biased towards land conservation and restoration (Recha et al., 2014). Although, in situ and micro-catchment RWH practices are effective in improving soil moisture retention, they are less suited to mitigating risks of water scarcity in irrigation systems (Bouma et al., 2016; Ngigi et al., 2006). Subsequently, there has been a slow but steady increase in the uptake of macro-catchment technologies. Similar trends are emerging in Kenya with studies pointing to upscaling potential of on-farm water storage technology (Malesu et al., 2012; Ngigi, 2018; Oguge & Oremo, 2017).

Studies shows that on-farm water storage technology can potentially reduce dry season irrigation water abstraction and bridge water gap in agriculture (De Trincheria et al., 2017; Jägermeyr et al., 2016; Jägermeyr et al., 2017; Malik et al., 2014; Ngigi et al., 2006, 2014; Richter et al., 2003; Rockström & Falkenmark, 2015; Srivastava et al, 2009). Further, on-farm water storage technology is less expensive than *in situ* and micro-catchment practices, when taking into consideration the operation and maintenance costs, water storage capacity and lifespans (Lasage & Verburg, 2015). However, technical knowledge and initial investment costs are more demanding for on-farm water storage technology (Ngigi, 2018).

On-farm water storage system consists of rainwater collection and water use components (Liang & van Dijk, 2011). The rainwater collection component includes runoff conveyance channel, silt trap and water storage facility (tanks/ponds); while water use component consists of water pump, overhead tank and irrigation facilities (Figure 2.1). During a storm event, runoff is generated in the upstream catchment and directed towards the pond through conveyance channels. The runoff is directed to the automated silt trap, which also serves as a spill way, before it is emptied into the pond. A water pump is used to abstract water from the pond to the overhead tank for irrigation.

Farm ponds can take different shapes with either vertical or slanted walls depending on geological conditions. The size is determined by farmer' financial clout and intended water use (Ngigi, 2018; De Trincheria et al., 2017). However, farm ponds are largely trapezoidal in shape and lined with a polyethylene sheet or compacted clay, especially in sites with permeable soils to reduce water loss through seepage. In locations where the soils are impermeable, such as clays, farm ponds are usually hemispherical in shape, and plastic lining is not necessary (De

Trincheria et al., 2017). Farm ponds have a storage capacity of about 50 to 1000 m^3 and can be classified into small (50 – 100 m^3), medium (100 – 250 m^3) and large (250 – 1000 m^3) sizes (Liang &van Dijk, 2011; Ngigi, 2018). Moreover, they are scalable and applicable to a wide range of biophysical and socio-economic contexts (Ngigi, 2018). However, their success can be constrained by siltation and seepage risks (De Trincheria et al., 2017; Yosef & Asmamaw, 2015) and high initial cost of investment (Malik et al., 2014). Despite these shortcomings, they are economically viable. Studies shows that farmers can recover the investment cost in approximately four farming seasons (about 2 years) (Kattel, 2015; Malik et al., 2014; Ngigi et al., 2015).

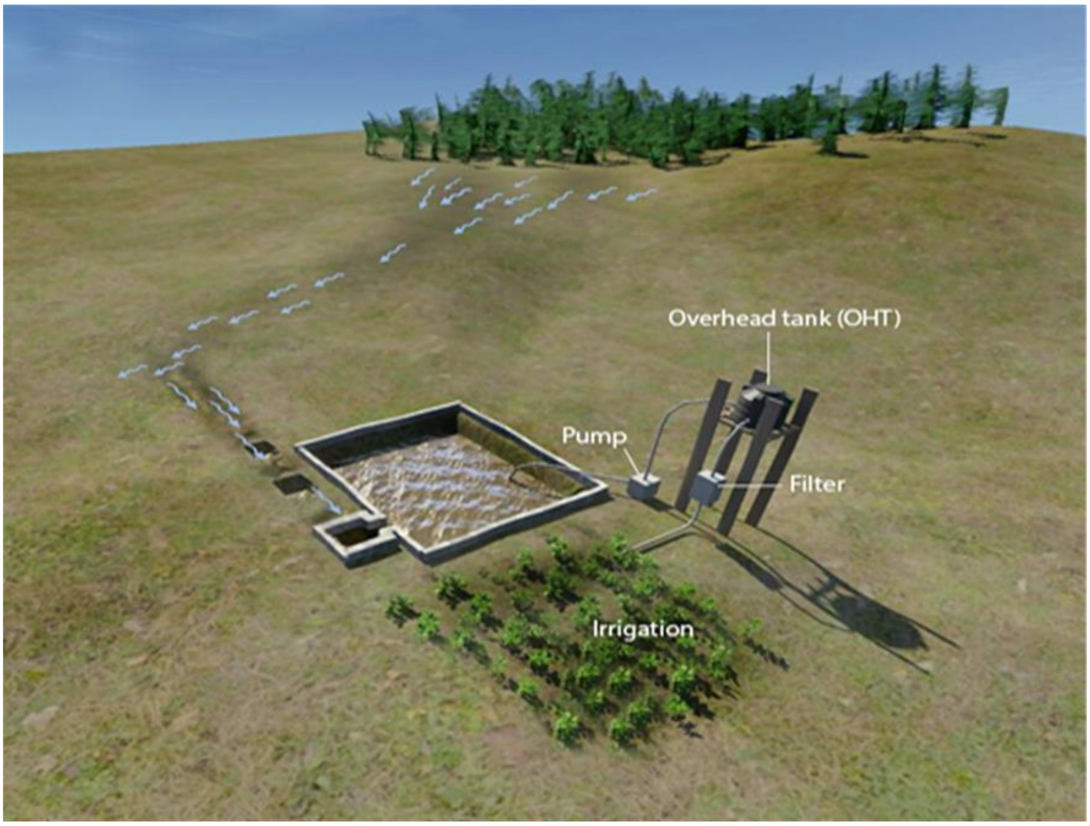

Figure 2.1: Ground catchment systems with farm ponds and irrigation. It highlights three main components of on-farm water storage technology: a run-off collection catchment, runoff storage structure and low-cost drip irrigation system

Source: Pixiniti Studios- https://www.google.com/search?client=firefox-b-d&q=pixiniti+studios

2.4.2 Benefits of RWH systems

Many studies associate RWH systems with positive welfare benefits such as increased farm productivity and ecosystem services (ATPS, 2013; Biazin et al., 2012; Bouma et al., 2016; Girma et al, 2019; Hatibu & Mahoo, 2000; Lasage & Verburg, 2015; Malesu et al., 2012; Mati, 2007; Mutabazi et al., 2005; Penning de Vries et al., 2005). An analysis of crop yield impact has established that on average RWH increases crop yields by 78%, with highest recorded increase of 500% in low rainfall years (Bouma et al., 2016). However, further research is needed to determine yield impacts for different cropping systems. Lasage and Verburg (2015) reviewed 85 published articles and reports, and found that on average, RWH techniques and practices increase crop yield by 11% to 1000%. Yosef and Asmamaw, (2015) show that RWH systems have a positive effect on agricultural productivity and ecosystems. Similar studies in India (Garg et al., 2012; Malik et al., 2014) show that on-farm water storage systems have enabled farmers to extend growing seasons, expand cropping area, increase productivity, diversify into livestock and fish farming, and improve farm incomes by up to 70%.

Other ecological benefits such as the rising density of wildlife have been associated with on-farm water storage systems in India. In South Africa (Ncube et al., 2008), on-farm water storage technology has generated welfare benefits including improved yields. The yield impacts under supplementary irrigation were higher in low rainfall seasons. In semi-arid environments of Tanzania, Hatibu and Mahoo (2000) reported improved water availability for domestic and agricultural production as positive benefits of RWH. However, they observed the mismatch between investment in soil moisture conservation and nutrient management. This shows that optimum benefits from RWH can only be met when it is integrated with other agronomic practices, such as soil fertility management (Oweis & Hachum, 2001; Rockström et al., 2004). Other similar studies show that with RWH, farmers will not just attain household food security, but improve labour productivity and net incomes (Penning de Vries et al., 2005). Improved reliability of agricultural water supply gives farmers the confidence to invest in farm inputs and soil management practices which result in increased productivity (Malesu et al., 2012).

While RWH can stabilize and increase agricultural productivity, it has not been widely adopted by farmers. Moreover, literature on RWH ignores governance mechanisms required to improve uptake, replication and up-scaling of RWH systems. Further, the research on RWH is largely focused on investigating its role in upgrading rainfed agriculture (Bouma et al., 2016; Lasage & Verburg, 2015; Oweis & Hachum, 2001) and improving domestic water supply (Ward, 2010). So far, there is limited understanding based on empirical work of the contribution of RWH systems in improving the productivity, sustainability and stability of smallholder irrigation systems. Similarly, there is a dearth of literature on utilization of on-farm water storage technology in smallholder irrigation systems. Hence, this study was designed to make a contribution towards bridging these gaps.

2.5 Farmer Preferences in Agricultural Water Management

A growing body of literature on RWH points towards increasing recognition of its social, economic and ecological benefits (Ngigi et al., 2014; Rockström & Falkenmark, 2015; Jägermeyr et al., 2017). Studies show that RWH strategies can achieve much in terms of sustaining environmental flows and bridging water gap in agriculture (Richter et al., 2003; Srivastava et al, 2009; Ngigi et al., 2014; Rockström & Falkenmark, 2015; Jägermeyr et al., 2016; Jägermeyr et al., 2017; De Trincheria et al., 2017). This is pivotal to the realization of SDG target 2.3 on double agricultural productivity, and target 6.4 on sustainable water withdrawals.

Water resources for agriculture are threatened by anthropogenic developments and climate change. The adoption of innovative RWH technologies and practices can improve water availability for agriculture and minimize or offset adverse impacts of surface water withdrawals. (Ngigi et al., 2006; Jägermeyr et al., 2017). Thus, it is necessary to encourage the uptake of on-farm water storage technology and management of its attributes, which include year-round water availability for small-scale irrigation, stability in crop productivity and incomes, improvement in water quality for domestic use and for environmental flows and a reduction in water resource conflicts (Stijn & Chellatan, 2012; McCord et al., 2018). Several approaches and techniques can be used to value these attributes and estimate WTP among farmers.

Environmental valuation approaches can be broadly divided into revealed preference methods and stated preference methods. The revealed preference methods are widely applicable where conventional or proxy market prices exist. The hedonic pricing and travel cost methods are the most common revealed preference techniques (Alpizar et al., 2001). Stated preference methods, on the other hand, rely on "constructed or hypothetical markets". The contingent valuation method (CV) and choice experiments are the most common stated preference techniques. Stated preference methods have gained broad popularity among policy makers and practitioners as versatile tools for estimating use and non-use values. However, contingent valuation method is prone to potential biases which can affect the validity and reliability of WTP estimates (Pearce et al., 2006; Birol & Koundouri, 2008). The biases may include: strategic bias, where the respondents can deliberately mis-state their WTP; starting point bias, where the valuation depends on the first bid presented; hypothetical bias, where WTP is over- or under-stated in relation to what is offered in the real market; and, information bias, where the framing of the question unduly influences the answer (Pearce et al., 2006). Choice modelling can overcome these biases (Adamowicz & Boxall, 2001), and has therefore become an alternative of contingent valuation in the estimation of non-use values.

Choice experiments are used to model choices among hypothetical multiple-attribute alternatives (Birol & Kounduri, 2008). Implicit in these choices are trade-offs between attributes that allow marginal willingness-to-pay (MWTP) and the total welfare effects to be estimated (Price et al., 2015). In this study, welfare estimates reflect both the tangible (e.g. improved farm output) and intangible (e.g. reduced water conflicts) benefits associated with on-farm water storage technology.

Farmers' preferences and WTP for on-farm water storage technology is critical in finding long-term solutions to challenges hindering the uptake of the technology. It is also important for social and economic sustainability of the on-farm water storage technology. However, there is scant empirical evidence about preferences and WTP for on-farm water storage technology among smallholder irrigators. Previous choice experiment studies show mixed results on farmers' preferences and WTP for improved irrigation water supply. Khan and Zhao (2019) assessed preferences for water service attributes for a river basin, and identified water quality as the most preferred attribute. Aydogdu and Bilgic (2016) evaluated farmers' WTP for efficient irrigation system in Turkey, and showed that farmers were willing to pay nine per cent of the net annual income for efficient irrigation technologies. Bozorg-Haddad (2016) assessed WTP for irrigation water supply during periods of scarcity, and showed that farmers deploy efficient irrigation technologies to manage water demand and reduce water use charges. Their study however, showed that water charges do not affect water use when water resources are abundant. Price et al. (2016) evaluated household preferences for water storage systems to supplement irrigation needs and supply domestic uses in the Koshi Basin of Nepal. Their study showed while better educated and wealthier farmers demonstrate higher preferences for supplemental irrigation, less privileged groups are concerned about domestic water needs. Alcon et al. (2014) assessed farmer' receptiveness to irrigation water resource management policies and found that farmers were willing to pay twice as much as the existing price to improve reliability of water supply. Assefa (2012) analyzed farmers' preferences and WTP for irrigation water during periods of scarcity, and showed that farmers are willing to pay more for reliable water supply. Similarly, Chandrasekaran et al. (2009) analyzed farmers' WTP for irrigation water supply under improved conditions. Their findings indicated that preferences and WTP for tank technology are considerably low. Farmers were less prepared to forgo existing practices in favour of tank irrigation technology.

Similarly, many studies identified demographic and socio-economic factors (e.g. farming experience, gender of household head, household size, educational attainment, level of income, primary occupation and access to extension services) and farm location (e.g. farm distance relative to a water source) as predictors of farmers' WTP for improved irrigation water supply (Alcon et al., 2014; Price et al., 2016; Aydogdu & Yenigun, 2016; Aydogdu & Bilgic, 2016; Altobelli et al., 2018; Khan & Zhao, 2019; Aydogdu, 2019). However, there is limited empirical evidence how tenure rights could possibly influence WTP for on-farm water storage systems. Moreover, there are no previous studies to date in the Tsavo sub-catchment or any river basin in Kenya that has assessed farmers' preferences and WTP for the attributes of on-farm water storage. The application of choice experiment in estimating ecological and socio-economic benefits of on-farm water storage technology among irrigators distinguishes this research from previous choice experiment studies.

2.6 Regulatory Frameworks Governing Rainwater Harvesting

Regional economic development framework such as the African Union Agenda 2063 gives high priority to agriculture as a major thrust of economic development. Similarly, Kenya's long-term development blueprint, *Vision 2030* and agricultural sector policies recognize sustainable water resource management as a key enabler to economic development. Sustainable water resource management strategies such as RWH can enable productive and sustainable cropping systems. Policy frameworks relevant to sustainable land and water management are discussed below.

2.6.1 The Constitution of Kenya

The Constitution of Kenya provides the basis for water resources management and development. Article 10 of the Constitution recognizes sustainable development as one of "the national values and principles of governance" that is binding in all aspects of public policy (RoK, 2010a). The national government is required to "ensure sustainable exploitation, utilisation, management and conservation of the environment and natural resources, and ensure the equitable sharing of the accruing benefits". Under the Constitution (2010), the national government is functionally responsible for water resources management, while catchment protection is a shared function with county governments, which are also mandated to implement national government policies on water resources. The management responsibility of the National government over water resources is undertaken through the Water Resources Authority (WRA) which also possess regulatory responsibilities. While the Constitution places a mandate on counties to implement specific national government policies on natural resources, including soil and water conservation, there is lack of legal clarity on the institutional mechanisms through which counties can perform this function.

Articles 42 and 43 of the Constitution reinforce sustainability with their provisions on the right to a clean and healthy environment, and social and economic rights, respectively. Socio-economic rights guarantee basic standards of subsistence that are essential to human dignity. The rights, which include the human right to water, food and health and social security cannot be fully provided for unless specific measures are taken to improve water supply. In recognizing human right to safe water and sanitation, the Constitution compels the state to put in place measures to improve access to water in adequate quantities. The right to water in adequate quantity is interpreted broadly to include social and economic values of water, suggesting the need to put in place measures to improve water availability for agricultural production.

Although, the right to water is protected under the Constitution (2010) as enforceable entitlement, it does not in itself guarantee the realization of this entitlement. Broadly enforceable socio-economic entitlements have the potential to impose financial burden on the economy (Usher, 2008). Accordingly, many countries tend to avoid this path by keeping socio-economic rights within the realm of statutory regulation, as opposed to being entrenched in constitutional provisions. However, in Kenya, where socio-economic rights are entrenched in constitutional provisions, there is imminent danger for such entitlements to recoil like a boomerang on the government, especially if the implementation falls short of promise held up by the supreme law. The situation can be further complicated by possible socio-economic rights litigation and court rulings obligating executive arm of government to provide socio-economic entitlements in the face of budgetary constraints.

Although, human right to water for economic development such as irrigation is fundamental, all that is possible for the government is to act reasonably in pursuing policy and legislative mechanisms that will ensure progressive fulfilment of the right to water for social and economic development. The progressive realisation doctrine, alongside the level of resource availability is often considered in assessing the reasonableness of state policy (Wesson, 2011).

2.6.2 Kenya Vision 2030

Kenya's long-term planning instrument, *the Vision 2030,* strives to create "a globally competitive, middle income and prosperous country, providing high quality of life for her citizens by 2030" (RoK, 2008). The *Vision* is "anchored on three pillars: economic, social, and political", and implemented through five-year Medium-Term Plans (MTP). The economic pillar set to achieve and sustain a "10 percent annual economic growth rate" through 2030. The social pillar strives to "create a just, cohesive and equitable society in a clean and secure environment". The political pillar, on the other hand seeks to realize "an issue-based, people-centred, result-oriented and accountable democratic system". The achievement of these targets is premised on sustainable management of natural resources and strengthening of institutional capacities for environmental governance.

Water management is critical in realizing the targets under the three pillars of *Kenya Vision 2030*. This is particularly so if water supply is adequate and reliable to sustain social and economic needs, and the integrity of ecosystems. Securing reliability of water supplies can reduce resource-based conflicts, improve food security and boost efforts to reduce poverty, particularly among vulnerable groups. This is important as agriculture is documented as a key sector through which to deliver "ten percent annual economic growth rate".

Agriculture sector supports more than 80% of the population and makes up 27% of the gross domestic product (RoK, 2017). The sector is expected to spur economic growth through various programmes including the expansion of cropping and irrigable areas in ASALs and increased investment in water harvesting and storage. Despite its potential to promote economic growth, agriculture faces a dire outlook in light of future uncertainty of water supply (Boulange et al., 2018; RoK, 2019). *Vision 2030* takes cognizant of this challenge and alive to the connection between agricultural productivity and water availability. It also gives recognition to RWH and storage in strengthening resilience of smallholder agricultural systems (RoK, 2008). Moreover, the *Vision* recognizes the importance of extension service in enhancing knowledge and use of RWH technology among rural households (RoK, 2008). Additionally, the *Vision 2030* takes cognizance of the need to strengthen technical capacities as key fundamentals for economic transformation. This goal has since permeated agricultural policies which prioritize technical and extension support services in natural resource protection and conservation.

2.6.3 Policies

2.7.3.1 National water policy (1999)

Following the development of the "National Policy on Water Resources Management and Development (Sessional Paper No. 1 of 1999)", the reforms in the water sector transited from centralized decision-making to one represented by decentralization and integration. Throughout the 20th century, water policy was characterized by hierarchical top-down command-and-control approach. This mode of governance was associated with water governance challenges, such as weak coordination among actors, weak inter-linkages with water-related sectors, institutional fragmentation and conflicts and insufficient financial resources for water resources management and development (RoK, 1999). However, at the turn of 21st century, there was a shift towards decentralization and commercialization as a cure of various ailments bedeviling the water sector. The reforms underscored dominance of markets, as mode of governance, over central regulation. This was based on a realization that deliberative governance would promote accountability and efficiency in water management.

The "National Policy on Water Resources Management and Development" gives recognition to water governance crisis. In particular, it redefines the role of the government in water management "with emphasis on regulatory and enabling functions". Moreover, it emphasized the role of public-private partnerships (PPP) in water resource governance and development, and delegated water resource management and service provision to the private sector, local authorities and communities. However, in many developing countries with weak water governance institutions, such as Kenya, decentralization has led to fragmentation rather than integration. Whereas decentralization and commercialization are emphasized in water policy, no attempt was made to provide support mechanism for individual investment in water harvesting and storage. The incentive to enable uptake of sustainable water resource management practices and technology were not incorporated in the water policy

The aspirations of the 1999 national water policy found legislative expression in the Water Act 2002. The Act established and delineated water resources management responsibilities to national, regional and basin-level institutions. The Water Resource Management Authority (WRMA) was mandated to manage water resources, and the Catchment Areas Advisory

Committees (CAAC) to advise WRMA on catchment water resources management. Water Resource Users Associations (WRUAs) were established to address water resource conflicts through collaborative management at the sub-basin level. These institutions provided a leeway for community participation in water management decision-making. However, productive water uses such as water storage and irrigation were not articulated in the 2002 water reforms. Despite growing appreciation of the separation of water resources management from service provision, the arrangement is faulted for weakening existing customary water governance arrangement in many rural communities which uphold the integration of water resources management and service provision (Gachenga, 2015).

Despite the gains made in the management of water resources under the 2002 water reforms, many challenges still confound the water sector. Such challenges include: weak coordinating capacities between national government, its agencies and county governments; weak participatory decision-making processes; increased conflicts and disputes over water access rights; degradation of water catchment areas and encroachment on wetlands and riparian reserves; and lack of a clear and coherent policy on RWH and storage. Subsequently, a new National Water Policy is currently being developed to replace the 1999 Water Policy, and align water sector reforms with the devolved framework of the Constitution (2010) and other emerging realities relevant to the water sector, such as, the Kenya Vision 2030, and national climate targets embedded National Climate Change Action Plan (NCCAP). The Water Policy is equally being aligned with global and regional commitments, such as the 2030 Agenda for Sustainable Development, AU Agenda 2063 and East Africa Community Vision 2050. The review is expected to pay particular attention to coordinating capacity challenges that are most evident between the national government, its agencies and county governments.

2.7.3.2. National Land Policy (2009)

The National Land Policy (NLP) sets a framework to address the land question in Kenya, particularly those related to land tenure, restitution for historical and contemporary claims of land injustices and sustainability of land resources (RoK, 2009). Past land policies recognized the superiority of private land tenure over customary arrangements (Okoth-Ogendo, 1995). As a result, customary land rights were extinguished and replaced with private tenure which prioritized economic productivity over equity and sustainability in the use of land. However, the NLP signalled a momentous turnaround in land policy reforms, and adopted a plural approach where "different forms of tenure co-exist and benefit from equal guarantee of tenure security" (RoK, 2009, p.9). The plural approach is premised on philosophy that "equal recognition and protection of all forms of tenure will enable the realization of economic productivity, equity, environmental sustainability and cultural preservation in the use of land".

The NLP outlines several principles for sustainable management of land, such as "equitable access to land, secure lands rights, intra- and inter- generational equity, effective regulation of land development, sustainable land use and productive land management". Security of land rights refer to conviction that individual's right to land is recognized and protected by the law. Sustainable and productive use of land use incorporates an understanding that social and economic benefits that flow from the land use must be obtained in a manner that does not harm environmental sustainability. In the absence of environmental sustainability, the state reserves the right to apply the principle of effective regulation of land.

Land tenure denotes "terms and conditions under which rights to land and land-based resources are acquired, retained, used and disposed of, or transmitted" (RoK, 2009: p.13). The NLP recognizes three land tenure categories: public land, community land and private land. Public land refers to land that is neither privately nor communally owned, or "any other land declared to be public by an Act of Parliament". Community land, on the other hand is land that is "lawfully held, managed and used by a given community". Private land is "land lawfully held, managed and used by an individual or other entity under statutory tenure".

The NLP takes note of the contribution of land tenure to sustainable and productive land use. Land tenure confers user rights and obligations to landowners to make decisions over productive and sustainable use of land. The private entitlements and obligations that exist in relation to land ownership and use can create incentives for sustainable use of land and related resources (Kameri-Mbote, 2006). However, in the course of using the land and related resources for socio-economic benefits, many landowners fail to incorporate environmental considerations in land use management. The absence of environmental obligation on tenure rights justifies the application of state authority to regulate private interest in land or entirely abrogates property rights in land in the interest of sustainable development.

The NLP retains the principles of eminent domain (compulsory acquisition) and police power (development control) in sustainable management of land and related resources. Eminent domain denotes the "power of the state to compulsory acquire private property for public purposes" subject to prompt and just compensation. The police power, on the other hand, connotes the "command of the state to regulate land use in public interest" (Kameri-Mbote, 2008). The acquisition of private property through the eminent domain is rarely done to pursue environmental agenda, but rather to advance the state's socio-economic interests. The police power on its part, has been used with relative success to regulate the use of land and ensure sustainability, particularly in administration of agricultural land use and physical planning. However, the regulatory potential of "police power" is scattered in several uncoordinated agencies, suggesting the necessity of enhancing the capacity of relevant agencies. While the police power has significant potential to safeguard environmental considerations in land use management, sustainable land use would benefit more from participatory land use management approaches. This is particularly so if policy choices and actions are based on democratic processes that draw largely from local experiences, knowledge, institutions and innovations. Moreover, provision of incentives, extension support and financing can enable diffusion appropriate technologies that can integrate environmental considerations in economic land use choices.

The aspirations of NLP found legislative expression in the Constitution (2010) and "new" land laws i.e. "Land Act (2012), Land Registration Act (2012), National Land Commission Act (2012) and Community Land Act (2016)". While the Land Act (2012) provides a "mechanism for sustainable administration and management of land", the Land Registration Act (2012) has revised, consolidated and rationalized registration of title to land. The National Land Commission (NLC) Act (2012) "provides for functions and powers of the NLC" and "gives effect to the objects and principles of devolved government in land management and administration". The Community Land Act (2016), for its part, "provides for recognition, protection and registration of Community Land rights, and management and administration of community land".

The NLP, the Constitution (2010) and enactment of new land laws since 2012 was widely viewed as a cure for land question, and as such unproductive and unsustainable land use. However, contentions and contestations over land ownership, access and control persist. While tenure rights incorporate obligations with regard to land use, it does not articulate specific obligations required to ensure sustainability. The NLP should incorporate specific sustainability measures in the land tenure and identify specific technology and practices that will integrate environmental objectives in economic land use choices. Such technology and practices should then be prioritized for uptake by land users, such as farmers.

2.6.3.3 National Land Use Policy (2017)

The National Land Use Policy (NLUP) sets a framework for efficient and "sustainable utilization of land and land-based resources" at the national, county and community levels. Not surprisingly, Kenya's land and land-based resources are at significant risk from anthropogenic developments, and the anticipated or observed environmental damages are substantial. While rapid population growth is a key driver of unsustainable land use practices, its impact is amplified or attenuated by public policies and institutions. For this reason, lack of a national policy on land use in Kenya was associated with the State's apparent inability to address land use management challenges. These challenges are manifested by haphazard developments, land and resource use conflicts, environmental degradation and underutilization of land. Over the past decades, land use management issues were addressed through a multiplicity of uncoordinated policy and legal regimes that did little to unravel land management challenges.

Land use denotes "economic and cultural activities practiced on the land" (RoK, 2017). These activities include: "agriculture, industrial, commercial, infrastructure, human settlements, recreational areas, rangelands, fishing, mining, wildlife, forests, national reserves and cultural sites" (Ibid, p.14). Poor land use practices have negative impacts on food production, water resources, ecosystems and economic development.

The NLUP is premised on the philosophy that land is a critical and finite resource, a cultural heritage and the foundation of economic development. For this reason, land should be managed in equitable, efficient, productive and sustainable manner. These aspirations are captured by the provisions of Chapter Five of the Constitution (2010), particularly "Article 60 on principles of land policy; Article 66 on regulation of land use; and Article 69 on enforcement provisions with respect to the environment" in which the State is mandated to "ensure sustainable exploitation, utilization, management and conservation of the environment and natural resources".

The success of NLUP is dependent on the achievement of "productive and sustainable use of land resources" (RoK, 2017). However, this is constrained by many challenges such as "incompatible land uses leading to human-wildlife and resource use conflicts; land degradation resulting from demographic pressures, cultivation on fragile ecosystems, use of inappropriate farming technologies and climate variability; and abandonment of agricultural activities due to poor infrastructure and inadequate financing and extension services". The NLUP prescribes a range of interventions to address these challenges. They include: stakeholder' participation in environmental management, provision of appropriate incentives, application of efficient agricultural technology and assessment of land resources to provide data and information that can support evidence-based land-use management decision-making.

The NLUP upholds State's right to regulate land use practices through the principle of police power. To realize this goal, the policy provides for the strengthening of regulatory, enforcement and coordinating capacities of relevant agencies, such as National Environmental Management Authority (NEMA), Kenya Forest Services (KFS), Water Resources Authority (WRA) and Kenya Wildlife Services (KWS). Moreover, it advocates for "participatory land use planning and security and equity in access to land resources". Land tenure insecurity can undermine the uptake of sustainable land use practices. However, with secure tenure, appropriate technology can be easily adopted.

The NLUP recognizes the critical role of the county governments in land use management. The biophysical and socio-economic contexts under which environmental degradation occurs bestow enormous responsibility on county governments to prioritize sustainable land use management in development planning. The adoption of sustainable land use practices is dependent on contextual factors, that can be unravelled more effectively by county governments.

Despite providing a portfolio of specific measures for optimal and sustainable utilization of land, the NLUP has many shortcomings. Land use management measures are disjointed and scattered across institutions and policy domains. This can potentially undermine implementation of proposed land use management initiatives, particularly if regulatory, enforcement and coordinating responsibilities are not clearly delineated across levels of government. Moreover, the NLUP does not sufficiently address how resources will be mobilized to enable diffusion of proposed land use management interventions. Significant resources are required to support implementation of land use management measures, such as application of appropriate technology and innovative governance configurations. As a result of these shortcomings, the country has continued to experience many land use management challenges such as resource use conflicts and land degradation. Tsavo sub-catchment, for example, has continued to witness rapid encroachment on wetlands and riparian reserves. This can be attributed to weak coordination with county governments which are responsible for approval of development permit applications.

2.6.4 Legislations

2.6.4.1 Water Act (2016)

The Water Act (2016) is framed within devolution, specifically to align the water sector with devolved framework of the Constitution (2010). Under the Act, water related functions are shared between national and county governments. While the national government has the mandate over policy development, regulation and management of water resources and water harvesting and storage; the county government is responsible for catchment protection and implementation of national government policies on water resources management.

The Water Act (2016) has established an apparatus of institutions at all levels of water governance: national, basin and sub-basin levels. The Water Act (2016) has replaced the WRMA with Water Resources Authority (WRA) to protect, conserve, control and regulate use of water resources. Subsequently, the WRA is mandated to grant permits for water use and monitor and enforce compliance with standards, procedures and regulations. While the water-permit system is envisioned to control and regulate water resource use, it is perceived to criminalize water rights of less privileged users, who are not aware of, or do not have the incentive to comply with the requirement. Moreover, the permit system underestimates the capacities required to enforce compliance among a large number of small-scale water users (Richards, 2019).

The Water Act (2016) ties issuance of water permit to holding rights to land. A land holder is "a registered owner of the land or the person in whom the land is otherwise vested by law". For this reason, evidence of land ownership, such as title deed, lease agreement, or letter from landowner is required prior to granting a water right (WRMA, 2007). However, linking water right to land right is criticized for perpetrating the concept of privatization of water right (Shurie, Mwaniki & Kameri-Mbote, 2017), and limiting such right to those with holding rights to land (Gachenga, 2018). A large segment of smallholder farmers operates under customary land rights, suggesting the necessity of a hybrid system of water rights which acknowledges customary water rights, alongside water permit. A one-size-fits-all water rights regime cannot guarantee equitable allocation to water users who exhibit considerable economic inequalities.

Under the Water Act (2016), the CAAC is replaced with BWRCs to play an advisory role to the WRA and county governments in water resources management. BWRCs draw membership from basin stakeholders including "a representative of the ministry for water resources, representative of farmers or pastoralists, representative of NGOs engaged in water resources management programmes, representative of the business community operating within the basin area, and representative of county government whose territory falls within the basin". In this way, the BWRCs are expected to give effect to participatory decision-making processes on water resources management. County representative in the BWRC is nominated by the WRA and approved by respective county assembly. For this reason, the Water Act (2016) provides a leeway for county governments to play a key role in catchment protection. While the Water Act (2016) places a mandate on counties to protect and conserve water catchment areas, there is lack of legal clarity on the institutional mechanisms through which counties can manage water resources that fall within their territories and how they will relate with the BWRCs and WRUAs to support the WRA in basin-level water resources management activities.

The BWRCs are further mandated to formulate basin area water resources management strategy in consultation with the WRA and county governments whose territories lie within the basin. The strategy provides a critical guide for water resources management in the basin, and is required to, among others, outline specific measures for "sustainable management of water resources, incorporate water resource allocation plan, provide systems for collaborative water governance, develop financing plan, and facilitate the formation of WRUAs". However, the independence of BWRC has come under sharp focus. While the tenure of its members is secure under the Water Act (2016), they are still appointed by the WRA in consultation with the Cabinet Secretary in-charge of water resources. Moreover, their operations are still guided by the regulations made by the WRA.

The Water Act (2016) has retained WRUAs at the sub-basin level to promote cooperative governance and address water-related conflicts. While WRUAs are community-based voluntary organisations, they are critical for sustainable water resource allocation and use, and can serve as agents of BWRCs. This suggests that WRUAs have legal mandate in the sub-basin water governance and can take up formal governance responsibilities, such as, approval and enforcement of permits for abstraction rights and implementation of water resource management strategy. Although the Water Act (2016) has expanded the mandate of WRUAs, it has failed to incorporate appropriate measures that would strengthen financial and technical capacity of local governance institutions. The Water Act (2016) makes a weak attempt to address financial sustainability of WRUAs through a provision which allows an agreement with the WRA to "make available a portion of water use charges" to support regulatory functions undertaken on WRA's behalf. Through this provision, the Water Act (2016) has anticipated WRUAs' potential to substitute the WRA in water resources management.

The Water Act (2016) has established the National Water Harvesting and Storage Authority (NWHSA) to "develop and manage national public water works for water resources management and flood control; and to develop and implement water harvesting policy and strategy". The establishment of the NWHSA aligns to the constitutional provisions that recognize access to water in adequate quantities. However, public investment in water infrastructure may not provide water needs of smallholder irrigators. This may necessitate a review of the water policy and related legislations to incorporate on-farm water storage technology, and to provide for intergovernmental framework to develop and implement appropriate incentive mechanisms for the adoption and utilization of RWH at the farm-level.

While the BWRCs and WRUAs have been established under the Water Act (2016) to provide forum for participation of local communities and other stakeholders in water governance, it has failed to meet their expectations. The Act is faulted for perpetuating a centralized water governance framework at the national government level while devolving the task of water resource management to communities (Gachenga, 2018; Orlendo, 2019). Moreover, the Water Act (2016) does not embed appropriate incentives for sustainable practices.

2.6.4.2 Irrigation Act (2019)

The Irrigation Act (2019) is critical in the development and management of the irrigation sector in Kenya. It aligns irrigation management to the devolved framework of the Constitution (2010) and introduces momentous changes to the institutional landscape. The Act "sets the framework for expansion of land under irrigation and drainage through establishment of the National Irrigation Development Authority (NIDA)", with specific mandates to (i) "develop and improve irrigation infrastructure for national or public schemes; (ii) provide irrigation support services to private, medium and smallholder schemes, in consultation and cooperation with county governments and other stakeholders; and (iii) provide technical advisory services to irrigation schemes". More importantly, NIDA is mandated to facilitate the formation and strengthening of irrigation water users' associations (IWUAs).

Before the enactment of Irrigation Act (2019), irrigation reforms were grounded on the Irrigation Act 1966 (Cap 347) which created the National Irrigation Board (NIB) to provide for "development, control and improvement of centrally managed irrigation schemes". Smallholder schemes were however, self-regulated through IWUA.

The Irrigation Act (2019) put county governments at the centre of irrigation reforms. As a result, they are mandated to establish irrigation development units to meet county irrigation needs through the formulation and implementation of county irrigation strategy; development and maintenance of irrigation database; identification of community-based smallholder schemes for implementation; mainstreaming irrigation related statutory obligations particularly those related to environment, water and health; supporting local capacity and establishment of IWUAs to develop and manage irrigation schemes; and setting up measures to strengthen climate resilience and sustainable environmental management. Notably, the Act empowers Cabinet Secretary for matters related to irrigation to improve reliability of irrigation water supply, including seeking appropriate advice from WRA on development of alternative irrigation water sources.

Irrigation development is associated with land degradation, unsustainable water withdrawals, deterioration of water quality and conflicts. The Irrigation Act (2019) seeks to cure these ailments by mainstreaming environmental considerations in irrigation development and management. While the Act seeks to expand land under irrigation and drainage, it should be emphasized that such measures need to consider sustainability of land and water resources. For this reason, environmental assessment is necessary before approval of any plan to expand land under irrigation.

The Irrigation Act (2019) highlights greater scope for expanding alternative technologies that will improve water use efficiency and water availability for community-based irrigation developments. However, barriers to the alternative technologies still exist, such as unfamiliarity with alternative technologies, lack of appropriate incentives to promote diffusion of innovation and weak capacities among local governance institutions. Moreover, the Irrigation Act (2019) gives undue attention to centralized water storage infrastructure to supply irrigation needs. Very little effort is directed towards supporting investment in decentralized water storage systems, such as on-farm water storage technology.

The Irrigation Act (2019) imply a significant role for county governments in the implementation of irrigation policies. County governments have a primary role in the deployment of agricultural extension services. However, intricacies surrounding water harvesting and storage have not explicitly been identified as functions of the county governments. Moreover, the Act provides for private sector, civil society organisations and user participation in irrigation planning and management. This can improve governance of the irrigation sector and provide incentives for investment in alternative water storage and efficient technologies. User participation in irrigation planning and management can improve access to information, enhance equitable allocation of water resources, reduce monitoring costs and promote accountability and oversight.

The Irrigation Act (2019) provides for establishment of bottom-up institutions such as IWUAs to maintain and operate irrigation schemes. However, the Act does not specify how IWUAs will share tasks with county irrigation development units and coordinate their mandate with the WRA and WRUAs. Until now, the relationship between the WRA and county governments is strained by competing institutional priorities. While the WRA is focused on sustainable water resource allocation and use, county governments place priority on water-intensive projects, such as expansion of community-based irrigation schemes. Effective implementation of irrigation Act (2019) would require established structures to coordinate relevant ministries and departments at national and county levels.

2.6.5 Agricultural Strategies

Agricultural policies are contained in sector strategies such as the Strategy for Revitalizing Agriculture (SRA) 2004 – 2014, Agricultural Sector Development Strategy (ASDS) 2010 – 2020) and the Agriculture Sector Transformation and Growth Strategy (ASTGS) 2018 – 2030). The dominant theme of these strategies is modernization and commercialization of agriculture.

2.6.5.1 Strategy for Revitalizing Agriculture (2004)

This SRA was adopted in 2004 to create a vibrant and market-oriented agriculture that would "achieve a progressive reduction in unemployment and poverty". The strategy took note of key challenges constraining agricultural growth, such as climate variability, inadequate extension service, improper land policy and land degradation; and proposed a raft of intervention measures. Key among these measures were: agricultural sector policy and legal reforms, research and extension services, improved access to financial services, promotion of agri-business and enhanced coordination among actors in the agriculture sector. The SRA was lauded as forward looking due to its strong focus on agricultural productivity in an economy with fast growing population and high levels of unemployment. However, the SRA did not sufficiently address challenges of environmental sustainability in a productive agricultural system. While it took note of land degradation as a key constraint to agricultural growth, it did not offer any concrete intervention in form of incentives and awareness programmes that could address this challenge or enable the uptake of sustainable technology and practices. In 2010, the SRA was reviewed and replaced with a ten-year ASDS, probably to align the agriculture sector with the *Kenya Vision 2030.*

2.6.5.2 Agricultural Sector Development Strategy (2010)

The ASDS set out to increase productivity, commercialization and competitiveness of agriculture (RoK, 2010c). The ASDS, just like its predecessor, took note of key challenges in the agriculture sector, such as low farm output, inadequate research and extension support, inadequate budgetary allocation, poor agricultural land use, price volatility and weak value chains. Among other key interventions, the ASDS prioritized irrigation, water development and river basin management. In prioritizing investment initiatives for irrigated agricultural development, the ASDS underscored the critical role of water harvesting and storage in productive and sustainable agricultural systems. Moreover, in recognizing poor land use as a constraint to agricultural productivity, the ASDS set out to enhance land productivity through catchment management, effectively highlighting the connection between land productivity in agriculture and environmental sustainability. Despite this recognition, the ASDS did not provide any concrete incentive to enable diffusion of appropriate small-scale irrigation technology, such as RWH, among farmers.

2.6.5.3 Agricultural Sector Transformation and Growth Strategy (2019)

The emerging realities and new global dynamics necessitated a review of the ASDS. In its place, Agricultural Sector Transformation and Growth Strategy (ASTGS) was developed to transform and align agriculture with the devolved framework of the Constitution (2010), the medium-term national agriculture sector priorities, and food security priority under the Big Four Agenda (2017-2022). The ASTGS is equally aligned with the regional commitments to the CAADP/Malabo Declaration, the AU Agenda 2063, and the 2030 sustainable development agenda. The ASTGS embraces evidence-based approach in managing agricultural challenges, and put county governments at the heart of transformation agenda. For this reason, the ASTGS prioritizes "research and innovation to guide decision-making and improve agricultural productivity".

The ASTGS places priority on three anchors to drive agricultural transformation: the first one focuses on "increasing farmer' incomes, the second on improving farm output and value addition, and the third on increasing household food security" (RoK, 2019). Nine flagship projects underpin these anchors: two flagship projects for each anchor, and three enablers that spread across the transformation. The first flagship project seeks to connect a million small-scale farmers to small and medium enterprises (SMEs) for “last-mile services”, such as farm inputs or marketing services. The second flagship sets out to “empower 1.4 million registered high needs farmers” to access farm inputs through a government subsidy programme. The third flagship seeks to establish “six large-scale agro- and food processing hubs through Public-Private-Partnership (PPP)”. The fourth flagship strives to “unlock 50 new large-scale private farms (more than 2,500 acres each)” with about 150,000 acres under sustainable irrigation. The fifth flagship project seeks to “restructure governance and operations of the Strategic Food Reserve (SFR)”; while the sixth one strives to boost food resilience for households in ASALs through community-driven interventions. The three flagship projects under enablers seeks to promote knowledge and skill programmes; strengthen research and innovation; and monitor food system risks “through sustainable and climate-smart natural resource management and rapid-response crisis management for pests and diseases, climate change and global price shocks”.

The agricultural transformation strategy is implemented through established government structures and ministries. A collaborative forum has been established to aid agricultural transformation agenda. The forum is chaired by the President and draws membership from Cabinet Secretaries from the following Ministries: Agriculture, Livestock and Fisheries (MoAL&F); Water and Irrigation, Devolution and ASALs; the National Treasury; Industry, Trade and Cooperatives; Environment and Forestry; Lands and Physical Planning; and Transport. The Agricultural Transformation Office (ATO) has been established to stimulate coordination among government actors. Accordingly, the ATO works with the Council of Governors to facilitate the domestication of the strategy at the county level. The institutional frameworks established to drive the agricultural transformation agenda demonstrate high level of political will and leadership from both levels of government. However, the envisaged transformation should not be viewed as a government-only issue. Private sector and civil society groups need to be brought on board to support extension and awareness programmes on scaling up the results.

The ASTGS is an ambitious evidenced-based national policy on agriculture. It is a strong shaping force for sustainable national economic growth and development, and incorporates several measures required to enable transformation towards a productive and sustainable agriculture. In particular, its emphasis on monitoring of food system risks, such as soil degradation and land use highlight a strong connection between agricultural productivity and environmental protection. In managing the food risks, the ASTGS pays specific attention to climate change and prioritizes sustainable development and management of water resources to provide adequate irrigation needs. It acknowledges the role of rainwater harvesting practices and technology in securing water availability for sustainable smallholder irrigation systems (RoK, 2019). Moreover, the ASTGS has established sophisticated structures to promote coordination among actors in the agricultural transformation agenda. While acknowledging the importance of coordinating units in enabling vertical and horizontal alignment of planning for agricultural transformation agenda, appropriate incentive is needed to enable uptake and diffusion of innovative agricultural technologies and practices. Measures that have been taken to promote agricultural transformation in past strategies have failed to incorporate incentive mechanisms for sustainable agricultural practices.

2.7 Gaps in Literature Review

Recent studies have highlighted the critical role of multi-level institutions and participatory approaches in water governance (Pahl-Wostl et al., 2012; Lienert et al., 2013; Mott et al., 2016; Mees et al., 2017; Buriti et al., 2018; Bertule et al. 2018; Hidalgo-Toledo et al., 2019. These studies propose frameworks for effective stakeholder engagement and suggest that water governance has become more polycentric. However, there is limited analysis of multi-level water governance and their impacts on diffusion of sustainable technology and practices in a river catchment.

The relationship between knowledge and practices in water management is well demonstrated (Gilbertson et al., 2011; Dean, Fielding, et al., 2016; Dean, Lindsay, et al., 2016; Rolston et al., 2017). However, farmers' knowledge, attitudes and practices in water resource management at the sub-catchment is not clearly understood; and neither is the influence of policies in addressing existing gaps in knowledge and practice.

Much of the literature review on RWH points towards increasing recognition of its social, economic and ecological benefits (Mutabazi et al., 2005; Biazin et al., 2012; Malesu et al., 2012; ATPS, 2013; Malik et al., 2014; Ngigi et al., 2014; Recha et al., 2014; Lasage & Verburg, 2015; Nicol et al., 2015; Rockström & Falkenmark, 2015; Jägermeyr et al., 2017; Girma et al, 2019). These studies show that RWH can alleviate water resource constraints to food production and ecosystems. While RWH can improve and stabilize agricultural productivity, it has not been adopted by many farmers who could derive such benefits. Past studies ignore governance frameworks required to improve uptake and replication of RWH technology and practices. Significant research on RWH pays much attention to technical issues, while ignoring the role of policy in technological change. Moreover, previous research on RWH is focused on investigating its significance in rainfed agriculture (Oweis & Hachum, 2001; Mati, 2007; Lasage & Verburg, 2015; Bouma et al., 2016) and domestic water supply (Ward, 2010; Mahmoud et al., 2018; Akuffobea-Essilfie et al., 2019; Sharma, 2019; Susilo, 2019). So far, there is limited understanding based on empirical work of the contribution of RWH technologies in improving the productivity and stability of smallholder irrigation systems in water stressed environments. Similarly, there is dearth of literature on utilization of on-farm water storage technology in smallholder irrigation systems.

A large body of literature examines farmers' preferences and WTP for irrigation management services (Chandrasekaran et al., 2009; Alcon et al., 2014; Bozorg-Haddad et al. 2016; Price et al., 2016). However, limited studies have estimated preferences and WTP for on-farm water storage technology particularly among smallholder irrigators. Moreover, very few studies have used choice experiments to estimate social and environmental benefits of on-farm water storage technology. Similarly, most studies examine socio-demographic factors and farm characteristics that influence farmers' WTP for improved irrigation water supply. However, there is limited empirical evidence how tenure rights could potentially influence WTP for RWH technologies. Hence, this study was designed to make a contribution towards bridging these gaps.

2.8 Theoretical framework

The theoretical structure informing this study is drawn from the diffusion of innovation theory which posits that adoption decision follows a rational analysis based on observed attributes of the technology and information made available to the individual through communication channels (Rogers, 1995). Diffusion of innovation is defined as "the process by which an innovation is communicated through certain channels over time among members of the social system" (Rogers, 1983, p.13). Although interrelated, diffusion and adoption are distinct. Whereas diffusion is the spatial and temporal spread of a new technology across a population, adoption is individual decision to use a new technology.

The diffusion of innovation theory is premised on assumptions that new technologies are taken up on the basis of rational individual choices, leading to a selection of improved and scale-appropriate technology (Rodgers, 1995). The new technology is assumed to be better than existing or previous ones. Additionally, personal encounter with a technology is assumed to be a dichotomous decision – adoption or non-adoption. On the basis of these assumptions, the diffusion of innovation theory relates adoption decisions to distinct and measurable technological attributes[2], individual characteristics, social systems and communication process (Rogers, 1995; 2003). Accordingly, the diffusion of innovation theory puts emphasis on four key elements: the innovation, communication channels, social system and time (Rogers, 2003). Rogers (1995) highlights the importance of personal knowledge in the adoption process, and considers it as the first step of a five-stage communication channels. The other stages are persuasion, decision-making, implementation and confirmation.

Diffusion of innovation is framed through the context of time which follows a normal distribution curve as new technology becomes mainstream. Subsequently, the following five adopter categories have emerged: innovators, early adopters, early majority, late majority, and laggards (Rogers, 1995; 2003). The curve shows a smaller percentage (2.5%) of innovators, small segment (13.5%) of early adopters, a large group (68%) of mainstream adopters (early and late majority) and a small portion (16%) of late adopters. Each category exhibits distinct demographic and psychographic characteristics. For example, early adopters tend be privileged in terms of income, education and access to communication channels.

The diffusion of innovation theory offers a framework that fits both formal and informal adoption environment. The theory has widely been applied to shape the implementation design of new agricultural technologies. Adoption and diffusion of an innovation in farming system depend on personal, social and economic considerations, and characteristics of the proposed technology. Farmers are likely to adopt a new technology when it is perceived to improve the achievement of a wide range of social, economic and environmental goals. The theory relates low adoption to failure of an innovation to provide a "relative advantage" and difficulties that farmers may encounter in trialling the technology (Rodgers, 2003). This implies that agricultural technologies that have a high "relative advantage" and readily "trialable" may be

[2] Innovation attributes are: "relative advantage, trialability, compatibility, adaptability, observability and complexity"

considered for adoption. In the context of this study, on-farm water storage technology is associated with a wide range of social, economic and ecological benefits which makes it superior to current farming practices in the Tsavo sub-catchment.

Despite its extensive application in adoption and diffusion of agricultural technologies, Rogers' diffusion of innovation theory is faulted for simplified conceptualization of the adoption. Rogers (2005) himself later acknowledged that a technology does not diffuse as a discrete entity, but reconfigured by adopters' knowledge, experiences and local contexts. Similarly, Lyytinen & Damsgaard (2001) and Glover et al. (2019) question the conception of technology as discrete entities capable of being diffused homogeneously across social system. They argue that innovation systems are complex reconfiguration of social, cognitive, epistemological, institutional and technical aspects. Bunclark et al. (2018) demonstrated dynamic nature of adoption of RWH technologies by farmers and dismissed the notion that adoption decision is dichotomous. They postulated that adoption process occurs along continuum corresponding to the degree or intensity of adoption. This implies that farmers can intensify, modify, abandon or replace a new technology over time. Brown and Keith (2007) explain that technology does not necessarily diffuse in serial stages. The adopters may discontinue the use of a technology, given their dissatisfaction with the experience.

Further theoretical development follows Jeffrey and Seaton's (2004) who refined Rogers' diffusion of innovation theory to explain how individuals learn about, accept and acquire innovation options. They argue that in analyzing individual encounter with a new technology, there is need to shift attention to priorities and capabilities of target population. Adoption process requires better understanding of potential users, particularly, their knowledge, skills, institutions and norms. In the context of this study, access to relevant knowledge and information can facilitate internalization of new norms and catalyze the uptake on-farm water storage technology. Similarly, communication pathways through which farmers become aware of the new technology can shape attitudes towards the innovation. This implies that effective awareness programmes can reduce the perceived “complexity” of on-farm water storage technology, increase its “observability” and “adaptability” and enhance its “adoptability”.

Jeffrey and Seaton (2004) propose four major phases of adoption: awareness, association, acquisition and application. While awareness can improve knowledge of on-farm water storage technology, intended users may fail to connect this knowledge to their needs and capabilities or lack capacities and incentives to adopt the technology. Farmer motivation for a technological change is subject to capabilities for change. This perspective places institutions and farmers at the heart of on-farm water storage adoption initiatives.

Additional theoretical modification based on social learning perspectives (Leeuwis et al., 2002; MacVaugh & Schiavone, 2010) explain how social actors – farmers, extension agents, researchers, scientists, entrepreneurs, manufacturers, policy-makers – interact to innovate and propagate a technology. This perspective acknowledges how actors interact to develop scale-appropriate configuration of technological practice. In this study, actors’ interactions and actions can improve access to relevant information and knowledge, offer incentives for adoption, and enhance ownership of, and trust in the proposed on-farm water storage technology.

The subsequent refinements of diffusion of innovation theory makes it more appropriate for understanding the adoption of on-farm water storage technology among smallholder irrigators in the Tsavo sub-catchment. The theory underscores critical role of information and knowledge in establishing new norms for technological change. Similarly, it highlights the importance of innovative water governance in the diffusion of on-farm water storage technology. The complex nature of technology adoption requires governance arrangements that integrates social learning for strengthening human capabilities, farmer engagement and institutional improvement. The diffusion of innovation theory identifies entry points for interventions required to scale up adoption of on-farm water storage technology, and improve and stabilize crop yield without depleting environmental flows.

2.9 Conceptual Framework

Global food demand is rising rapidly, as are freshwater withdrawals for agricultural expansion and intensification. While intensive freshwater withdrawal could improve food production levels needed to meet nutritional requirements, it poses dire consequences for sustainable development. The conceptual framework (Figure 2.2) shows the current state of affairs in the Tsavo sub-catchment, where farmers predominantly abstract surface water resources to supply irrigation needs. Under the "business as usual" scenario, there is uncertainty of irrigation water supply which ultimately leads to uncontrolled surface water abstraction, reduced downstream flows, water resource conflicts and unstable farm productivity and incomes.

The conceptual framework highlights proposed interventions for improved uptake of on-farm water storage technology. It begins with innovative water governance, an approach that integrates technological innovation, social learning, farmer engagement and institutional improvement. Effective engagement between farmers, governments, private sector and CSOs can improve access to knowledge and information, and create interest, responsibility and new norms. Engagement in water governance, therefore will determine what is known, believed and done in relation to water management. Due to effective engagement, irrigators will acquire knowledge of water issues through awareness and extension services, and persuaded to engage in sustainable practices. This will result to positive attitudes and decision to adopt on-farm water storage technology. This in turn will lead to implementation and confirmation of the technology by irrigators. An outcome is a sustainable sub-catchment which entails sustained environmental flows, reduced conflicts and stability in food production and incomes. The conceptual framework places priority on developing a framework for uptake of on-farm water storage technology which features actors' interactions in technology design and diffusion.

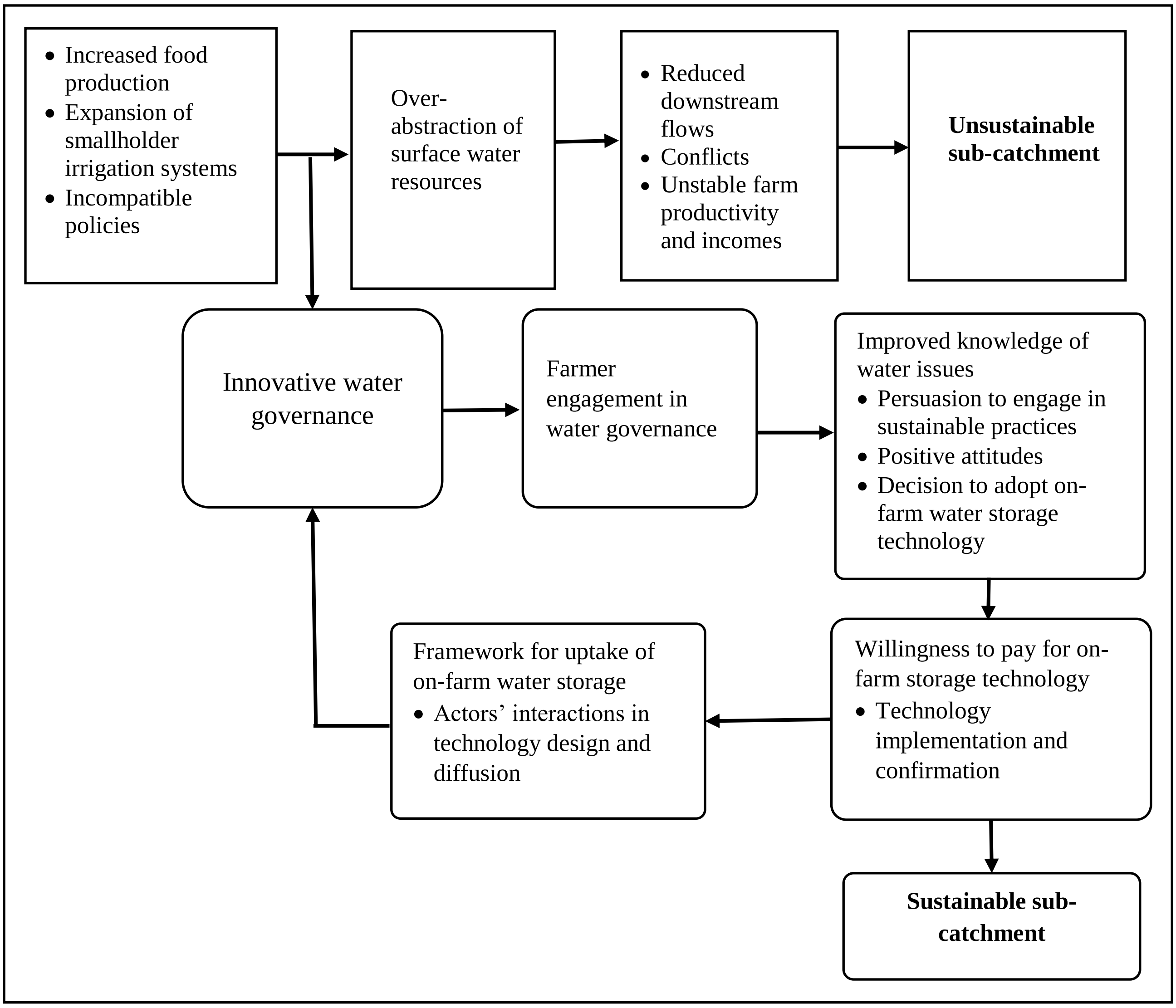

Figure 2.2: Conceptual framework showing uptake of on-farm water storage technology. The stages in technology adoption help in understanding the role of innovative water governance in enhancing access to knowledge and information, and creating social norms for sustainable practices

Source: Author

CHAPTER THREE: STUDY AREA AND METHODS

3.0 Overview

This chapter presents the geographical context of the study area and discusses the philosophical assumptions underpinning the research study. A mix of methods comprising qualitative and quantitative research approaches are used in this study. For this reason, both interpretivist and positivist research paradigms are deemed appropriate for this research. The chapter discusses various research approaches and their suitability to address specific research objectives. Quantitative household survey, and qualitative key informant interviews and focus group discussions (FGDs) are used in this study. The chapter concludes with sampling approaches, methods of data analysis and ethical considerations with regard to data collection.

3.1 Study Area

3.1.1 Position and Size

This study was carried out in the Tsavo sub-catchment of the Athi River basin, located in the southern parts of Kenya (Figure 3.1). It is situated between Longitudes 37°25´ and 38°32´ East and between Latitudes 2°28´ and 3°24´ South with an area of approximately 6,216 km^2. A larger portion of the sub- catchment is occupied by the Tsavo National Park, and Maasai and Taita group ranches. Tsavo River is the main perennial water course in the region. Most of the flows originate from natural springs and swamps, such as Nolturesh, Kimana, Namalok and Leinkati which drain the northern slopes of Mt Kilimanjaro. These natural wetlands are currently under siege from irrigated agriculture. Three community-based irrigation schemes in the sub-catchment were purposefully selected for this study: Kimana, Rombo and Njukini (Figure 3.1).

3.1.2 Physiographic and natural conditions

The Tsavo sub-catchment lies at the foot slopes of Mt. Kilimanjaro. Its lowest altitude is 411 m.a.s.l. at the confluence of Tsavo and Athi rivers, while the highest is 2198 m.a.s.l. on the northern slopes of Mt. Kilimanjaro (Jaetzold & Schmidt, 1983). The landscape is characterized by plains, valleys and volcanic hills. The sub-catchment has diverse geology and soil types such as volcanic rocks (basalts and phonolites) and cambisols (gravely to sandy-loamy of medium depth) in the upper catchment; Ferrasols (reddish, deep, and sandy-clay) in lower catchment; and vertisols, luvisols and fluvisols along river valleys and on wetlands (Jaetzold & Schmidt, 1983).

The Tsavo sub-catchment has five agro-ecological zones: sub-humid, semi-humid, semi-humid - semi-arid (transitional), semi-arid, and arid (Jaetzold & Schmidt, 1983; Sombroek et al., 1982). These zones are determined by rainfall, temperatures and potential evapotranspiration. The climate of the Tsavo sub-catchment ranges from arid to sub-humid, with mean annual rainfall of 1200 mm on upper catchment and 400 mm in the vast semi-arid lowland areas. The rainfall pattern is bi-modal, with long rains between March and May; and short rains between October and December. The elevation and orientation of topographical features, influence rainfall distribution over the sub-catchment (RoK, 2013c). Temperatures vary both with altitude and season; maximum temperature of 35°C is often recorded in February and March, while minimum temperature of 12°C is recorded in July and August. Spatial and temporal rainfall variability and high potential evaporation result in a net water deficit which affects socio-economic and ecological systems.

Vegetation consists of moist and dry forest in sub-humid areas on the slopes of Mt. Kilimanjaro and Chyulu hills; dry forest and moist woodlands in semi-humid zones; dry woodland and bushland in transitional zones; bushland in vast semi-arid zones; and bushland and scrubland in arid areas (Sombroek et al., 1982). However, patches and strips of riparian vegetation and riverine forests are common on natural wetlands and along riverbanks. The riparian vegetation consists of "*Cyprus immensus, Acacia xanthophlea, Salvadora persica, Acacia tortillis, Hanyne, and Commiphora woodlands"* (Okello & Kioko, 2011).

3.1.3 Demographic features

The population of the Tsavo sub-catchment is estimated at 290,471 (RoK, 2019). The population growth rate in the region is five percent, and among the highest in the country. This is largely attributed to migration from the neighbouring areas. (Ali et al., 2014; WRA, 2017). However, population distribution is uneven and largely determined by ecological potential, water availability and infrastructure. Thus, human settlements are concentrated around riparian areas, urban centres, and on the upper catchment.

3.1.4 Land and land use

Land is a critical resource to sustainable development. It is a factor of production and critical feature in politics and cultural expression (Juma & Ojwang, 1995; Boone et al., 2019). Kenya's land policy pay attention to land tenure as a pathway to achieving sustainable development goals, particularly those related to social cohesion, poverty reduction, women empowerment and ecosystem management (RoK, 2009). However, land management is still entangled in conflicts over ownership, access and control (Kameri-Mbote, 2016). While land conflicts are pervasive virtually throughout Kenya, it manifests itself in relative intensity and breadth across regions.

The Tsavo sub-catchment is one of the regions with deep seated land-related tensions and contestations. This is mainly attributed to colonial occupation and resultant appropriation of large tracts of land through group ranches and trust lands (Koissaba, 2016). Related to this is exclusion and highly discretionary decision-making by local elites to allocate land to powerful individuals (Hughes, 2005). Migration by neighbouring communities into the Tsavo region has led to endemic land sell-off (Koissaba, 2016) and subsequent encroachment on ecologically sensitive areas. Further efforts to promote productive uses of land through adjudication and allocation of small parcels of land to individuals, mainly settled farmers, as private property have compounded land conflicts in the region.

Although large areas of the Tsavo sub-catchment are taken by group ranches, wildlife conservation and pastoralism are the dominant land use in the vast semi-arid lowlands (KWS, 2008). Notably, the sub-catchment is dotted by pockets of thriving crop farming on the upper catchments and riparian areas in the lowlands (Ali et al., 2014; WRA, 2017). While crop farming is largely rainfed, irrigation is extensively practiced particularly in the lowland areas to bridge dry spells and extend growing seasons. The dependence on irrigation makes crop farming in this region more vulnerable to climate risks.

Under the prevailing land tenure arrangement in the Tsavo sub-catchment, most farmers cultivate their own land, while a considerable number rent agricultural land under tenure rights that permit the cultivation for a specified period (WRA, 2017). However, the farm rental agreements, including their impacts on farm efficiency and sustainable use of land and water resources remain obscure. Although, the state has the right to ensure sustainable utilization and management of land through the principle of police power, its exercise of this right is repeatedly been challenged in practice.

3.1.5 Irrigation systems

Over the past decades, the Tsavo sub-catchment has experienced haphazard spread of community-based smallholder irrigation developments with several dispersed points of surface water abstraction (KWS, 2008; Ali et al., 2014). Linked to excessive abstraction is water resource conflicts and resource degradation (WRA, 2017). During dry seasons, farmers abstract surface water by canals and pumps to supply irrigation needs (Ali et al., 2014). Surface irrigation techniques, such as furrow and basin systems are widely used to distribute water for irrigation. Water crisis in the sub-catchment is further compounded by weak regulatory regime and poor enforcement of water abstraction permit.

The construction of irrigation canals and thriving horticulture have led to uncontrolled abstraction of surface water resources and related deterioration of ecosystem services.

Subsequently, the regulatory frameworks on water resources management (WRMA, 2007) have incorporated on-farm water storage technology to improve water availability for irrigation while safeguarding environmental flows. Despite such efforts, there is low uptake of the proposed technology among irrigators in the sub-catchment.

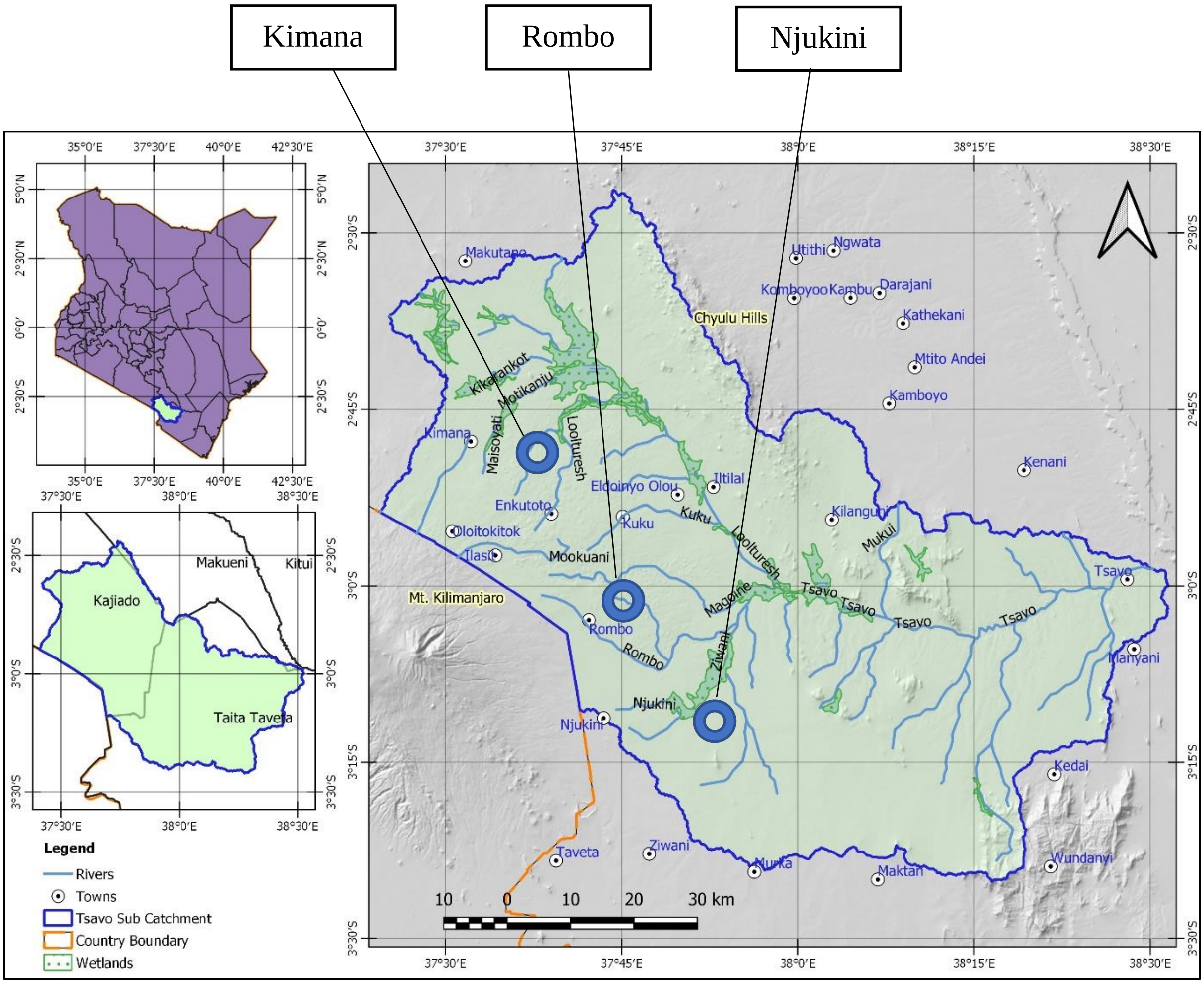

Figure 3.1: Topographical map showing Tsavo sub-catchment and location of sampled study areas – Kimana, Rombo and Njukini

***Source**:* Author

3.2 Research Philosophies and Paradigms

Philosophy is a set of beliefs and thinking about knowledge and how it is discovered or created (Saunders et al., 2009). Research philosophy shapes the reasoning of researchers in the production of knowledge and therefore, has a significant influence on research process and outcomes. Paradigms, on the other hand, is a "set of assumptions or ways thinking about some aspects of the world" (Oates, 2006). Research paradigm therefore, is a set of beliefs, values and assumptions adopted by researchers in the process of an inquiry (Jarvie et al., 2011).

Research methods are based on philosophical foundations of ontology, epistemology and axiology. Ontology is the branch of philosophy that studies the nature reality (Richards, 2003). It is concerned with the existence of nature, and inquires whether objects of nature exist in themselves independent of human understanding (Keating & Porta, 2008). Epistemology, on the other hand, is the branch of philosophy that studies the nature of truth, particularly with regard to the process of acquiring and validating knowledge (Saunders et al., 2009). As such, epistemology sets the standards and procedures for data collection and analysis. Axiology is the branch of philosophy that studies values. Scientific research is conducted in the background of values which influence decisions to undertake certain studies and to keep in sight ethical obligations that accompany methodologies of collecting data related to human persons (Jarvie & Bonialla, 2011).

Ontological foundations have two contrasting claims about the nature of reality categorized as realism and idealism. Realism assumes that objects of nature exist in themselves independent of human understanding. This implies that reality is external, predetermined, structured and can be discovered through experience (Saunders et al., 2009). Idealism, on the other hand, assumes that reality is socially constructed and varies from one individual, culture and period to another (Haigh et al., 2007). These contrasting claims – realism and idealism – have implications for epistemology. The realist perspective accounts for an objective approach to knowledge while the idealist perspective implies a subjective approach to knowledge.

Objectivism, assumes that knowledge is external and can be discovered through observation and measurement (Richards, 2003). In this way, facts and figures are extracted to make generalizations and propose theories. Thus, objectivism is aligned with positivism and quantitative research techniques which strives to "understand the social world in the same way as the natural world". In this way, positivists exclude themselves in the research process in order to observe the reality from unbiased standpoint. In this sense, positivists do not influence the research process (Saunders et al., 2009). Subjectivism, on the other hand, is associated with interpretivism and qualitative research techniques. This paradigm assumes that knowledge is created, and not discovered (Richard, 2003). Interpretivists therefore, do not isolate themselves from the phenomena under investigation – they immerse into the world of the research subjects to extract their personal understanding of reality. Interpretivist focuses on unquantifiable data such as attitudes and behaviours that could enable or hinder implementation of environmental policies (Repko, 2012).

The epistemological position taken for this study is a mixed approach where both qualitative and quantitative techniques are used. Mixed methodology was preferred to benefit the phenomenon of investigation from the strengths of both quantitative and qualitative research paradigms. Water resource governance challenges are complex. In order to develop a governance framework for improved uptake of on-farm water storage technology from the study findings, quantitative data alone may limit the ability to understand and resolve value concerns applicable to technological change. The methodology, therefore involved quantitative survey with limited qualitative aspects.

3.3 Research Methods

3.3.1 Data types and sources

This study employed a mix of methods comprising qualitative and quantitative research approaches. Primary data was collected through household survey with irrigators, interviews with broad array of key informants drawn from county and national levels, and focus group discussions (FGDs) with WRUAs and farmers. Household survey was undertaken using semi-structured questionnaires, while interview schedules were used in key informant interviews and FGDs. Secondary data was derived from scholarly and professional literature and relevant policy and legal publications. The data used in this study and their sources is shown in the *Table 3.1*.

Table 3.1: Summary of data set and sources

Data Set	**Possible Sources**
Water resources data	Water Resources Authority (WRA) and Water Resource Users Association (WRUAs)
Socio-economic data	Household survey using semi-structured questionnaires; key informant interviews (WRUAs, National and County governments, WRA, private sector, CSOs), FGDs and literature review
Policies and legislations	Ministries of Water; Agriculture, Livestock and Fisheries (MoAL&F); Environment and Forestry; Devolution and Planning; WRA

Three research tools were used to address the research objectives:

i. Knowledge, Attitudes and Practices (KAP) model
ii. Choice experiment
iii. Water governance assessment tool (GAT)

3.3.2 The KAP survey model

This study undertook KAP survey to assess farmers' knowledge, attitudes and practices in water resources management. The survey was conducted face-to-face using semi-structured questionnaires (see Appendix 3). A KAP survey is a "quantitative study that gathers information on what is known, believed and done in relation to a particular issue" (Caribbean Institute of Media and Communication [CIMC], 2012; Tran et al., 2018; WHO, 2008). Water management challenges are complex and partly attributed to human activities. In this sense, pursuing change of attitudes and behaviours necessitates insight into "what is known, believed and done" relative to water management. KAP studies are therefore useful in revealing misunderstandings or misconceptions that may hinder policy implementation; and in identifying most effective ways to educate the public on sustainable water management issues. Moreover, KAP studies can establish baseline indicators for evaluating impacts of water policies.

The variables of knowledge, attitudes and practices in water management were adapted from past studies (Dean, Lindsay et al., 2016b; Tran et al., 2018; Warner et al., 2018; Paneque et l., 2018, Okumah et al., 2019). In the context of this study, knowledge of water resources management refers to farmers' understanding of IWRM principles. Their responses were tested and rated on a likert scale of 1 to 4 where 1 was 'No understanding', 2 was 'Poor', 3 was 'Average', and 4 was 'Good'. Attitudes towards water resources management was defined as inclination to undertake specific sustainable practices in water management, which include: (i) soil conservation, (ii) water and land pollution reduction and (iii) adoption of on-farm water storage technology. The respondents were provided with these options and asked to provide a "Yes/No" answer. The Practices in water management were categorised into two: water resource management measures (i.e. (i) collaborative water management, (ii) on-farm water storage technology and (iii) compliance with water abstraction permit); and adjustments in irrigation water use in response to water scarcity (i.e. (i) use of boreholes for supplemental irrigation, (ii) reduction of farm size under irrigation and (iii) suspension of irrigation farming). Several models were evaluated for their suitability in predicting the determinants of knowledge, attitudes and practices, and two models were selected to aid in the task and they are discussed below.

Variables on likert scale are considered ordinal and the kind of regression model that is typically used in analysing them is the ordered logistic regression. If an ordinal response let's say Y which has a c levels, such that $(1, \; \ldots.., \; c)$, and $X = (x_1 \;\; , x_2 \; \ldots , x_p)'$ be a vector of p explanatory variables (i.e. the factors that influence the respondents understanding of IWRM principles); then an ordered logistic regression model will describe the relationship between Y and X via $c-1$ logit equations:

$$g_1(X), g_2(X), \dots, g_{c-1}(X)$$

The logits relate a set of intercepts $(\alpha_s)$and regression coefficients (βs) to the probability of the response categories.

The attitude and practice components of the KAP study had binary outcome variables coded as either a "1"for a Yes or "0" for a No response; therefore, binary logistic regression was employed to help identity factors that influence these components of the KAP study, and the directions they take. Binary logistic regression is a statistics technique for the case of dependent variables of two outcomes. It expresses the probability of the occurrence of a dependent variable as a function of the independent variables. Logistic regression takes an equation of the form:

$logit(p) = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + \cdots + b_kX_k$, where p is the probability of presence of the characteristic of interest. Knowledge comprised of ordered responses, while attitudes and practices comprised binary responses. These three dependent variables were regressed against a number of independent variables as described in Table 3.2.

Table 3.2: Variables used in ordered and logistic regression analysis to estimate predictors of knowledge, attitudes and practices in water management

Dependent variable	**Type**	**Questions**
Knowledge	Ordinal	Rating the understanding of IWRM principles on a four-point likert scale: No Understanding, *labelled 1*; Poor, *labelled 2*; Average, *labelled 3*; and Good, *labelled 4.*
Attitudes	Binary	Performance of the following activities: soil management, pollution control, on-farm water storage (1: Yes, 0: No)
Practices i. Measures taken to manage water resources	Binary	Participation in the following activities: collaborative governance, on-farm water storage and abstracting within permitted levels (1: Yes, 0: No)
ii. Response to water scarcity	Binary	Response to water scarcity: use boreholes, reduce size of land under irrigation or suspend irrigation (1: Yes, 0: No)
Independent variables	**Type**	**Questions**
Occupation	Categorical	Respondent' principal economic activity: Crop farming, 1; Business, 2; pastoralism, 3; formal employment, 4; or casual employment, 5
Income	Categorical	Average monthly income (Ksh.): up to 10,000, *labelled 1*; 10,001 – 30,000, *labelled 2*; 30,001 -50,000, *labelled 3*; or over 50,000, *labelled 4*
Membership to network	Categorical	Respondent' membership to a network: Environment, 1; social, 2; or economic, 3
Access to credit	Binary	Respondent access to credit (1: Yes, 0: No)
Farmer workshops	Binary	Respondent participation in farmer' educational workshop/seminar (1: Yes, 0: No)
Access to extension	Categorical	Respondent access to extension services: Government, 1; private, 2; and none, 3
Farm distance from water source	Categorical	Distance from farm to the nearest river/stream: Less than 1 km, *labelled 1*; 1-3km, *labelled 2*; 4-5km, *labelled 3*; and over 5km, *labelled 4*
Type of land ownership	Categorical	Type of land ownership: Private (1: Yes, 0: No); communal (1: Yes, 0: No); leasehold (1: Yes, 0: No)
Length of residency	Categorical	How long has the respondent lived in his community? Less than 10 year, *labelled 1*; 11-20 years, *labelled 2*; 21-30 years, *labelled 3*; and over 30 years, *labelled 4*

3.3.3 Choice experiment (CE)

3.3.3.1 Selection of attributes

Choice experiment comprises a series of cyclic steps: the first one entails the selection of the relevant attributes and levels, and the second step is the experimental design where specific attributes and levels were combined using the statistical design theory to generate alternatives (Altobelli et al., 2018). This was followed by the construction of choice sets, questionnaire development and sampling design (Mukhopadhyay et al., 2017).

The selection attributes of on-farm water storage technology begun by literature review on the universally known factors that influence farmers' decisions to adopt a new or alternative technology. This was followed by focus group discussions and interviews with key informants drawn from farmer' groups and water resource experts. The discussions involved an analysis of what would be required to scale up on-farm water storage systems among smallholder irrigators. It also entailed quantification of benefits obtained from the ecosystems and then a scoring system of listing the services in order of priority. Issues related to equity, efficiency and sustainability in water allocation and distribution were some of the key themes from these discussions. In this study, six attributes and levels of on-farm water storage technology were selected. The first one was the cost of the technology expressed as a price (Ksh/acre.) of installing on-farm water storage and drip irrigation system. The costs of setting up the technology was one-off and ranges from Ksh 300 -1000 per m^3 of rainwater collected, stored and utilized (Ngigi et al., 2015). Depending on site conditions, costs ranging from Ksh. 190,000 – 350,000/household/acre were proposed for 250 m^3 on-farm water storage. The second attribute was stability in productivity and incomes, the third one was the quantity of irrigation water, while the fourth attribute was the quality of water for domestic use and ecosystems (Table 3.3). The fifth attribute was related to the level of occurrence of water resource conflicts under different policy options. The last attribute was the water user fees paid by farmers expressed as the cost (*Ksh 0.5/m^3 for the first 300m^3/day and Ksh. 0.75/m^3 for above*

300m³/day) of abstracting a specific amount of water for irrigation in compliance with water permit.

Table 3.3: List of attributes and attribute levels of a choice set.

Attributes	Description	Levels
Cost (Ksh)	The installation cost of on-farm water storage technology (a 250 m^3 on-farm storage and drip irrigation system)	Ksh. 350,000 Ksh. 270,000 Ksh. 190,00 *Ksh. 0*
Stability in production and income	Frequency and consistency in farm output and income throughout the year due steady supply of water for irrigation	Stable, *Unstable*
Water quantity	Reliability of irrigation water supply	Abundant, Moderate, *Declining*
Water quality	Water quality for domestic use and ecosystems	Good Average *Deteriorating*
Conflict	Frequency of water related conflicts among irrigators, between water user groups (upstream vs. downstream), between irrigators and water authority and between water users and conservationists	None, Occasionally, *Common*
User Fees	The fees that users of natural water sources such as streams and boreholes pay to the water regulatory authority on monthly basis	Ksh. 600/month Ksh. 300/month Ksh. 150/month *Ksh.0/month*

Italics indicate status quo or business as usual

Three policy options were considered: an opt out option (status quo) which entails the current state of affairs in which farmers predominantly use local streams to supply irrigation needs (i.e. there is uncertainty of irrigation water supply and access to good quality water for domestic use and ecosystems is limited; water resource use conflicts are not uncommon; most irrigators are engaged in illegal abstraction and few compliant ones pay water user fees. Two other generic choice options, A and B were selected. While *option B* entailed partial use of local streams alongside an on-farm water reservoir, *option A* was a full-time use of on-farm water storage for irrigation.

3.3.3.2 The experimental design

The experimental design is defined as the "process of generating specific combinations of attributes and levels that respondents evaluate in choice questions" (Altobelli et al., 2018; Whitty & Kauf, 2013). In this study, the attributes and their levels were combined using statistically efficient design to generate choice alternatives. The design theory is statistically efficient in terms of predicted standard errors of the parameter estimates. In this respect, it is superior to orthogonal designs that are fundamentally focused on inspecting the correlations between the attribute levels (Choice Metrics, 2014). In using the efficient design to generate choice alternatives, a pilot study was conducted with 27 farmers who were randomly interviewed using orthogonally designed choice cards generated by *Ngene* software. The collected data was analyzed and the resulting coefficients were used as priors to generate efficient choice sets. In particular, a multinomial logit model was used together with D-error measure to find an efficient design. It is important to state that the status quo option was not assigned any parameters even though it was entered in the design.

The development of efficient design usually involves the generation of full factorial results which is a permutation of the levels, attributes and alternatives, and for this study that would typically result into $(2^3 x\ 3^2)^2$ excluding the status quo. This number was deemed too large to administer given resource constraints and the potential of cognitive burden. This necessitated adoption of the fractional factorial in which the total choice sets were capped at 12 and blocked into 4 groups so that an individual would respond to four choice sets, culminating into three sub samples for the study (Table 3.4). The multinomial logit model was used together with D-error measure to generate the efficient design. Constrains were also imposed to ensure that the resulting choice sets were as realistic as possible, for instance the water user fees that farmers were to pay was always consistent with cost of on-farm water storage systems that translated into whether or not they would abstract water from the surface streams.

Table 3.4: An example of the choice set of alternatives.

Attributes	**Option A**	**Option B**	**Status Quo**
Cost of Initial investment in on-farm water storage technology (a 250 m^3 on-farm storage and drip irrigation system)	Ksh, 350,000	Ksh. 270,000	Ksh. 0
Stability in Crop Production & Income	Stable	Stable	Unstable
Quantity of Irrigation Water	Abundant	Abundant	Declining
Quality & Quantity of Water for Ecosystem Services & Domestic Use	Average	Good	Deteriorating
Conflict	None	Occasionally	Common
User Fees per Season	Ksh. 0	Ksh 150	Ksh. 600
Option Chosen (tick one only)			

3.3.3.3 Empirical framework

In Choice Experiments, individuals select between several "bundles of products, services or technology" characterized by different attributes and levels. The utility U that individual i gains from the choice j is made up of an observable deterministic component V (the utility function) and a random component ε (unexplained consumer utility) and is defined as follows:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \qquad (1)$$

where;

U_{ij} represents utility derived for the consumer (e.g. the farmer) i for option j;

V_{ij} is an attribute vector representing the observable component of utility from option j for farmer i;

ε_{ij} is the unobservable component of latent utility derived for farmer i from option j

Based on this expression, the utility function of an individual can be disintegrated into a systematic and a stochastic part. The individual is assumed to have a utility function as expressed below:

$$U_{ij} = V(X_j, Z_i) \quad (2)$$

Utility derived from on-farm rainwater storage systems is assumed to depend on the attributes of that option X_j and the socio-economic and institutional characteristics of the farmer Z_i (Cascetta, 2009). However, the econometric justification for this random component is that the farmer may omit variables or commit measurement errors; the farmer may be inattentive to the particular decision (Adamowicz et. al., 1998). To explain such variations in choices, a random element, ε is included as a component of utility function. Equation 3.2 can then be re-written as:

$$U_{ij} = V(X_j, Z_i) + \varepsilon(X_j, Z_i) \quad (3)$$

The presence of random component permits the description of the probability of selecting alternative j among a set of options k as follows:

$$Pr[i|CS] = Pr[U_j > U_k], \quad \forall j \in CS \quad (4)$$
$$= Pr[(V_j + \varepsilon_j) > (V_k + \varepsilon_k)]$$
$$= Pr[(V_j - V_k) > \xi]$$

Where C is the set of all possible alternatives (Adamowicz et al, 1994).

A key fundamental objective of choice applications to determine the preferences and willingness to pay of the target population in a study. The marginal willingness to pay (MWTP) for each attribute is calculated as the ratio between the negative of the coefficients of each attribute and that of price attribute (Gan & Luzar, 1993). When comparing two attributes with the cost included as the denominator in trade-off calculations, MWTP is estimated as shown in equation 5 (Ryan et al, 2008).

$$MWTP_i = \frac{dx_i}{dU_{Time}} = \frac{dx_i}{dt} = \frac{\beta x_i}{-\beta_t} \qquad (5)$$

3.3.4 Water governance assessment model

The study used Governance Assessment Tool (GAT) to appraise the implications of water governance on sustainable utilization on water resources in the Tsavo sub-catchment. The GAT is a "matrix" model (Table 3.5) comprising of five governance dimensions and four quality criteria (Bressers et al., 2013; Kuk, 2012). The governance dimensions are: levels and scales, actors and networks, problem perspectives and goal ambitions, strategies and instruments and responsibility and resources. These dimensions are based on the assumption that governance has a multi-level character for all scales, multi-actor character for relevant networks, multi-faceted character for problems and ambitions, multi-instrumental character for actors' strategies and complex multi-resource basis for implementation (Kuks, 2012; Lordkipanidze et al., 2019).

To shed light on whether governance dimensions are supportive or restrictive to policy implementation, GAT model uses four quality criteria: extent, coherence, flexibility and intensity. The extent is the "completeness" of the regime in terms of levels and scales, diversity of actors, problems and goals, instrumental strategies, and responsibilities and resources (De Boer, 2012). Coherence refers to the level of integration in the governance network. It presumes that different levels of governance are mutually dependent, and strengthen rather than weaken each other (De Boer, 2012; Flores et al., 2016). Flexibility is the level in which "inter-regime elements support and facilitate adaptive actions and strategies" (Boer & Bressers, 2011). It proposes the use alternative trajectories in the face of opportunities or threats to policy implementation (Boer & Bressers, 2011). Intensity is the "degree to which the regime elements strive for a deviation from the status quo" (Boer & Bressers, 2011, p.94). Greater intensity can either invite resistance or provoke enthusiasm for reforms.

Table 3.5: Water governance matrix consisting of five governance dimensions and four quality criteria, and evaluative questions of the Governance Assessment Tool

Governance dimensions	**Quality of governance criteria**			
	Extent	Coherence	Flexibility	Intensity
Levels and scales	What are the levels/scales of water governance in the sub-catchment? Are all levels/scales involved	How do these levels/scales interact with one another? Are they mutually dependent?	How adaptive are governance levels to opportunities or threats to water resource management?	Is there any strong deviation by a particular level of governance from "business as usual"?
Actor and networks	Who are stakeholders in the sub-catchment water governance?	What is the level of interactions among diverse actors in sub-catchment water governance?	Is it practicable to engage new actors or shift them when there are opportunities or threats to policy implementation	Is there any strong deviation by a particular actor or actor group from "business as usual"?
Problem perspectives and goal ambitions	What are the problem perspectives and goals ambitions?	Do the institutional goals support or contradict each other?	To what extent can institutional goals be re-assessed to address new challenges or take advantage of opportunities?	How does goal ambition deviates from "business as usual"?
Strategies and instruments	What strategies and instruments are applied in water resources management?	To what extent do the existing strategies and instruments create synergy and promote integration?	Are there prospects to blend or use different types of strategies and instruments to achieve specific outcomes?	To what extent are the strategies and instruments able to enforce a deviation from status quo?
Responsibility and resources	Are mandates clearly demarcated and facilitated with adequate resources?	How does institutional mandate enable or hinder interaction?	Is it possible to pool resources to support integrated objectives?	Are the resources sufficient to implement targeted reforms?

***(Source:** Moderated from Boer et al., 2013; Bressers et al., 2016; Flores et al., 2016)*

The evaluation of five governance dimensions on the basis of four quality criteria provides an understanding of how the governance context enables or restricts implementation of policies and other resilience measures. On this basis, the GAT defines governance as:

> *"the combination of the relevant multiplicity of responsibilities and resources, instrumental strategies, goals, actor-networks and scales that forms a context that, to*

some degree, restricts and, to some degree, enables actions and interactions" (Bressers et al., 2013, p.6)

The GAT has been widely applied in multi-level water governance arrangements to draw attention to conditions that enables or hinder implementation of water policies and resilience measures (Bressers, 2015; De Boer, 2012; De Boer & Bressers, 2011; Flores et al., 2016). The GAT as applied in this study is consistent with OECD governance assessment tools (OECD, 2015).

Water governance context in the Tsavo sub-catchment was analyzed inductively on the basis of key informants' responses and a review of relevant policy and legal publications. The results for each governance criteria were ranked as low, moderate or high and graded as restrictive, partially supportive or supportive. In addition to GAT, stakeholder analysis was used in this study. Stakeholder analysis is a qualitative technique used to identify, differentiate and classify stakeholders, and assess the strengths of interactions in a governance network. The categorization of stakeholders in the Tsavo sub-catchment was based on functional roles and relevance in water resources management. Information related to their interest and influence on water resource governance was obtained from FGDs.

In the context of this study "interests" in sub-catchment water governance relates to how stakeholders use water resources for social, cultural and economic activities, and other environmental considerations; as well as the statutory obligations of specific stakeholders in ensuring sustainability, equity and efficiency in resource use. "Influence" on the other hand, is the "scale of resources – human, financial, technological, or political – available to a stakeholder and its ability to mobilize them. This may determine the level of power with which a stakeholder can support or oppose a policy". Therefore, influence" can be defined by the statutory mandate; extent of resources committed in, and duration of involvement in water governance; and existing rights to water resources within the basin (Ogada et al., 2017). Stakeholder interaction was elaborated as the direct links through information sharing and social learning.

Stakeholder analysis categorizes stakeholders according to their levels of influence and interests in water resources governance. This categorization is informed by Reed et al. (2009) who distinguished water actors into four categories: "*Players, Subjects, Crowd, and Context Setters".* Stakeholders with high influence and interest in water resources decision-making are known as Players. Subjects exhibit "high interest but low influence" and can organize themselves into coalitions to increase their bargaining power. Context Setters have "low interest but high influence" while Crowd has "low interest and low influence". Stakeholder analysis is widely used in natural resource management research to address complex governance challenges, such as those inherent in water resources (Yang et al., 2018).

3.3.5 Sampling and sample size determination

A combination of purposive sampling and multi-stage random sampling techniques were used in this study. Purposive sampling was used to select three study areas (community irrigation schemes) – Rombo, Njukini and Kimana – based on land tenure and spatial locations. Multi-stage sampling and simple random sampling techniques were used to select irrigation villages and households where questionnaire survey was administered. The target population for this survey was the smallholder irrigation farmers in the Tsavo sub-catchment. The sample size in each study area was determined by the estimated number of irrigators as provided by respective WRUAs. Slovins's formula was used to obtain the representative sample that would give a margin of error of 0.05 accuracy. The formula is represented by following equation:

$$n = N/(1 + Ne^2)$$

Where:

n is number of respondents,

N is total population, and

e is error tolerance level

Based on about 2,000 households in three sampled irrigation schemes, 279 (123 in Rombo, 94 in Kimana and 62 in Njukini) respondents were selected for this study. For choice experiment, this sample size is highly acceptable because 4 choice sets each were provided to each respondent.

3.3.6 Data collection

Research assistants were recruited locally in consultation with WRUAs in each study area. A one-day training session was held for research assistants before commencing household survey to take them through interviewing techniques, choice modelling questions and selection of respondents for the study. The questionnaire comprised of five sections *(see Appendix 3)*. The first one was the consent form which introduced the prospective respondents to the study objective and sought their permission to engage in the survey. It had ethical guidelines in which respondents were informed that their participation in the study was not presenting any risk or benefit and that there were no personal details such as names that would be reported. The second section comprised of warm-up questions introducing the respondents into the study in which their familiarity with the sub-catchment was sought and if they have experienced water scarcity in the recent past. The third section contained KAP questions which sought to assess farmer knowledge, attitudes and practices in water management. The fourth section contained choice experiment questions that were introduced by creation of a hypothetical market for on-farm water storage technology, explaining the attributes, their levels and the payment vehicle and the cards from which only one alternative out of the three policy options available was required. It also contained debriefing questions which sought to establish possible reasons that informed respondent's choices. The final section had demographic and socio-economic questions whose purpose was to check if they play any role in influencing farmer knowledge, attitudes and practices in water management; and preferences and WTP for on-farm water storage technology or maintain the status quo.

While the household survey was a key technique for data collection, key informant interviews and FGDs were by used in this study. Key informant interviews were focused on getting insights into policy and institutional contexts for uptake of on-farm water storage technology *(see Appendix 4).* It also sought to provide information on key themes arising from household survey and data analysis. Key informants were drawn from agencies and departments of the national government, county governments, local NGOs, and WRUAs (Table 3.6).

Table 3.6: Organisations represented in key informants' interviews

Organisation Type	**Name of the Organization**
Agencies and departments of national government	• Water Resources Authority • Kenya Wildlife Services • Kenya Forest Services • Ministry of Water and Irrigation • National Government Administration • Ministry of Agriculture • The National Environment Management Authority
County governments	• County government of Kajiado • County government of Taita Taveta
Local NGOs	• Wetland international • Centre for Social Planning and Administrative development (CESPAD)
Water Resource Users Associations	• Ilkisonko • Nalepo • Lumi • Kajiado WRUA Council

Purposive sampling was used to select the key informants. The target sample size for each organization was at least one informant depending on the relevance of the organization and level of access to informants. Moreover, three FGDs with 10 – 15 participants were undertaken with WRUAs and farmers to explore institutional context, farmers' knowledge of water policies and related practices, and perceived benefits and costs related to uptake of on-farm water storage technology. A ten-point semantic differential response scale was used to quantify the perceived interests and influence of various stakeholders on sub-catchment water governance *(see Appendix 5).* The semantic differential scale was in the range of zero (0) (no influence or interest) to 10 (very high influence or interest). The focus group was required to discuss and state the main interest of stakeholders, their level of interactions with WRUAs and WRAs, and level of interest and influence on sub-catchment water governance on a scale of 0 – 10. Secondary data on water resources management, RWH, environmental valuation, multi-level water governance, stakeholder processes, water and agriculture policies, laws and institutional structures for water resources management was derived from scholarly and professional literature, legal publications, and reports.

3.3.7 Data analysis

The analysis entailed descriptive statistics for the socio-economic characteristics of the respondents. A "one-way analysis of variance (ANOVA)" was applied to compare household variables between three study locations: Kimana, Rombo and Njukini community irrigation schemes. Such variables included age of household heads, level of education, household income and farm sizes under irrigation. Chi-square ($\chi 2$) test was used to inspect for relationships between variables of knowledge, attitudes and practices in water management issues and socio-economic characteristics. Predictors of farmer knowledge, attitudes and practices in water resources management were estimated using ordered and logistic regression models.

Farmers WTP for on-farm water storage technology and factors influencing their preference of either the current practice of drawing irrigation water directly from the springs and local streams, paying for complete or partial shift to on-farm water storage technology was analyzed and modelled using conditional logit and alternative specific conditional logit. Conditional logit model estimates the attributes variables only (Hole, 2013) but it can also include interaction terms and be used to estimate respondent specific characteristics. There was multi-collinearity in two alternative specific variables namely: the variable on stability for crop production and incomes, mainly because it was constant for both alternative A and B; the variable water user fees to be paid by farmers abstracting water from springs was also collinear. Investigation revealed that it measured the same thing with the variable on cost of installing on-farm water storage technology. This cost was introduced to make the experiment as realistic as possible. If there was no cost of installing an on-farm water storage technology, then farmers would abstract surface water sources and pay water user fees. However, if farmers fully adopt on-farm rainwater storage technology, they would not pay any water user fees. These two variables – water user fees and stability in crop production and incomes – were therefore not used in the final analysis to avoid the effects of multicollinearity. The marginal WTP values were obtained through division of the cost coefficient by the negative coefficients of each of the attributes considered in the study.

Qualitative data was coded and analyzed by themes according to the study objectives. This involved categorizing data in terms of research questions and emergent themes. Coding was used to reduce and organise collected data from key informant interviews and FGDs in order to develop an analytical structure. Following the coding process, content analysis was undertaken to interpret the data. Additionally, stakeholder analysis was used to evaluate micro-level governance in the sub-catchment.

3.3.8 Ethical considerations

The permission to administer household survey and undertake key informant interviews was consensual. If the respondents showed discontent, the interviews were re-scheduled or cancelled. The respondents were informed beforehand that should parts of their interview be used in a publication, their personal details would be kept confidential.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.0 Overview

This chapter presents the results of the household survey, qualitative key informant interviews and FGDs, and secondary data analysis following the methodology outlined in Chapter 3. The results are discussed in relation to the literature review and research questions. The study findings for each study objective are explained and interpreted within the context of existing scholarly literature and other relevant knowledge. The results are presented in six sections: the first one presents the socio-demography of the study population, the second addresses the perceptions on the Tsavo sub-catchment's environmental status, and the third section shows the knowledge, attitude and practices in water management. The fourth section provides the results on farmer' preferences and WTP for the attributes of on-farm water storage technology, the fifth presents micro-level water governance assessment results, and sixth one models a governance framework for uptake of on-farm water storage technology.

4.1 Socio-demography of study population

A total of 279 respondents from the Tsavo sub-catchment were interviewed. One hundred and ninety-eight (71%) belonged to male-headed households, while eighty-one (29%) were female-headed (Table 4.1). The sex ratio of the household heads for Rombo (40:100) Kimana (41:100), and Njukini (42:100) was significantly different from 1:1 ($p < 0.001$).

Table 4.1: Gender distribution of respondents according to irrigation schemes

Variable		**Community irrigation schemes**						**Regional average**	
		Rombo (n = 123)		**Njukini (n = 62)**		**Kimana (n = 94)**			
		n	%	n	%	n	%	n	%
Sex	Males	88	71	44	71	66	70	198	71
	Females	35	29	18	29	28	30	81	29

The mean age of the respondents in Rombo (42.3 ± 0.3), Njukini (44.8 ± 0.5) and Kimana (44.4

± 0.5) community irrigation schemes was not significantly different *($F = 0.904$, $p = .406$)*. The youngest farmer was 21 years old while the oldest was 76 years. Sixty three percent of respondents were long term residents having lived in the sub-catchment for more than 20 years. Only 15% were new immigrants having lived in the area for 10 years and below (Figure 4.1).

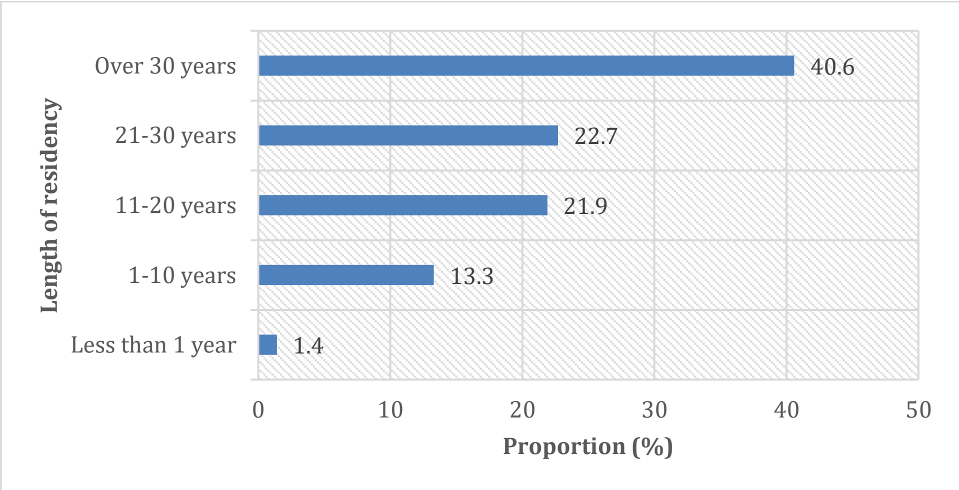

Figure 4.1: The distribution of respondents by length of residency in the sub-catchment

Forty-three (43%) of the respondents had secondary and tertiary education (Figure 4.2). Gender disparities in the attainment of education at different levels of schooling was not statistically significant *($P=0.398$, $F= 5.148$)*.

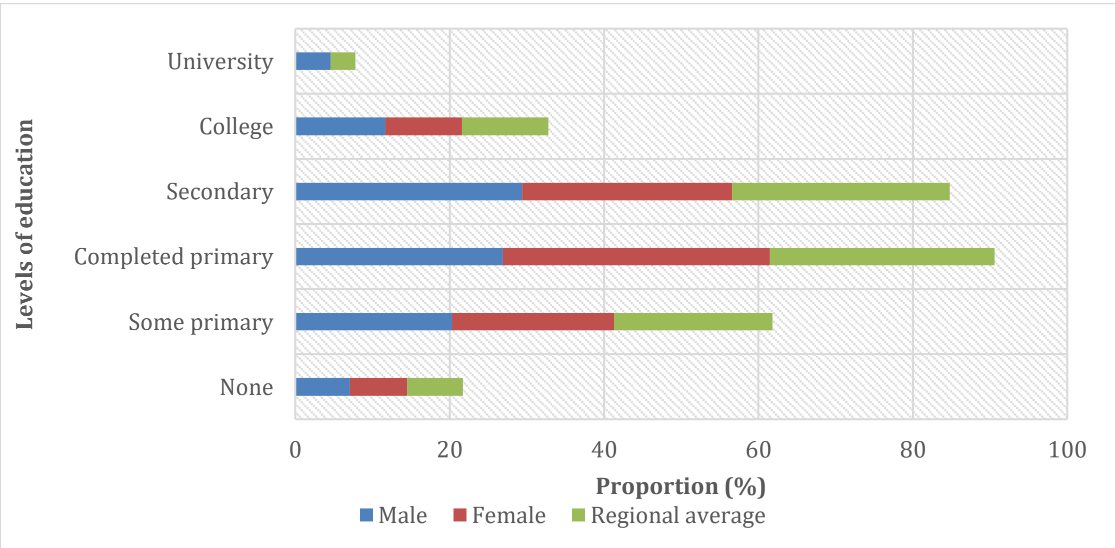

Figure 4.2: The distribution of male and female respondents by levels of education

A majority (86%) of the respondents were married, engaged in crop farming as the primary source of income (86%), and belonged to local networks (84%) organized along environmental conservation, economic and social issues. The main food crops grown in area included maize, horticultural crops and lentils. Nearly a third (32%) of the respondents had direct contact with government and private extension services for the past one year.

Table 4.2: The frequency distribution of demographic and socio-economic variables

Characteristics	**Description**	**Proportion (%)**
Gender of household head	Male	71
	Female	29
Main source of income	Crop farming	86
	Business	7
	Pastoralism	3
	Formal employment	2
	Casual employment	2
Level of monthly income in US$	Up to Ksh 10,000	40
	Ksh. 10,001 – 30,000	40
	Ksh. 30,001 – 50,0000	15
	Over Ksh 50,000	5
Access to credit	Respondent had access to credit	49
	Respondent had access to credit	51
Type of land ownership	Private	58
	Communal	14
	Leasehold tenure	28
Source of extension	None	21
	Government	65
	Private	14
Frequency of Extension	None	21
	Weekly	1
	Monthly	8
	Quarterly	42
	Occasionally	28

Among the sampled households, 20% had a mean monthly income of over Ksh 30,000, and more than half (51%) had access to credit services (Table 4.2). One-way ANOVA showed significant differences by mean monthly across community-based irrigation schemes *(P=0.005; F=2.268).* Households in Kimana had a higher mean monthly income that those from Rombo and Njukini.

The households showed considerable diversity in household size and asset ownership. The mean household size was six persons, and each has over one unit of livestock. Farmers had access to land through three different ways: secure tenure with title deed (58%), leasehold (28%) and communal tenure (14%). Majority (79%) of irrigators in Kimana had secure tenure with title deed compared to 40% in Rombo (Table 4.3).

Table 4.3: The distribution of households across the community irrigation schemes by type of land ownership

Type of land ownership	Community-based irrigation schemes			Catchment average
	Rombo (n = 123)	Njukini (n = 62)	Kimana (n = 94)	
	%	%	%	%
Private (with title deed)	40	65	79	58
Communal	26	3	4	14
Leasehold	34	32	17	28

The mean size of land owned by households was 4.6 acres. However, the mean size of land under irrigation in Rombo, Njukini and Kimana was 3.5(± 0.8), 1.6 (± 0.4) and 2.0 (± 0.5) acres, respectively. These values were significantly different *($P < 0.005$, $F = 5.4$)*.

4.2 Perceptions of sub-catchment's environmental status and water access

Fifty-four (54.3%) of the respondents rated Tsavo sub-catchment as degraded and 18% as very degraded (Figure 4.3). However, 27% felt it was good. Similarly, the respondents had a diverse perception of the status of water quantity and quality, with 28% rating the availability of irrigation water from dry-season sources as good and 29% as satisfactory. A majority (66%)

rated quality of water in the area as between bad and satisfactory compared to 27% who rated it as good. Despite these perceptions, the impacts of surface water abstraction and resource degradation were visually manifest in the sub-catchment.

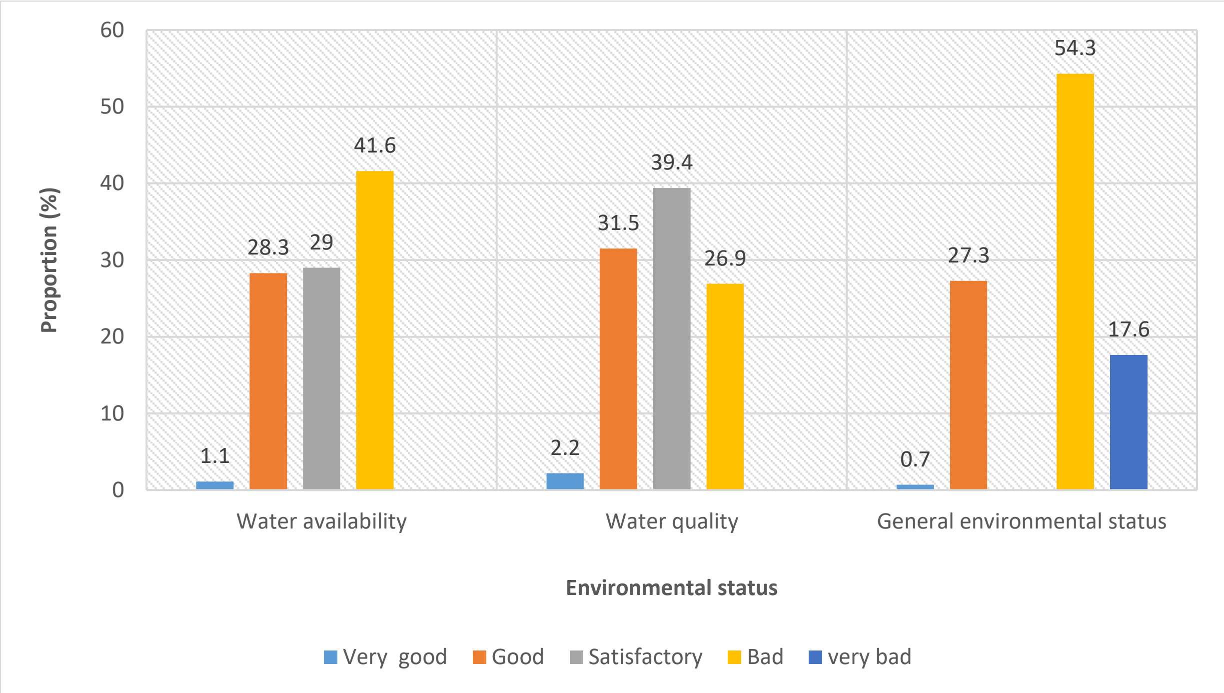

Figure 4.3: Respondents' perceptions of water availability for irrigation and water quality for human use, and of general environment status

The perceptions about general environmental status *($\chi2$ (6), p = .001),* water availability *($\chi2$ (6) = 106.0, p = .000)* and water quality *($\chi2$ (6) = 100.2, p =.001)* were significantly associated with farm location relative to a water source. Farmers situated close to water sources, such as spring or stream indicated limited water stress. Similarly, such farmers perceived the status of water quality and general environmental conditions as good. This finding is consistent with a previous study (Haiyan, 2013) that individual respondents in different locations demonstrate diversity of perception on water availability and quality. While some of these perceptions may be inaccurate, they can help water managers and policy makers to better understand and resolve local water resource challenges in a more localized and effective way.

Majority of the respondents perceived water scarcity and resource conflicts as a major constraint to irrigation development, and reported experiencing these challenges at least three times in the past five years. This finding was echoed in both interviews with key informants and focus groups. Water conflict in the Tsavo region was outlined as human to human, human to wildlife and institutional to institutional; and reported at five levels: between farmers within the irrigation schemes, among upstream and downstream users, between water users and conservationists, among farmers and the WRA over illegal water abstraction, and between the WRA and county government over institutional priorities. Other major environmental issues cited by the respondents were illegal encroachment of riparian areas, over-abstraction of surface water resources and loss of biodiversity (Figure 4.4).

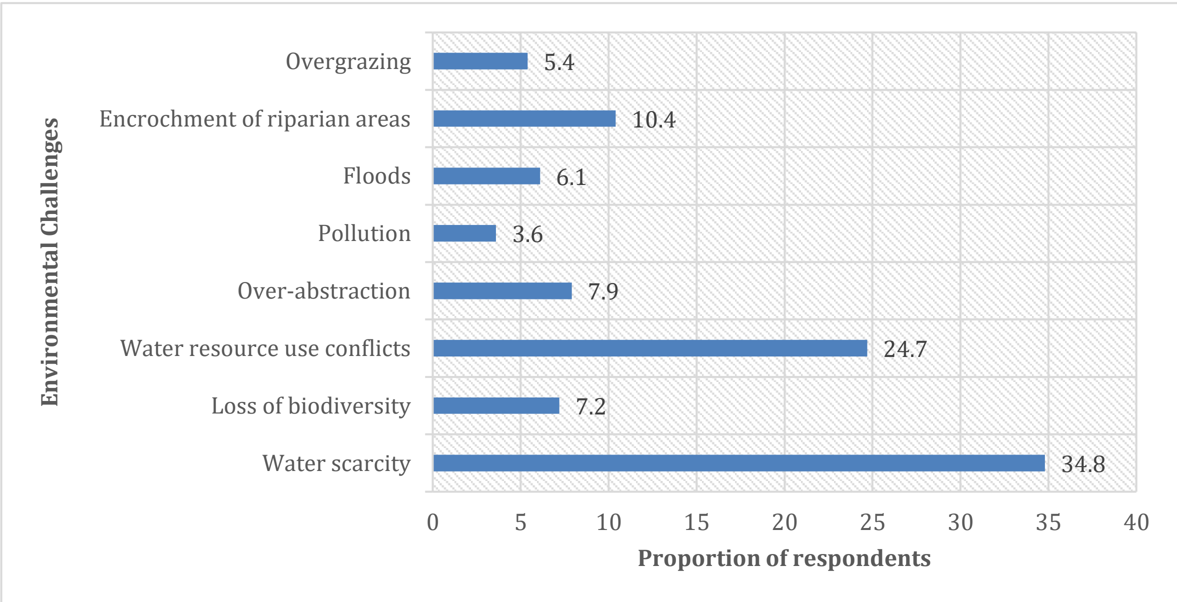

Figure 4.4: Major environmental challenges in Tsavo sub-catchment as ranked by respondents

The main water sources in the area were: springs, rivers, community water pans, shallow wells, boreholes and piped water. Irrigation water was accessible to 42% of the sampled farmers in less than 1 km, 47% between 1 and 3 km, 9% between 4-5 km and 3% over 5km (Figure 4.5).

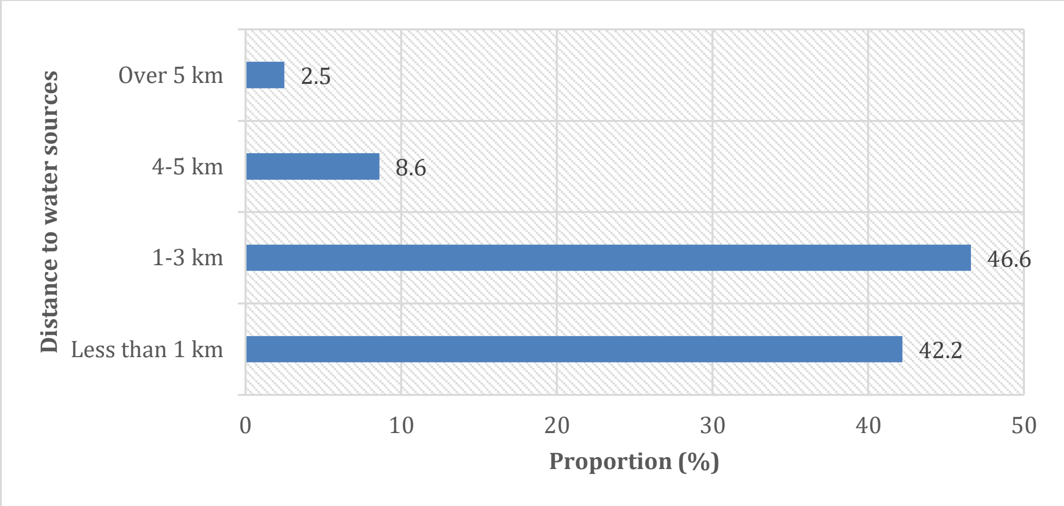

Figure 4.5: The distribution of households by the distance to the nearest water source

Respondents cited different challenges in accessing water for irrigation with most of them indicating conflict with other farmers and wildlife (70%) and distant farm locations from irrigation water sources (30%). While water access challenges were similar across community irrigation schemes, majority of respondents (91%) in Njukini cited conflict with neighbours and wildlife as the main challenge. Farmers reported loss of farm income due to water-related conflicts.

Among the sampled households, 23% had invested in boreholes (23%) to supplement surface water sources for irrigation. The rest would scale down farm operations (59%), or suspend irrigation activities (17%) when surface water sources are scarce (Table 4.4). Nonetheless, investments in boreholes have not reduced dry-season irrigation water abstraction. Considering the impact of investments in alternative irrigation water supply, respondents cited increase in farm productivity and incomes. According to key informants, the mean household farm income per acre per season is approximately Ksh. 300,000.

Table 4.4: Distribution of irrigators by coping strategies to water resource scarcity

	Community-based irrigation schemes			Regional average
	Rombo	Njukini	Kimana	
	%	%	%	%
Boreholes	32	7	18	23
Farm ponds	1	0	2	1
Reduce farm size under irrigation	51	90	54	59
Suspend irrigation activity	16	3	26	17

4.3 Farmers' knowledge, attitudes and practices in water resources management

4.3.1 Farmers' knowledge in water management

4.3.1.1 Knowledge of IWRM principles

More than half (55%) of respondents had heard the term "IWRM" and rated their understanding of the IWRM principles as either good, average or poor. The common theme from respondents' understanding of the IWRM principles was cooperative management of water resources among competing users. Most (90%) respondents agreed that water is finite, 61% acknowledged the importance of participatory water management decision-making processes, and 92% reported that their practices in water management can protect water resources from further degradation. The knowledge of IWRM among irrigators was significantly related to level of education *($\chi 2$ (2) =26.24, p = .000)* and access to extension *($\chi 2$ (2) = 21.2; p = .000)*.

Interviews with key informants and focus groups reported high level of risk awareness among water users, particularly those related to water scarcity. Despite this observation, they reported low levels of knowledge on IWRM principles among farmers and other water users in the Tsavo sub-catchment. Even though some respondents have fairly good understanding of water issues, they were unable to connect their actions with environmental challenges in the sub-catchment. This was reflected by low levels of compliance with abstraction permit and low uptake of sustainable technologies and practices in water management. These findings highlight the need for public awareness campaigns on water management.

4.3.1.2 Main sources of information on IWRM

The main sources of information on IWRM were farmer educational seminars (30%) and Chief's forums (24.6%). Other sources were electronic and print media (Figure 4.6). The most preferred channel for delivering information on water resources management were: seminars and workshops (31%), Chief's forums (28%) and Radio (21%) (Figure 4.7).

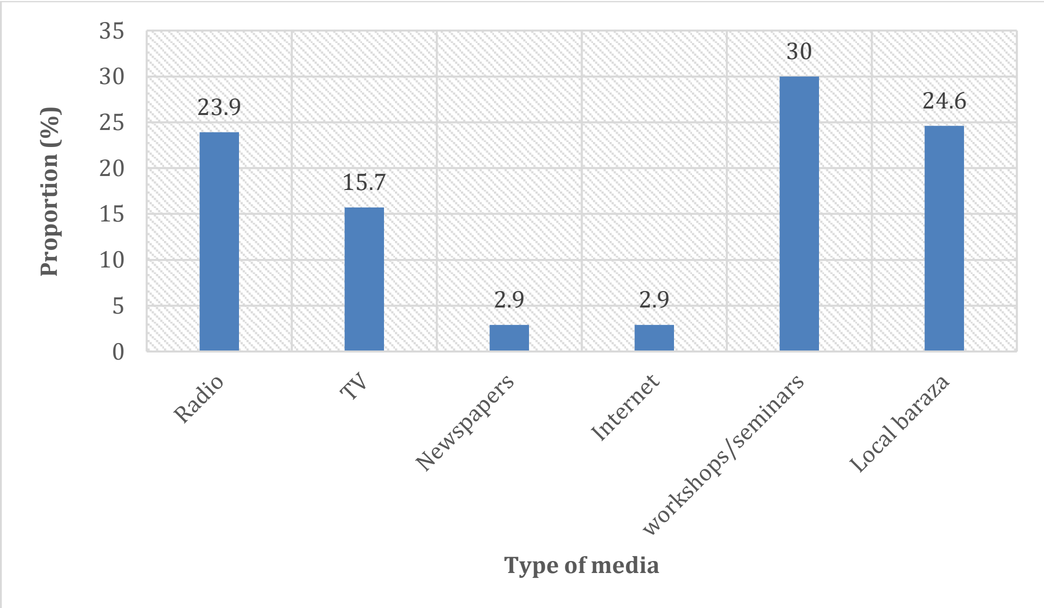

Figure 4.6: Main sources of information on IWRM

The use of a mix of traditional media (radio, television) and interpersonal communication strategies (Chiefs Barazas/forums, seminars/workshops) were echoed by key informants and focus groups in future awareness campaigns. However, a tactical selection of media for specific social groups is preferable. Some key informants preferred community Radio and interpersonal communication strategies as appropriate pathways for local outreach. However, the choice of media and communication strategies for future awareness campaigns on water resources management would require serious consideration because various technologies and practices must be promoted to ensure sustainable utilization of water resources.

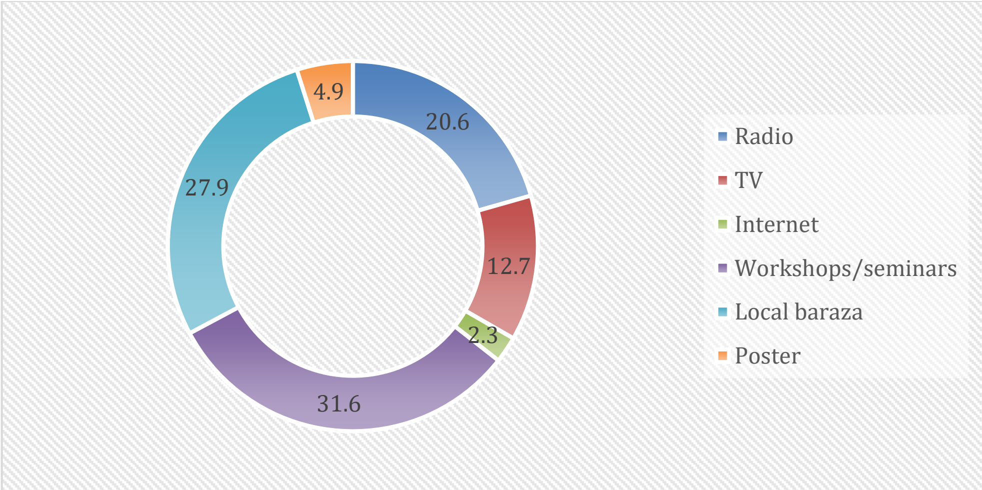

Figure 4.7: Most effective channels for delivering information on water resources

Close to thirty-two percent (31.6%) of respondents had recently attended farmer' educational seminars on IWRM that were organized by NGOs (39%), national government extensions (37%), and county government (24%) (Figure 4.8).

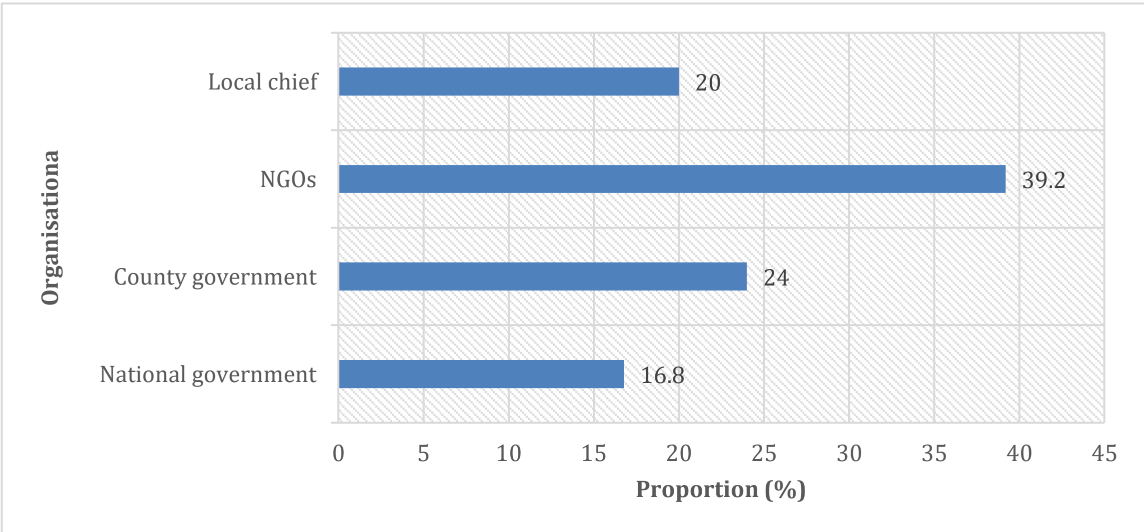

Figure 4.8: Organisation of farmer' educational seminars/workshops on IWRM

About thirty-five percent (34.8%) of the respondents who attended consultative workshops on IWRM learnt to cooperate with other stakeholders in the management of water resources; 18.7% to protect wetlands from human encroachment and install on-farm water storage facilities, and 12.3% to abstract water resources within permitted levels (Figure 4.9). Close to eleven percent (10.7%) learnt about sustainable soil and water management practices, and 10.2% about water conflict resolution mechanisms. Both interviews with key informants and focus groups reported that educational seminars and workshops on water resources management were organized by government agencies (e.g. the WRA, KWS and KFS) and NGOs, and focused on improving coordination among water user groups. It appears that awareness programmes on water management are biased towards enhancing cooperation and compliance with water abstraction permit and protecting encroachment on wetlands and riparian reserves.

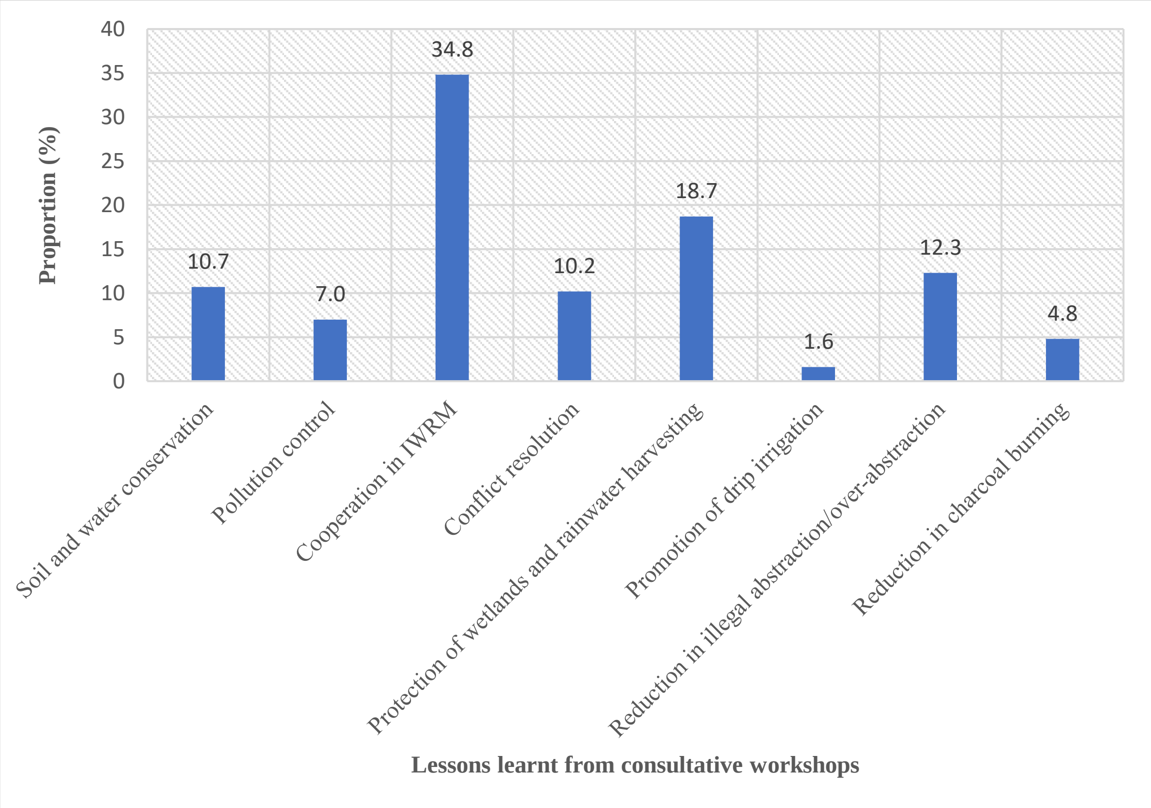

Figure 4.9: The distribution of respondents by lessons learnt in farmer' consultative workshops/seminars on IWRM

4.3.1.3 Determinants of farmer's knowledge of IWRM

The results from ordered logistic regression showed that an increase of one more year of schooling resulted in *1.07* times increase for odds of better understanding of IWRM principles compared to poor and no understanding. Respondents involved in crop farming as primary occupation were more likely to demonstrate a better understanding of IWRM principles than those engaged in business *(odds = 0.32)*. Similarly, access to government extension had a positive influence on farmers' knowledge of water resource management *(odds = 2.91)*.

Similarly, participation in environmental networks was associated with better understanding of water issues (Table 4.5).

Table 4.5: Ordered logistic regressions for determinants of farmer's knowledge of IWRM principles

Variable	Description	Co-efficient	Odds ratio	Standard error
Education	Number of years in formal education	0.68**	1.07	0.03
Main livelihood	Crop farming	-	-	-
	Business	-1.15*	0.32	0.58
	Pastoralism	-0.11	0.91	0.79
	Formal employment	-1.27	0.28	0.96
	Casual employment	-0.30	0.74	0.81
Level of monthly income in Ksh.	Up to Ksh 10,000	-	-	-
	Ksh. 10,001 – 30,000	-0.01	0.99	0.27
	Ksh. 30,001 -50,000	-0.43	0.65	0.42
	Ksh. Over 50,000	-2.14***	0.12	0.84
Access to extension	None	-	-	-
	Government	1.07***	2.91	0.34
	Private	0.68	1.98	0.49
Membership to group	Environment	-	-	-
	Economic	-1.21***	0.03	0.40
	Social	-1.54***	0.21	0.45
	No membership	-1.83***	0.16	0.47

Note: *** significant at 1% level ** significant at 5% level * significant at 10% level

These findings show that educational attainment, participation in local networks and access to extension information are major influencing variables for knowledge on water resources management (Table 4.5). These results are consistent with previous studies (Jacobs & Buijs, 2011; McDuff et al., 2008; Gilbertson et al., 2011; Dean, Fielding, et al., 2016, Dean, Lindsay, et al., 2016b; Meinzen-Dick, 2018; Shikuku et al., 2017; Hilimire & Greenberg, 2019; Thomas et al., 2020) that individuals with better education, more access to extension information and higher levels of social capital are better able to understand water management issues and express concerns about environmental degradation. Although, it is logical that less educated individuals are more likely to encounter stressors that limit access to knowledge and information and engagement in water governance, participation in local networks and interaction with extension agents can improve their knowledge on water management issues. Moreover, the study has established a significant influence of farming occupation on knowledge on water management, indicating that being a farmer is a predictive factor of understanding IWRM principles. This has implications for audience segmentation strategies when planning knowledge-based interventions on water management.

4.3.2 Attitudes towards water resource management

Nearly all respondents (97%) were concerned about water resource scarcity and more willing to take up various measures to improve water resource management. These measures were: soil conservation, water and land pollution reduction and installation of on-farm water storage technology (Table 4.6). While there might be high level of concern about water scarcity in the sub-catchment, low level of uptake of sustainable practices in water management is a cause of concern.

Table 4.6: Farmer' attitudes to water resources management measures

Attitudinal issue	Variables	Description	% age
Inclination to engage in water resources management	Soil conservation	1 = yes and 0 = otherwise	43%
	Water pollution management	1 = yes and 0 = otherwise	14%
	Installation of on-farm water storage technology	1 = yes and 0 = otherwise	75%
	No Action for water conservation	1 = yes and 0 = otherwise	3%

Farmers' attitudes towards water management were influenced by socio-economic, institutional and farm characteristics (Table 4.7). Access to government extension, farm distance relative to a water source and land tenure were the main influencing variables for willingness to engage in soil conservation practices. Farmers with access to extension were more likely to engage in soil conservation efforts.

In contrast, nearness to a water source had negative influence on farmers' attitudes towards soil conservation. Irrigators who were farming less than a kilometre from a water source were less willing to engage in soil conservation practices. The connection between land tenure and soil conservation was significant; farmers who had access to irrigated land through communal tenure had less favourable attitudes towards soil conservation. Secure land tenure was associated with *0.24*- and *1.32*-times higher odds of willingness to support soil conservation practices than communal and leasehold land ownership arrangements, respectively. In contrast, income was significant and negatively correlated with farmer' inclination to support water pollution reduction efforts *(odds = 0.15).*

Nearness to a water source had negative coefficient on farmers' attitudes towards pollution reduction efforts, suggesting that irrigators whose farms are situated close to water sources have less favourable attitudes towards pollution reduction practices. Being situated less than a kilometre from water sources is associated with *0.48*- and *0.16*-times lower odds of willingness to implement pollution reduction measures for farmers situated 1-3 km and 4-5 km, respectively. Members of economic networks were twice *(odds = 2.12)* more willing to install on-farm water storage technology. However, the willingness to install on-farm water storage technology was negatively influenced by access to credit *(odds = 0.54).*

The results highlight the importance of access to extension information, farm distance to a water source and land tenure in predicting attitudes towards practices in water management (Table 4.7). It is noteworthy that extension programmes can shape favourable attitudes towards practices in water management. This finding is consistent with previous studies (Nhemachena & Hassan, 2007; Meijer et al., 2015) that extension programmes are critical for pursuing changes of attitudes among farmers. However, access to extension has not played any significant role in shaping favourable attitudes towards on-farm water storage technology. This is a surprising finding because extension programmes are expected to stimulate interest in innovative agricultural technologies and encourage positive response among farmers. While it is beyond the scope of the water authorities to review farmer extension systems and design farm water management programmes, they can improve and leverage on existing extension programmes to disseminate and enhance understanding of on-farm water storage technology.

Table 4.7: Results of the binary logistic regressions for attitudes towards water conservation practices

Variable	Soil conservation			Pollution control			On-farm RWH		
Monthly income	Coeff.	Odds ratio	Std. Err.	Coeff.	Odds ratio	Std. Err.	Coeff.	Odds ratio	Std. Err.
Up to Ksh 10,000	-	-	-	-	-	-	-	-	-
Ksh. 10,001 - 30,000	-0.30	0.74	0.31	-0.55	0.58	0.42	-0.24	0.79	0.35
Ksh. 30,001 -50,000	0.31	1.37	0.44	-1.88**	0.15	0.91	-0.65	0.52	0.47
Over Ksh. 50,000	-0.74	0.48	0.68	(empty)			-0.45	0.64	0.72
Membership to network									
Environmental	-	-	-	-	-	-	-	-	-
Economic	0.46	1.59	0.46	0.18	1.20	0.73	0.75*	2.12	0.46
Social	0.61	1.84	0.52	-0.47	0.62	0.80	0.26	1.29	0.54
None	0.07	1.07	0.56	0.62	1.86	0.82	0.58	1.79	0.56
Access to credit	-0.41	0.66	0.30	-0.42	0.66	0.43	-0.61*	0.54	0.33
Access to extension									
None	-	-	-	-	-	-	-	-	-
Government	0.57*	1.77	0.37	0.64	1.89	0.57	0.21	1.23	0.40
Private	0.85*	2.35	0.52	1.59**	4.91	0.80	-0.03	1.03	0.54
Farm distance from water sources									
Less than 1km	-	-	-	-	-	-	-	-	-
1-3 km	-0.74***	0.48	0.29	-1.42***	0.24	0.45	0.21	1.23	0.32
4-5 km	-1.81***	0.16	0.61	-2.01*	0.13	1.08	0.51	1.66	0.62
Over 5 km	-1.09	0.34	0.91	-0.06	0.94	1.20	0.83	2.29	1.14
Type of land ownership									
Private	-	-		-	-	-	-	-	-
Communal	-1.41***	0.24	0.54	-1.35	0.26	1.09	-0.38	0.68	0.46
Leasehold	0.27	1.32	0.32	0.49	1.64	0.44	-0.64*	0.53	0.35

Note: *** significant at 1% level ** significant at 5% level * significant at 10% level

The significant effect of farm location relative to a water source on attitudes towards water and land pollution reduction is revealed (Table 4.7), suggesting possible association between crop habitat and occurrence of pests and diseases. According to Karp et al. (2018), crop habitat can constrain pest management efforts and necessitate extensive use of farm chemicals which ultimately leads to soil and water pollution. However, this study has not detected any significant connection between access to credit and farmers' attitudes towards on-farm water storage investment. This finding is not surprising as farmers are risk averse and would be hesitant to commit short-term credit on long-term on-farm storage investment, particularly when they are not assured of significant increase in net returns. This is consistent with previous studies (Xavier et al., 2011; Spiegel et al., 2018) that risk aversion has negative influence on the adoption of sustainable technologies.

4.3.3 Practices in water resource management and adjustments in irrigation water use in response to water scarcity

The practices in water resources management were categorized into two: water resource management practices and adjustments in irrigation water use in response to water scarcity.

4.3.3.1 Water resources management practices

The respondents listed three major practices in water resource management. Thirty-seven percent (37%) were involved in collaborative water management and 32% were abstracting within permitted levels, but only 1% had installed on-farm water storage technology (Table 4.8). Respondents felt that government support was necessary in the adoption of on-farm water storage technology. This was echoed by both key informants and focus groups who amplified the importance incentive mechanisms in the adoption of on-farm water storage technology. Although, 32% of the respondents had indicated that they were abstracting water resources within permitted levels, interviews with Water Resources Authority officers reported near-zero compliance with water abstraction permit among smallholder irrigators in the sub-catchment. Discussions with focus groups reported that community-based conservation groups (e.g.

WRUAs) have fenced off and plated trees in environmentally sensitive wetlands and riparian reserves.

Table 4.8: Water resources management practices

Variables	Description	% age
Collaborative water management	1 = yes and 0 = otherwise	37%
On-farm water storage technology	1 = yes and 0 = otherwise	1%
Compliance to water abstraction permit	1 = yes and 0 = otherwise	32%
No conservation measures being taken to conserve water	1 = yes and 0 = otherwise	32%

Participation in environmental networks and access to extension had positive and significant influence on collaborative management of water resources (Table 4.9). Similarly, farmers who had access to land through leasehold arrangements were more likely to collaborate with other water users *(odds = 4.52)* than farmers with title deed. Similarly, access to government and private extension were positively and significantly associated with collaborative management of water resources. Wealthier farmers were nonetheless less likely to support collaborative efforts, probably because they have the resources to invest in alternative irrigation water supply.

Access to government extension had negative and significant influence on adoption of on-farm water storage practices. Participation in economic network, access to government extension and land ownership through leasehold arrangements had positive and significant effect on compliance with abstraction permit. Notably, members of the economic network were thrice more likely to comply with water permit (odds = 3.02), indicating that wealthier farmers are less likely to engage in illegal abstraction.

Table 4.9: Results of the binary logistic regressions for water resource management practices

Variable		Collaborative water management			On-farm water storage technology			Compliance to abstraction permit		
Monthly income		Coeff.	Odds ratio	Std. Err.	Coeff.	Odds ratio	Std. Error.	Coeff.	Odds ratio	Std. Error.
	Up to Ksh. 10,000	-	-	-	-	-	-	-	-	
	Ksh. 10,001- 30,000	0.53*	1.69	0.35	1.09*	2.99	0.64	-0.43	0.65	0.33
	Ksh. 30,000 - 50,000	-0.29	0.75	0.48	0.99	2.69	0.76	-0.19	0.83	0.45
	Over Ksh. 50,000	-2.86***	0.06	1.16	1.58	4.86	1.02	-0.53	0.59	0.68
Membership to network										
	Environmental	-	-	-	-	-	-	-	-	-
	Economic	-1.11**	0.33	0.47	-0.07	0.93	0.80	1.11**	3.02	0.51
	Social	-2.40***	0.09	0.57	-1.04	0.36	0.93	0.59	1.81	0.59
	None	-1.63***	0.20	0.56	-0.83	0.44	1.06	0.71	2.03	0.58
Access to extension										
	None	-	-	-	-	-		-	-	
	Government	2.15***	8.61	0.54	-2.50***	0.08	0.65	0.99**	2.69	0.42
	Private	1.73***	5.62	0.67	-0.51	0.60	0.69	1.36	3.89	0.55
Type of land ownership										
	Private	-	-	-	-	-		-	-	-
	Communal	0.11	1.12	0.45	-0.19	0.82	0.72	1.18***	3.27	0.42
	Leasehold	1.52***	4.52	0.37	-0.84	0.43	0.63	0.88***	2.42	0.33

Note: *** significant at 1% level ** significant at 5% level * significant at 10% level

Similarly, farmers who rent agricultural land under leasehold arrangement were twice *(odds = 2.42)* more likely to comply with Water Rules Resource Management Rules. In the same way, access to government extension had a positive and significant association with compliance with water permit *(odds = 2.69)*. It is noteworthy that regression results are consistent with findings from chi-square tests (Table 4.10).

Table 4.10: Socio-economic factors influencing water resource management practices

socioeconomic characteristics	**Measures taken for water conservation**					
	On-farm RWH		Collaborative water management		Compliance to abstraction permit	
	$\chi 2$	*p value*	$\chi 2$	*p value*	$\chi 2$	*p value*
Level of education	17.1	0.004	15.2	0.009	11.6	0.04
Access to extension	31.8	<0.001	28.9	<0.001	8.1	0.017

Length of residency	35.0	<0.001	-	-	-	-
Size of household	30.6	0.004	-	-	-	-
Mean monthly household income	8.2	0.042	11.1	0.011	-	-
Access to credit	4.5	0.034	-	-	-	-
Type of land ownership	-	-	12.1	0.002	12.3	0.002

4.3.3.2 Adjustment in irrigation water use in response to water scarcity

Three variables were used to model how irrigators adjust to water stress. The variables were: investment in boreholes to supplement irrigation water needs, reducing farm size under irrigation and suspending irrigation operations (Table 4.10). Mean household income, participation in educational seminars and farm distance to a water source were the main influencing variables for investment in boreholes to supply irrigation needs. Irrigators with higher income in excess of Ksh. 50,000 were more likely to invest in boreholes by 15 times more than low income group households. Similarly, farmers with access to credit services were twice more likely to invest in boreholes *(odds = 2.01).* Likewise, farms that were distant – over 5 kilometres away – from a water source were 6.18 times more likely have a borehole than those situated less than a kilometre from irrigation water source. Communal and leasehold land ownership arrangements were positively and significantly associated with investment in boreholes. Wealthier irrigators were less likely to reduce farm sizes under irrigation in response to water stress. Similarly, farmers with leasehold land ownership arrangements were less likely *(odds = 0.14)* to reduce farm size under irrigation during dry seasons than farmers with title deed. Contrastingly, farmers with access to extension were more likely to reduce the size of irrigated land in response to water stress. Nearness to a water source was negatively and significantly associated with a reduction of farm size under irrigation. Access to extension and participation in economic network had negative influence on farmer' decision to suspend irrigation operations during dry seasons.

Noteworthy among the determinants of practice in water management are access to extension, land tenure and participation in local networks (Tables 4.9, 4.10 & 4.11). Studies on adoption have confirmed a positive relationship between access to extension and uptake of sustainable practices in water and land management (Valizadeh et al., 2007; Shikuku et al., 2017). While this observation is consistent with the findings of this study, mean monthly household income (Table 4.10) is critical in shaping the adoption of innovative technologies. Poor households may not be able to invest in alternative irrigation water supply technologies, such as boreholes and on-farm water storage systems. Amid the growing pressure on surface water resources in the Tsavo sub-catchment, it is reasonable that wealthier farmers be targeted for investment in innovative water management technologies.

The relationships between land tenure rights on one hand, and collaborative water management and compliance with water abstraction permit, on the other hand, are striking. Land tenure rights creates incentives for productive and sustainable use of land and water resources (Twerefou et al., 2011; Nkomoki et al., 2018). Although the findings of this study are consistent with this observation, it has not detected any significant connection between property rights and investment outcomes. Farmers in the Tsavo sub-catchment who rent agricultural land under leasehold arrangements are more likely to invest in boreholes as a supplementary source of water for irrigation (Table 4.11). This finding implies that tenure rights do not guarantee investment in sustainable practices. The study has also shown that farmers who rent agricultural land under leasehold arrangements are more likely to collaborate with other water users and comply with abstraction permits, probably to win the trust of leasers and avoid any confrontation with the water authority. This finding is supported by a previous literature (Dean, Fielding, et al., 2016) that collaborative approaches to water management can serve as "catalysts of trust" and sustainable practices. Similarly, the study has demonstrated a significant relationship between participation in local networks and collaborative water management and compliance with abstraction permits. Participation in local networks creates incentives for social learning and communication which may lead to new norms for sustainable practices (Walker & Ostrom, 2009; Thomas et al., 2020). This implies that farmers who participate in social networks are well positioned to understand environmental challenges and demonstrate support for sustainable practices. Given the pressure on water resources in the Tsavo sub-catchment, it is reasonable for relevant national government agencies, county governments and NGOs involved in water resources management programmes to strengthen capabilities of local environmental networks for sustainable practices.

The study has shown that farmers who rent agricultural land under leasehold arrangements are more likely to collaborate with other water users and comply with abstraction permits, probably to win the trust of leasers and avoid any confrontation with the water authority. This finding is supported by a previous literature (Dean, Fielding, et al., 2016) that collaborative approaches to water management can serve as "catalysts of trust" and sustainable practices. Similarly, the study has demonstrated a significant relationship between participation in local networks and collaborative water management and compliance with abstraction permits. Participation in local networks creates incentives for social learning and communication which may create social norms and responsibility for sustainable practices (Walker & Ostrom, 2009; Thomas et al., 2020). This indicates that farmers who participate in social networks are well positioned to understand environmental challenges and demonstrate support for sustainable practices. Given the pressure on water resources in the Tsavo sub-catchment, it is reasonable for relevant national government agencies, county governments and NGOs involved in water resources management programmes to strengthen capabilities of local environmental networks.

Table 4.11: Results of the binary logistic regressions for farmers' responses to water scarcity

Variable		Using boreholes			Reducing farm size			Suspending irrigation		
Monthly income		Coeff.	Odds ratio	Std. Err.	Coeff.	Odds ratio	Std. Err.	Coeff.	Odds ratio	Std Err.
	Up to Ksh. 10,000	-	-	-	-	-	-	-	-	-
	Ksh. 10,001 – 30,000	1.12***	3.06	0.37	0.48	1.62	0.47	0.35	1.42	0.35
	Ksh. 30,001 – 50,000	0.82*	2.26	0.50	-0.94*	0.39	0.54	-0.76	0.47	0.60
	Over Ksh, 50,000	2.72***	15.20	0.78	-4.30***	0.01	1.01	-0.64	0.53	1.12
Membership to network										
	Environmental	-	-	-	-	-	-	-	-	-
	Economic	0.13	1.14	0.47	-0.37	0.69	0.71	-0.64*	0.53	0.53
	Social	-1.00	0.37	0.63	-0.11	0.99	0.84	-0.17	0.85	0.57
	None	-0.65	0.52	0.57	0.48	1.61	0.86	-0.28	0.76	0.61
Access to credit		0.70**	2.01	0.34	-0.94**	0.39	0.43	-0.34	0.71	0.34
Access to extension										
	None	-	-	-	-	-	-	-	-	-
	Government	0.57	1.76	0.46	0.92*	2.51	0.48	-1.05***	0.35	0.38
	Private	-0.14	0.87	0.62	0.82	2.29	0.68	-0.82	0.44	0.61
Farm distance from water sources										
	Less than 1km	-	-	-	-	-	-	-	-	-
	1-3 km	0.28	1.33	0.34	-1.30***	0.27	0.45	0.47	1.60	0.36
	4-5 km	-0.86	0.42	0.72	-1.50**	0.22	0.65	1.28**	3.60	0.54
	Over 5 km	1.82*	6.18	0.99	-2.96***	0.05	0.95	1.39	4.03	0.93
Type of land ownership										
	Private	-	-	-	-	-	-	-	-	-
	Communal	1.01**	2.73	0.45	0.87	2.43	0.74	-0.30	0.74	0.49
	Leasehold	0.74**	2.27	0.37	-1.96***	0.14	0.45	-0.34	0.71	0.39

Note: *** significant at 1% level ** significant at 5% level * significant at 10% level

Other influencing variables of practices in water management include length of residency and size of household (Table 4.10). Length of residency as a surrogate of age and farming experience is associated with better knowledge and understanding of the local environment due to interactions with ecosystems over the years. Such farmers accrue more information that can enable them to adjust farming practices to changes in environmental conditions. Although this finding is aligned with previous literature (Tran et al., 2018), it is at odds with other studies

(Alcon et al., 2014) that youthful farmers are more receptive to alternative technologies. Household size as a proxy to labour availability is associated with investment in on-farm water storage technology, indicating that large household can easily adopt labour-intensive technology. This is consistent with previous studies (Kassie et al., 2013; Marenya & Barrett, 2007; Nkonya et al., 2008) that large households can overcome labour constraints and adopt innovative technologies.

4.3.4 Relationship between knowledge of water issues, attitudes and practices in water management

The variables of knowledge of water management issues were statistically significant in relation to attitude and practice variables. Chi-square ($\chi2$) tests show an association between knowledge of IWRM principles and willingness to undertake soil conservation practices *($\chi2$ (2) =21.8, p = .000)* and pollution reduction efforts among farmers *($\chi2$ (2) =40.6, p = .000).* Similarly, the relationship between knowledge of IWRM and user participation in water resources management *($\chi2$ (2) =40.7, p = .000)* and compliance with abstraction permit *($\chi2$ (2) =24*.5, p = .000) was statistically significant. These results show that better knowledge and understanding of water resource management issues is a pre-condition for sustainable water resource management. These findings provide a basis for improved awareness and extension support targeting not only farmers with low levels of knowledge of water issues, such as less privileged groups (i.e. poorer, less educated farmers); but other subgroups with limited access to appropriate sources of information on water management issues, such as educational workshops and seminars; and those who had shown favourable attitude towards water resources management. Specifically, agricultural extension should expand their operational scope and facilitate uptake of innovative technologies.

4.4 Farmers' willingness to pay for on-farm water storage technology

4.4.1 Estimation of WTP for on-farm water storage technology

The attributes of on-farm water storage technology: year-round water availability for irrigation, improved water quality for domestic use and for environmental flows, and a reduction of water resource conflicts were assessed by estimating WTP, which quantifies farmers' preferences for the attributes in monetary terms. The statistically significant and positive coefficients (Table 4.12) suggest that year-round water availability for irrigation, water quality for domestic use and for environmental flows, and reduction of water conflicts were the major attributes of on-farm water storage technology.

Table 4.12: Estimation results of the Conditional Logit and Alternative Specific Conditional Logit

Attributes	Conditional logit		Alternative specific conditional logit	
	coefficients	Standard error	coefficients	Standard error
Cost	-2.62e-06 ***	7.55e-07	-4.88e-06***	9.76e-07
Water Quantity	.8250269 ***	.0829499	.6994756***	.1060421
Water Quality	.7211357 ***	.0902327	.4276629***	.1140716
Conflict	.3704195 ***	.0677006	.753423***	.1446496
Log likelihood	-905.08188		-825.03738	
Number of observations	3348		3348	
Respondents	279		279	
LR chi2(4)	641.94		-	
Wald chi2(24)	-		153.77	
Prob > chi2	0.0000		0.0000	
Pseudo R2	0.2618		-	

Note: *** significant at 1% level ** significant at 5% level * significant at 10% level

Farmers exhibited strong preferences and WTP for these attributes. Households were willing to make a one-off payment of Ksh. 154,320.00 (US$ 1,543.20) per acre towards installation of on-farm water storage technology if it would reduce water related conflicts, and Khs.

143,270.00 (US$ 1,432.70) if assured of year-round water availability, but only Ksh. 87,596 (US$ 875.96) to improve water quality for domestic use and for environmental flows. The seemingly large MWTP values can be attributed to water resource conflicts in the Tsavo sub-catchment which have led to farming inefficiencies, leading to low-risk attitude among farmers and disincentives to operate at full potential. This finding is supported by a previous study (Stanbury and Lynott 1994) that head-end water wastage and tail-end deprivation have contributed to conflicts among resource users and subsequent crop damages and loss of incomes.

The high MWTP values may equally suggest that widely held perception among smallholder irrigators' that water is free environmental resource that should be utilized to increase production at no cost is fast fading away due to uncertainty in water supply. It also implies that farmers are frustrated with dry season irrigation water scarcity and attendant conflicts and would support any lasting solution to these challenges. These findings are consistent with previous studies (Alcon et al., 2014; Assefa, 2012; Ayashola et al., 2013; Aydogdu, 2019; Aydogdu & Bilgic, 2016; Aydogdu & Yenigun (2016), Khan & Zhao, 2019; Villanueva et al., 2018) that farmers are willing to pay more for improved irrigation water supply. The findings support a recent study (Zhuo, 2019) that water storage technologies can reduce agricultural water scarcity overtime.

Furthermore, the prevailing high demand for horticultural products by local and export markets can be associated with high MWTP values. Cost-benefit studies show that under appropriate conditions, on-farm water storage technology can recover the costs of investment within 2–4 seasons (1–2 years), depending on crop type and market conditions. Kattel (2015) puts the cost of a 45 m^3 on-farm water storage investment at US$ 2766 and payback period of 2 years. This is supported by a study in Kenya (Ngigi et al. 2015) that reported a seasonal income of US$ 600 for a 250 m^2 vegetable garden supplied by a 50 m^3 on-farm water storage. Thus, the MWTP values for on-farm water storage technology as estimated by this study are practically affordable to farmers in the Tsavo region.

The coefficient for the cost variable, was however negative and statistically significant (Table 4.12), an indication that farmers were averse to on-farm water storage technology with high costs of investment. This finding suggests that cost of the on-farm water storage technology is a key element in its uptake. This was echoed by focus groups who observed that initial costs of investment in on-farm water storage technology is prohibitive. However, interviews with agriculture officers showed that with an average farm household income of Ksh. 300,000.00 per season (3 months), the proposed technology is practically affordable to many smallholder irrigators. However, there was a general feeling that appropriate incentive mechanisms are needed to facilitate uptake of the proposed technology.

4.4.2 Determinants of WTP for on-farm water storage technology

Demographic and socio-economic parameters, such as respondent' age, household primary occupation, educational attainment, mean household income and land tenure were the main factors predicting preferences and WTP among smallholder irrigators. The coefficients for respondent' age, number of schooling years and level of income are positive (Table 4.13), indicating that more experienced, better educated and wealthier farmers are more likely to invest in farm pond technology.

The coefficients for occupation and land tenure were however negative. Farming as a primary occupation was positively associated with WTP. However other principal occupation such as business, pastoralism, formal employment or casual labour led to a decline in preferences and WTP. Similarly, farmers with secure tenure rights exhibited stronger preference and WTP than those who rent agricultural land under leasehold arrangements.

The significant influence of respondents' primary occupation, educational attainment, level of income and property rights in land (Table 4.13) suggests that preferences and WTP were relatively heterogeneous among farmers. Privileged farmers (wealthier, better educated and land owners) are willing to pay for on-farm water storage technology. Better educated, wealthier and more experienced farmers have financial security and better access to extension services that are imperative for uptake of agricultural technologies. These findings are consistent with previous studies (Aydogdu; 2019; Aydogdu & Yenigun, 2016; Khan & Zhao, 2019; McCord et al., 2018), Price et al., 2016; Tang et al., 2013) that wealthier farmers are less likely to encounter difficulties in trialling a new technology.

A considerable segment of farmers in the Tsavo region rent agricultural land under property rights that allow cultivation for a specified period of time. These farmers may lack incentives to invest in agricultural water management. This finding is consistent with other studies (Aydogdu, 2019; Stijn & Chellatan, 2012; Twerefou et al., 2011) that property rights in land can promote sustainable land and water management practices, and maximize farm productivity and incomes by permitting landowners to rent land to other potential farmers. The significant effect of farming as the primary occupation on WTP further highlights that farmers are heavily impacted by water scarcity. The significant influence of educational attainment, level of income and land tenure in farmers' WTP suggests that policy efforts towards scaling up on-farm water storage systems should shift attention to farmer-specific characteristics. Thus, specific support services, such as extension programmes, financial support and technical services will be more effective in scaling up the practice if tailored to suit socio-economic characteristics of farmers.

Table 4.13: Estimation results of the Alternative Specific Conditional Logit with covariates

Attributes	Alternative specific conditional logit	
	Coefficient	Standard error
Cost	-4.88e-06 ***	9.76e-07
Water Quantity	.6994756***	.1060421
Water Quality	.4276629***	.1140716
Conflict	.753423***	.1446496
Gender	.1240815	.4169699
Age	.0319545*	.0188776
Household size	-.032261	.0873488
Education	.5232484***	.19379
Knowledge of IWRM	.7589931*	.4000746
Occupation	-.8891787***	.1937723
Household income	1.120142***	.318254
Access to credit	.0599639	.4060538
Social networks	.4368608	.4721854
Land tenure system	-.8845624***	.2201426
Constant	-1.111538	1.424649
Log likelihood	-825.03738	
Number of observations	3348	
Respondents	279	
Number of cases	1116	
Alternative per case		
a. Minimum	3	
b. Average	3.0	
c. Maximum	3	
Wald chi2(24)	153.77	
Prob > chi2	0.0000	

Note: *** significant at 1% level ** significant at 5% level * significant at 10% level

4.4.3 Rate of adoption preferences of on-farm rainwater harvesting systems

The likelihood of respondents selecting policy options A, B or the Status quo was assessed based on the changes on each of the attributes and the costs of installing on-farm water storage technology. Overall, the difference between Option A and B was marginal because they both represented a complete or partial change from existing agricultural water management practices to the proposed new technology. The likelihood of respondents selecting the status quo i.e. Option C was 0.20 or 2% compared to 48% and 50% for options A and B, respectively (Table 4.14). An increase in the costs of installing on-farm water storage technology (option A or B) leads to a reduction in the probability of the option being selected by the respondents. However, an increase in water availability for option A or B enlarge the probability of the options being selected and a corresponding decrease in the probability of the other option with less water availability and status quo.

Table 4.14: Marginal effects of cost (price) and attributes of on-farm water storage technology on the policy options selected

Variable		X	Pr (Option A Chosen = .48)	Pr (Option B Chosen = .50)	Pr (Status Quo) Chosen= .02)
			dp/dx (Std. Error)	dp/dx (Std. Error)	dp/dx (Std. Error)
Cost	Option A	250627	-1.2e-06 (2.4e-07)	1.2e-06 (2.4e-07)	3.1e-08 (1.2e-08)
	Option B	229059	1.2e-06 (2.4e-07)	-1.2e-06 (2.4e-07)	3.2e-08 (1.2e-08)
	Status Quo	0	3.1e-08 (1.2e-08)	3.2e-08 (1.2e-08)	-6.3e-08 (2.3e-08)
Water Quantity	Option A	.5	.174641 (.026479)	-.170207 (.025868)	-.004434 (.001535)
	Option B	.49608	-.170207 (.025868)	.174852 (.026508)	-.004645 (.001607)
	Status Quo	-1	-.004434 (.001535)	-.004645 (.001607)	.00908 (.003127)
Water Quality	Option A	.50392	.106776 (.028478)	-.104065 (.027778)	-.002711 (.00111)
	Option B	.50392	-.104065 (.027778)	.106905 (.028514)	-.00284 (.001164)
	Status Quo	-1	-.002711 (.00111)	-.00284 (.001164)	.005551 (.002267)
Conflict	Option A	0.92059	.18811 (.036112)	-.183334 (.035229)	-.004776 (.001756)
	Option B	0.079412	-.183334 (.035229)	.188338 (.036158)	-.005004 (.001841)
	Status Quo	-1	-.004776 (.001756)	-.005004 (.001841)	.00978 (.003582)

Similarly, increase in water quality for either options A or B led to an increase in the probability of the respondents selecting the option with a decrease in the probability of the other option with poor water quality and the status quo being selected. This shows that smallholder irrigators in the Tsavo sub-catchment prefer on-farm water storage technology and would be willing to pay for the improvements of its attributes – a reduction of water use conflicts, year-round water availability for irrigation, and improved water quality for domestic use and ecosystems. Moreover, the value of these attributes increases as the cost of obtaining them decreases.

4.5 Micro-level water governance in the Tsavo sub-catchment

The results of micro-level water governance assessment are presented in the sub-sections below:

4.5.1 Levels and scales

The national and county governments are involved in water resource management policy at the sub-catchment level. However, the national government has the most decision-making power. The management responsibility of the national government over water resources is undertaken through the WRA which oversees water resource allocation, source protection and conservation and water quality management. The interventions towards management of water resources in the Tsavo sub-catchment occurred mainly through top-down impositions by the WRA. Some stakeholders expressed concerns that despite decentralization of water resource management responsibilities to basin and sub-basin levels, the national government still retains the highest decision-making power. This finding is not surprising because the national government is the higher-level authority with decision-making power and resources to foster sustainable practices in water management. The higher-level authority can play effective role in enabling sustainable practices through appropriate policies and incentive frameworks (Daniell et al., 2014).

The scale of the Tsavo sub-catchment covers two counties: Kajiado and Taita Taveta. They intervene directly in the sub-catchment water resource management through catchment protection and implementation of water management policies as set by the national government. Despite their enormous influence, county governments take little responsibility for the sub-catchment resource management challenges. This can be attributed to lack of legal clarity on the institutional mechanisms through which counties can manage water resources in their territories, and how they relate to WRUAs and other advisory bodies established to promote sustainable water resources management at the basin-level.

The relationship between national and county governments is institutionalized by the Constitution of Kenya (2010) and the Water Act (2016). However, coordinating capacity challenges were evident between the agencies of national government and county governments. Similarly, the coordination between the county governments of Kajiado and Taita Taveta was lacking, mainly due to insufficient orientation to address upstream and downstream water resource management challenges. This has led to weak management practices at the sub-catchment level, leading to inadequate stakeholder participation, inadequate enforcement and compliance with water management regulations, and weak stakeholder networks. Since county governments were less committed to addressing sub-catchment water management challenges, the strongest impulse against unsustainable and "business as usual" practices came from the WRA. However, the urge for deviation from current practices was met with resistance from irrigators.

4.5.2 Actors & Networks

Water actors in the sub-catchment governance are drawn from national and county governments, community groups (e.g. WRUAs), research institutions, NGOs, private sector and other resource users (Table 4.15). Government actors (e.g. the WRA, National government administration, KWS, and county governments) and WRUAs are the key Players in the sub-catchment water governance (Figure 4.10). The WRA was the most influential actor (Figure 4.10) in water governance. This finding is consistent with previous studies (Ogada et al., 2017; Yang et al., 2018) that governments play a critical role in water governance through planning, regulation, supervision and coordination.

Although local-level institutions (e.g. WRUAs) are equally influential (Figure 4.10), they were dependent on resources from external sources. This implies that water sector reforms have not been successful in strengthening local governance capacities. The WRUAs are bestowed with enormous water management responsibilities, yet little effort has been spared to address the mismatch between delegated responsibilities and resource allocation. This finding is consistent with a study in Kenya (Ogada et al., 2017) that WRUAs are still struggling to find their foot in executing their mandates.

The WRA and WRUAs were the most influential with frequent interactions and communication with actors. Despite limited capacities and resources, WRUAs had the highest relations and closest to other water actors (Figure 4.11). However, the horizontal interaction among other key actors – county government, private sector, NGOs, CBOs, research institutions – representing key element of water policy implementation was sparse. The operation of WRUAs in top-down and bottom-up frameworks and coalitions created with CSOs provided them with political visibility. This signifies an appreciation of decentralization of water governance. However, due to capacity challenges, WRUAs could not capitalize on its visibility to improve access to knowledge and information among members, pursue change of attitudes and behaviours, and mobilize resources for their operations. Previous studies highlight the importance of social relations in facilitating learning and communication (Meinzen-Dick, 2018; Ricart et al., 2018), and in providing leverage for resource mobilization (Ogada et al., 2017).

Resource users such as farmers, pastoralists, group ranches and conservancies were Subjects with the highest interest, but low influence in water governance. Context Setters, such as NEMA, NIDA and KFS, had high influence, but low interest in the sub-catchment water governance. Educational institutions and CBOs had less influence and interest in the sub-catchment water governance. Notable exception was Kimana wetland association (Figure 4.10) that had higher influence due to its role in riparian conservation. The unequal power relation among stakeholders was a hindrance to effective implementation of water policies. Van Kopper (2007) observes that power imbalance among stakeholders can undermine implementation of integrated water resources management principles.

Water resources users are nested within WRUAs. However, the association is built on voluntary membership with a large segment of members drawn from smallholder irrigators. Private sector players such as group ranches and conservancies were not represented in WRUAs, and neither did they recognize the association as advocates of private sector interests.

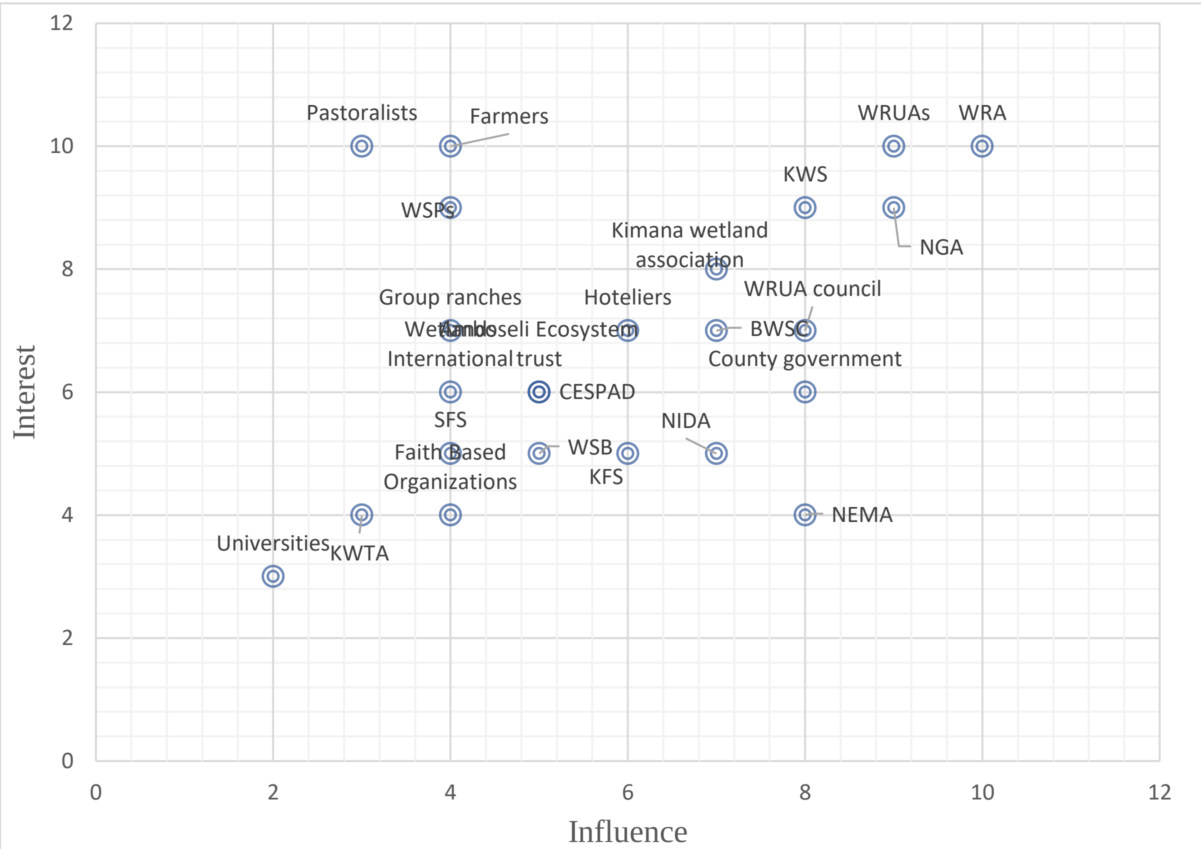

Figure 4.10: Perceived interest and influence of stakeholders in Tsavo sub-catchment water governance. (For more details, see the supplementary data in appendix 1)

(Scale ranges from 0 (No influence or interest) to 10 (Very high influence or interest).

These findings have shown the incompleteness of water governance regime in the Tsavo sub-catchment in terms of stakeholder involvement in decision-making processes. Despite measures to promote participatory decision-making, including through the WRUAs, the involvement of private sector, research institutions, NGOs and other stakeholders was sparse. Previous studies (Cole et al. 2017; D'Agostino et al., 2019; McCord et al., 2017; Obando et al., 2018) show that socially acceptable water policies are products of collaboration and broad participation between multi-level institutions and other stakeholders

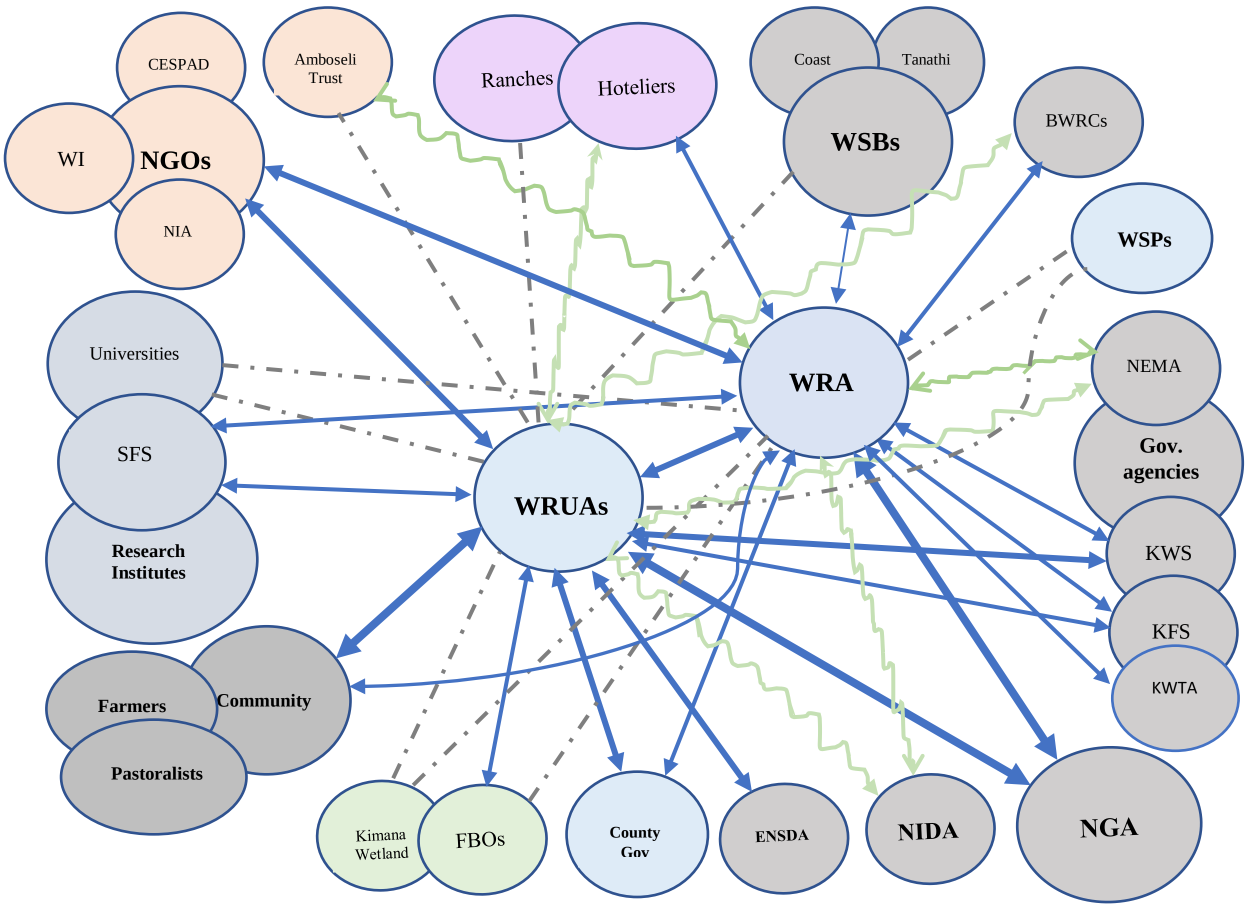

Figure 4.11: Stakeholder analysis of Tsavo sub-catchment. Relevant stakeholders were mapped on the basis of relations and interactions with the WRA and WRUAs

(Legend: Circles represent stakeholders; blue solid lines represent stakeholder relations; thicker lines show stronger relations. Green zigzag lines represent weak relations, while dashed grey lines represent absence of ties between stakeholders and the WRA and WRUAs)

Table 4.15: Stakeholders and their level of interest and influence in Tsavo sub-catchment water governance

Classes	Institutions	Categories	Functional roles
Governments	WRM	Player	Regulation of the management and use of water resources
	Basin water resources committee (BWRC)	Player	Management of water resources within a respective basin area
	National Environment Management Authority (NEMA)	Context setters	Supervision and coordination of environmental management
	Kenya Wildlife Services (KWS)	Player	Conservation and sustainable management of wildlife
	Kenya Forest Service (KFS)	Context setters	Sustainable forest resources management and conservation
	Kenya Water Towers Agency	Context setters	Coordinate efforts in the rehabilitation and restoration of water towers
	Water Services Boards (WSBs)	Crowd	Regulation of water services provision
	County government	Context setters	Managing water resources and catchment within their boundaries
	National Irrigation Development Authority (NIDA)	Context setters	Development and improvement of irrigation infrastructure Provision of irrigation support services to private, medium and smallholder schemes, and provision of technical advisory services to irrigation schemes.
	National government administration (NGA)	Player	Maintenance of law and order, including resolution of water resource conflicts
Resource users	WRUAs	Player	Collaborative management of water resources and resolution of water use conflicts Water resource use beneficiaries
	Farmers	Subject	Small-scale irrigation
	Pastoralists	Subject	Watering livestock
	WRUA council	Player	Conservation and sustainable management of water resources
NGOs & CBOs	CESPAD	Crowd	Sustainability of water use Improvement in the livelihood of water users
	Amboseli Ecosystem trust	Crowd	Providing ideas and suggestions for ecosystem Services and environmental protection
	Kimana wetland association	Subject	Wetland conservation and improvement of water quality
	Wetlands International (WI)	Crowd	Wetland conservation
	Faith Based Organizations	Crowd	Improvement in the livelihood of water users
Private sector	Hoteliers	Subject	Use large quantities of water to support their businesses
	Water service providers (WSPs)	Subject	Supplying water to local water users
	Group ranches	Crowd	Water resources for livestock
Educational and research institutions	School of Field Studies (SFS)	Crowd	Research on sustainable water resource use
	Universities	Crowd	Research on sustainable water resource use

4.5.3 Problem perspectives and goal ambitions

Multi-level institutions and stakeholders in the sub-catchment water governance had diverging perspectives and ambitions. Ensuring equitable water allocation among sectors was not addressed as a common goal. While the WRA had socio-economic and ecological perspectives on water management, county governments had own perspectives and ambitions. More precisely, due to the relative importance of the agriculture sector in the local economy, county governments were advocating for increased allocation of water resources to supply irrigation needs at the expense of ecosystems.

WRUAs' had economic and ecological perspectives on water resources management. However, their ability to ensure equitable water allocation was challenged by competing water demands, conflict of interest among their leaders, and limited technical and financial capacity. This not surprising because WRUAs are run by volunteers who could easily lose commitment to promote equitable water allocation and use.

The overall responsibility for water resources management lies with the Ministry of Water and Irrigation, which creates institutional conflicts. Water resources have an interdependent relationship with other ecosystems, such forests, wetlands, water towers and national parks. However, these ecosystems are managed by different agencies of government without a framework to guide how they can coordinate their activities with the WRA, WRUAs and county governments. Effective coordination can facilitate knowledge and information transfer among relevant government institutions and ensure complementarity of actions. The urge for deviation from unsustainable practices will be greater if multi-level institutions share a long-term integrated vision for water management.

4.5.4 Strategies and instruments

The Constitution of Kenya (2010) is the principal policy document that lays the basis for water resource governance. Other key instruments establishing water resource management policy are: Kenya Vision 2030, National Policy on Water Resources Management and Development (1999), National Water Master Plan 2030 and National Water Resources Management Strategy. The Water Act (2016) is the framework legislation for water resources management. The Water Resources Management Rules (2007) plays a pivotal role in the implementation of the Act, including with regard to sustainable utilization of water resources and adoption of innovative technologies. However, interviews with key informants reported that these instruments were largely focused on achieving policy targets through application of command-and-control regulatory approaches.

The WRUAs in the Tsavo sub-catchment have developed management plans for sustainable practices in water management. Some WRUAs, for example, have formulated sub-catchment management plans (SCMPs) to promote water conservation and catchment restoration. The SCMPs took note of the connection between livelihoods and ecosystems in the management of water resources. Specifically, SCMPs set out to ensure equitable water allocation, reduce water pollution, promote sustainable land management practices, improve agricultural productivity, and protect natural wetlands and riparian reserves from human encroachment. However, WRUAs faces serious difficulties in scaling up these initiatives.

In terms of rulemaking, some flexibility was apparent in the governance structure of water resources. The Water Act (2016) provides room for incorporating context-specific perspectives in water resource management. For example, WRUAs are provided with flexibility to devise by-laws and implement scale-appropriate measures. During periods of extreme water scarcity, the WRA and WRUAs could pool resources into integrated interventions to achieve a common goal. Similarly, their strategies and instruments created some synergy and could be combined to support integrated outcomes. However, county governments and other relevant agencies of national government, such as KWS, KFS and KWTA have own strategies aligned to their mandates. Interviews with government officers revealed that these agencies had inadequate personnel and resources, and focused their attention to meeting specific institutional mandates. This implies that existing instruments do not provide frameworks to guide how relevant government agencies and county governments can coordinate their programmes and activities with the WRA and WRUAs. Moreover, there is no legal provision for linking the programmes and activities of WRUAs with those of county governments.

4.5.5 Responsibility and resources

Responsibilities for water governance institutions (i.e. the WRA, BWRCs and WRUAs) are clearly demarcated by the Water Act (2016). The WRUAs plays a critical role in water resources management. They are mandated to apportion water equitably and resolve user conflicts and serve as agents of BWRC in the implementation of basin water resource management strategies. However, monitoring compliance and enforcement of water permits and resolution of conflicts are shared responsibilities between the WRA, BWRCs and WRUAs. While WRUAs are primary arbiters for conflicts among users within the sub-basin, the WRA is the principal arbiter for conflicts across sub-basins and other serious offences or grievances. Interviews with WRUAs revealed that despite their expanded mandate and operation in both top-down and bottom-up frameworks, limited effort was spared to bridge the gap between expanded responsibilities and existing capacities. WRUAs were largely dependent on external actors for resources.

Water Resources Management Rules (2007) makes provisions for WRUAs to "enter into a Memorandum of Understanding (MoU) with the WRA to provide for administrative, technical, and financial support". This provision has been incorporated into the Section 42 (3) of the Water Act (2016). While this is a positive step towards strengthening the financial capacity of WRUAs, it is not adequate because the agreement to "make available a portion of water user fees" to WRUAs is still left at the discretion of the WRA.

Interviews with key informants further revealed that despite its influence, the WRA was not supported with stable and sufficient resources to implement its goals. While a variety of water tariffs and levies are charged for the abstraction and use of water resources to support conservation and management activities, the WRA was unable to raise sufficient amounts to meet its necessities. It is not clear whether these funds are adequately ring-fenced and applied for water conservation and management purposes. Other relevant agencies of national government have access to some resources for sector-specific tasks. However, there was limited incentive to collaborate with one another, and few opportunities to pool resources and responsibilities for integrated interventions. On this basis, the governance context for responsibilities and resources was not adequate to achieve sustainable management of water resources.

4.5.6 Summary

An assessment of water governance dimensions and quality criteria for the Tsavo sub-catchment suggests that the degree of extent was high and coherence was low, but flexibility and intensity were moderate. High extent is mainly attributed to the 2002 water sector reforms which created a polycentric water governance regime. The management of water resources in the Tsavo sub-catchment is shared among multi-level institutions and stakeholders. Polycentric governance in the sub-catchment has created local networks with shared interests such as WRUAs, and enabled scale-appropriate measures to water resource challenges. Local governance institutions are provided with flexibility to devise, implement and revise their own rules. This finding is consistent with Pahl-Wostl et al. (2012) that polycentric regimes enable resource users to define sustainable pathways for water resource management. However, polycentric water governance arrangement was less effective in the Tsavo sub-catchment due to weak coordinating capacities. Previous studies (Cole, 2011; Pahl-Wostl et al., 2012; Baldwin et al., 2016; McCord et al., 2017) show that effective water governance requires coordination between multi-level institutions and stakeholders to ensure compatibility and complementarity of actions.

The low coherence was linked to diverging perspectives and ambitions on water resources management. Relevant government institutions and other stakeholders were working independently with limited coordination on water management issues. Their strategies did not reinforce each other nor create synergies for sustainable management of water resources. Similarly, sufficient resources could not be obtained to support policy implementation. The degree of flexibility was moderate because a few agencies of national government and local institutions could pool resources during crisis into integrated interventions to achieve a common goal. While the instruments were in place, the resources were not adequate for effective implementation of sustainable water management practices. Similarly, the governance instruments failed to incorporate incentive mechanism for sustainable practices. The interventions towards sustainable management of water resources occurred in the form of top-down impositions by the WRA. This suggests that the degree of intensity was moderate.

4.6 Governance Framework for Uptake of On-Farm Water Storage Technology

Consideration of key study findings has supported the identification of strategy areas relevant to uptake of innovative on-farm water storage technology. These include:

i. Technology development
ii. Awareness and targeted extension support system
iii. Actor' linkages and interactions
iv. Financing and incentive mechanisms
v. Policy and institutional support

4.6.1 Strategy areas

4.6.1.1Technology development

Agricultural innovations that are deliberately framed by researchers and extension programme have two essential components: hardware and software (Glover et al., 2019). The hardware corresponds to biophysical resources, while software refers to standard practices elaborated as a set of instructions, protocols or guidelines. Agricultural innovation is product of experimental science of researchers, extension agents and farmers. Even when agricultural innovation is deliberately framed by researchers, farmers have a wide scope to reconfigure the new technology to suit biophysical and socio-economic circumstances (Bunclark et al., 2018). Farmers' experiences and interactions with local contexts can result in a new idea or concept that can transform agricultural practice.

This study has shown that uptake of on-farm water storage technology is constrained by inadequate knowledge of water management issues, high initial costs of investment and inadequate institutional support services. At the household level, investment decisions are shaped by a range of socio-economic factors including resource endowment. Interview with experts showed that on-farm water storage technology is adaptable to a wide range of farming systems based on site conditions and farmer' needs and capacity. For this reason, research on technology development needs to place emphasis on designs that are technically and socially acceptable and applicable to a wider range of biophysical and socio-economic conditions. Thus, the suitability of on-farm water storage technology should be based on situational analysis to ensure the development of flexible technological package.

4.6.1.2 Awareness and targeted extension support system

One key aspect of technological change relates to the manner in which a new technology is introduced to potential users. The quality and intensity of awareness and extension programme can determine how the value and utility of new technology is interpreted and assessed (Glover et al., 2019). Deliberately convened, choreographed and orchestrated awareness and extension support can stimulate interest and encourage positive response.

This study has established a positive relationship between knowledge of water management issues and sustainable practices, indicating the necessity of awareness campaigns and targeted extension support in the development and implementation of policy decisions on water resources management. While there is a variety of pathways for personal encounter with innovative on-farm water storage technology, the study has acknowledged the role traditional media (e.g. Radio) and interpersonal communication strategies (e.g. farmer educational meetings and chief's *Baraza*). High preference for traditional media suggests that the WRA needs to establish partnership with mainstream media to disseminate awareness on innovative water management practices. Key messages of awareness and extension programme need to pay attention to potential benefits of on-farm water storage technology, not just its ability to augment water supply in smallholder irrigation system, but its part in water conflict reduction, improvement of water quality for domestic use and for environmental flows as highlighted by this study.

Interviews with key informants have reported public awareness campaigns on sustainable water resources management in the Tsavo sub-catchment. However, such campaigns appear biased towards enhancing cooperation and compliance with water abstraction rules rather than uptake of alternative water use technologies. This observation was echoed by focus groups who suggested that access to RWH information can be improved if local governance institutions (e.g. WRUAs) and actor' networks take the lead in disseminating knowledge on on-farm water storage technology and other sustainable practices. Although, farmers' networks, educational meetings and chiefs' *Baraza* can serve as good forums for disseminating RWH information, additional benefits will be obtained through demonstration trials and pilot schemes. These encounters can improve individual capacities to innovate and implement systems that suit local contexts. Moreover, they provide opportunities for farmers to interact with a range of institutions and social actors – such as extension services, regulators, NGOs, value-chain actors and other farmers – who possess different kinds of influence and interest. Although power is notably imbalanced between farmers and other social actors, inclusivity, trust, communication, and joint experimentation and learning need to be prioritized over commands. Thus, depending on how the interactions play out, farmers may be disposed to adopt the technology or reconfigure it to suit individual and local circumstances.

4.6.1.3 Actor networks and interactions

This study has established that actor networks are critical for effective implementation of water policies and related practices. Local governance institutions, such as WRUAs, provide effective platforms for knowledge and transfer which can create new norms and responsibility required to drive the uptake of innovative on-farm water storage technology and other sustainable practices. Interviews with public officers revealed weak coordination and stakeholder' linkages in the implementation of water policies and sustainable practices. Since, the sub-catchment water governance is influenced by a multiplicity of actors with competing interests and different levels of authority, it is critical to create a coalition of actors; and identify, incorporate and streamline their roles in scaling up the adoption of the technology.

Based on interviews with agriculture officers, it was revealed that despite their role in the deployment of extension programmes, county governments were involved in the WRA's efforts to promote the uptake of on-farm water storage technology. This was echoed by focus groups that extension programmes have not played any significant role in shaping favourable attitudes towards on-farm water storage technology and other sustainable practices. These findings suggest that the coordination between national government agencies and county governments in the development and implementation of water resource management policy was inadequate. To cure this ailment, some key informants suggested the formation of a sub-catchment stakeholders' forum.

Studies attribute successful adoption of innovative water technologies to actor coalitions and networks (Murase, 2009; Daniell et al., 2014; De Trincheria et al., 2017). Such networks need to incorporate potential users, value-chain actors, policy-makers, researchers and CSOs. Daniell et al. (2014) assessed the interactions between multi-level actors in the adoption of innovative water technologies and found that innovation uptake requires multi-level coalitions or networks across governing levels, including one with decision-making power and resources to implement the innovation.

Actors' networks are associated with certification and standardization frameworks, intensity and quality of awareness and extension programmes and lobbying for enabling policies that would facilitate innovation uptake (Malesu et al., 2012). Discussions with focus groups suggested that strong actor networks can facilitate exchange visits to showcase best practices in RWH for replication in the sub-catchment. This is consistent with studies that acknowledge actor' interactions in the uptake of RWH systems. Neke et al. (2009) and De Trincheria et al. (2017) proposed "Rain networks" as appropriate platforms for exchange of information among institutions and stakeholders in the uptake of RWH technologies and practices. In a fragmented multi-level governance system where power and resources are distributed between governance levels and other stakeholders, "Rain networks" can support the identification of niches for innovation uptake.

4.6.1.4 Financing and incentive mechanisms

Lack of appropriate incentive mechanism poses serious threat to uptake of on-farm water storage technology. This is consistent with previous studies (Daniell et al., 2014; Mills, et al, 2016) that monetary incentives can facilitate the adoption of innovative water management technologies. Since irrigators in the Tsavo sub-catchment are averse to the technology with high initial costs of investment, economic instruments, such as subsidies and rebates on RWH products, and other non-monetary incentive programmes are needed to facilitate the uptake of on-farm water storage technology. Interviews with agriculture and water officers reported that existing legal instruments do not provide non-monetary incentives for innovation uptake.

On-farm water storage technology is both capital and labour intensive, indicating that many smallholder farmers would need monetary incentives, such as grants or subsidies on RWH products. A study in Germany (Schuetze, 2013) attributes widespread uptake of RWH systems to fiscal incentives. However, the use of non-monetary incentives, such as extension and technical support services can also play a key role in the adoption of on-farm water storage technology.

This study has shown that large number of irrigators in the Tsavo sub-catchment have access to credit facilities. While this portends well for financing on-farm water storage systems, irrigators are less willing to commit short-term credit on on-farm water storage investment. Farmers are risk averse and will be less motivated to access credit if investment in on-farm storage technology does not present any opportunity for significant increase in net returns (Shalander et al., 2013; Kattel, 2015). However, with low interest credit facilities, many farmers can be persuaded to adopt the technology. Apart from credit, other financing mechanisms can be created voluntarily through bottom-up initiatives by county governments and development agencies. However, farmers can still be persuaded to commit a share of farm income and family labour for the construction and operation of on-farm water storage systems.

4.6.1.5 Policy and institutional support

Policy and institutional contexts play a key role in enabling the sustainability of RWH technology (Murase, 2009; Schuetze, 2013; Ndeketeya & Dundu, 2019). Expert interviews have reported a policy and institutional gaps at national and county levels that needs to be addressed to facilitate the uptake of on-farm water storage technology. The development of

RWH and storage mechanisms at various levels – farm, county and national – is not well coordinated and regulated by an integrated national plan or approach. Kenya has a weak framework on development and maintenance of water harvesting and storage infrastructure including with regard to the classification, registration and licensing of professionals; and identification and establishment of safety standards. Moreover, data and other relevant information on the number and value of existing investments, the potential in rainwater harvesting and storage, the needs for maintenance or rehabilitation, or additional national capacity that is required, is not documented. These hinder planning and implementation of RWH systems and the identification of opportunities for private sector and community investments.

Interviews with focus groups reported lack of public farm demonstration trials to outline key components of the technology. However, few RWH product suppliers have been promoting the technology in the sub-catchment. While this could signal some interest in the technology, appropriate guidelines are required to clarify standard practices. Further interviews with experts revealed that water resources management was mainly dependent on command-and-control approaches. Incentives that encourage sustainable practices in water management were not manifest. Thus, there is need to incorporate monetary incentives into water policy and other relevant statutory provisions.

4.6.2 Proposed Framework for Uptake of on-farm water storage

The proposed framework for uptake of on-farm water storage technology pays attention to technological design and its alignment with farmers' needs and capacities. It also lays emphasis on the critical role of policy and institutional contexts, particularly in disseminating and enhancing understanding of the technology among farmers. Perceptions of opportunities associated with the innovation uptake are generated through awareness and targeted extension support mechanisms. Additionally, policy and institutions play a significant role in the development of appropriate extension programmes and financing mechanisms.

In proposing a model governance framework for improved uptake of on-farm storage technology, this study has identified four sets of actors: farmers, government, private sector and civil society organizations (CSOs) (Table 5.1). The government includes county government, national government agencies and departments and public research/educational institutions. The private sector encompasses financial and credit institutions, private research institutions and value chain actors. The CSOs includes NGOs and CBOs.

Table 4.16: Example of actors and institutions for implementing governance framework for improved uptake of on-farm water storage technology

Key actors	**Actor groups**	**Actions**
Farmers	Farmers Farmer groups	• Access, adopt and benefit from new technology • Experiment with local context to generate new ideas or concept • Adapt, adjust and reconfigure new technology
Government	Research/educational institutions Extension systems	• Undertake research independently or jointly with users of the technology • Disseminate knowledge and information on RWH technology
	Government agencies and departments e.g. MoAL&F, county government, WRA, BWRC, NEMA, NWHSA, NIDA	• Develop and implement favourable policies and strategies to support the innovation and uptake of on-farm water storage technology • Provide grants and subsidies
Private sector	Financial and credit institutions	• Provide financial and credit services
	Product suppliers, Service providers (e.g. engineers, artisans, trainers, consultants) Marketing organizations	• Develop/supply RWH products • Farmer training • Design, repair and maintenance of on-farm water storage systems • Market linkages
	Private research institutions	• Research systems • Dissemination of knowledge and information on RWH technology
Civil society organisations (CSOs)	NGO, INGOs CBOs	• Provide platform for knowledge transfers • Disseminate knowledge and information of RWH technology • Farmer training

The actions and interactions among multi-level institutions and stakeholders are critical for innovation uptake. Such interactions can occur vertically across levels and horizontally between actors at the same governance level. Such interactions define how the technology is designed, brought to the attention of farmers, benefits perceived and farmers' responses to perceived benefits. Figure 5.1 below shows a model governance framework for improved uptake of on-farm water storage technology. It highlights the relations and interactions between actors in technology development and deployment. Awareness and targeted extension support explain how the new technology is brought to the attention of farmers and other relevant stakeholders. Depending on how it is convened, choreographed and orchestrated, awareness campaigns can enable knowledge and information transfer and create social norms. It can also serve as a platform for receiving feedback from potential technology users and other stakeholders.

Local governance institutions play a crucial role in disseminating knowledge and information and shaping favourable attitudes and responses. Similarly, appropriate policies can shape perceptions and individual decision to adopt the technology. The framework demonstrates the need for continuous reconfiguration of the technology based on farmer' capacity and needs and biophysical conditions. The reconfiguration is usually done in the initial stage of technology development and deployment. Further learning over time is necessary as the technology is contextualized. Moreover, the perspectives and goals of local networks, such as WRUAs, need to be aligned with the proposed technology.

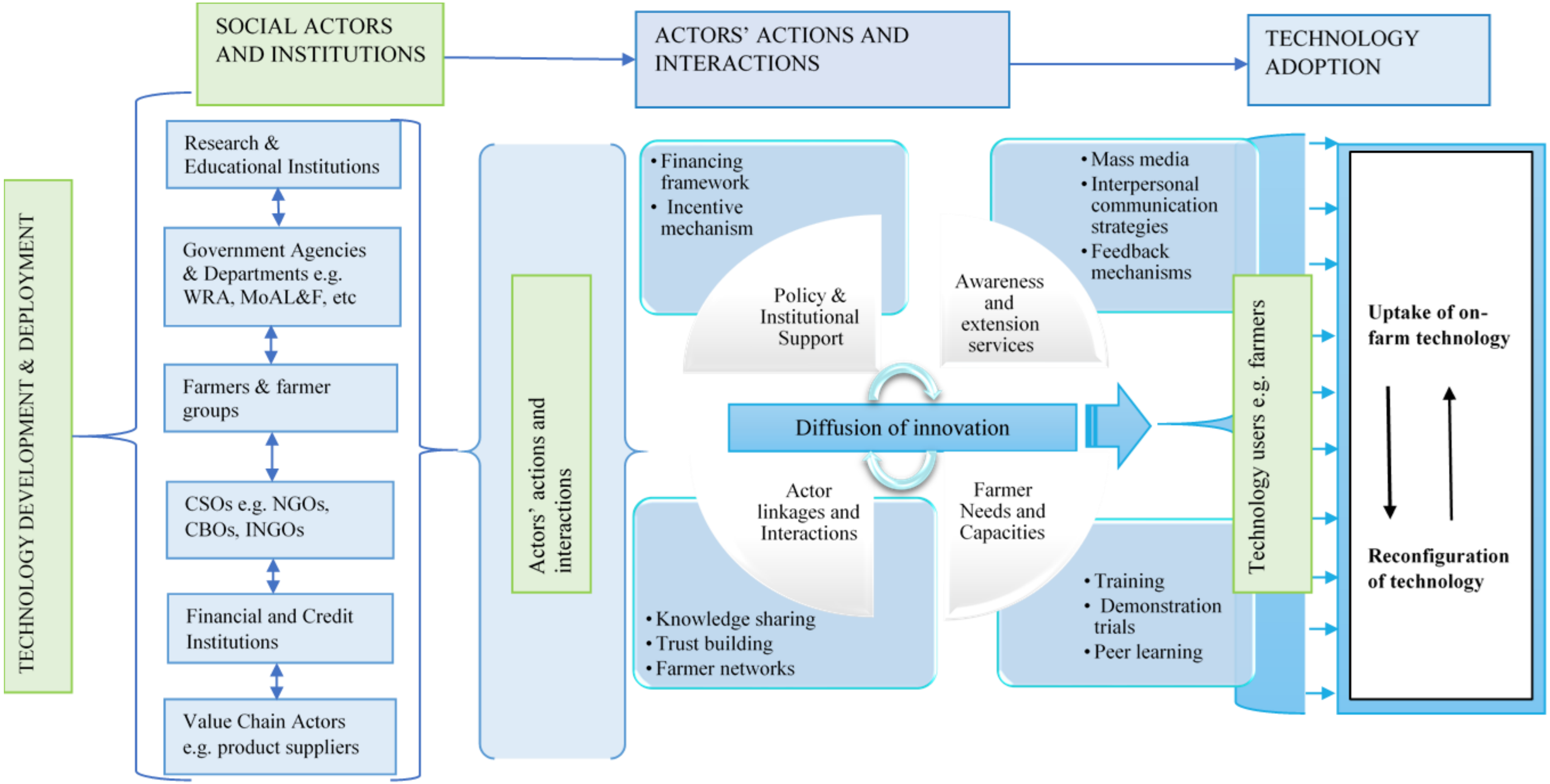

Figure 5.1: A model governance framework for improved uptake of on-farm water storage technology. The framework puts emphasis on actors' relations and interactions in technology development and deployment

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.0 Overview

This chapter presents the summary of key findings, conclusions, recommendations and areas for further research.

5.1 Summary of Key Findings

This thesis has examined governance context for sustainable utilization of water resources and improved uptake of on-farm water storage technology among irrigators in the Tsavo sub-catchment. This was prompted by a realization that integration of innovative technologies into water policy is required to alleviate water resource constraints to food production and ecosystems. Guided by four specific objectives, the study assessed farmers' knowledge, attitudes and practices in water resources management; analyzed farmers' willingness to pay (WTP) for the attributes of on-farm water storage technology; appraised the implications of water governance on sustainable utilization on water resources; and developed a model governance framework for uptake of on-farm water storage technology.

The results from the first objective established the relationship between variables of knowledge, attitudes and practices in water resources management. Educational attainment, level of income, access to extension, participation in local networks and land tenure were the main influencing variables. Irrigators demonstrate better understanding of water management issues if they are well educated, earn higher income, participate in local networks and have regular access to agricultural extension. These findings provide the basis for improved awareness and extension programmes on water resources management. Less educated and low-income irrigators can be targeted for these programmes.

The findings from second objective showed that irrigators are willing to pay for on-farm water storage technology. Well-educated, wealthier and more experienced irrigators were more willing to pay for the technology. A reduction of water resource conflicts, year-round water availability for irrigation and improved water quality for domestic use and ecosystems were the main attributes of on-farm water storage technology. However, farmers were averse to the technology with high costs of investment. Based on these findings, the integration of on-farm water storage technology into water and agriculture strategies, and use of monetary incentives could be effective way to improve uptake of the technology. Additionally, social, economic and ecological benefits of on-farm water storage technology can be used to inform farmers' engagement in the technology adoption initiatives. Furthermore, policy efforts towards scaling up on-farm water storage technology need to shift attention to well-educated, wealthier and older farmers, particularly for rapid diffusion.

The findings from the third objective showed polycentricity as a key feature of the sub-catchment water governance. This arrangement created local networks with shared interest in water governance. However, influential multi-level actors have diverging perspectives and goals on water resources management. This has led to missed opportunities for integration and participatory decision-making. Similarly, governance instruments failed to incorporate incentive tools for sustainable practices. Interventions towards sustainable management of water resources occurred in the form of top-down impositions by the WRA. Although, WRUAs provided a mechanism for pursuing changes in attitudes and behaviours among irrigators, they lacked capacities and resources to facilitate social learning and communication. This implies that WRUAs need to seek out support from governments and external agencies to scale up local capacities and resources for sustainable practices. Based on these findings, there is need to strengthen local governance capabilities, and enhance collaborative multi-level water governance in the Tsavo sub-catchment. Long-term shared vision needs to be built on actor' relations and interactions to define responsibilities and provide incentives.

The fourth objective developed a model governance framework for improved uptake of on-farm water storage technology with emphasis on actors' relations and interactions in defining how technology is designed, brought to attention of farmers, benefits perceived and farmers' responses to perceived benefits. The framework underscores the importance of research-extension-farmer linkages and financing mechanism in the uptake of the technology.

The study has made methodological, empirical and practical contributions. In terms of methodological contribution, it has shown that choice modelling applications can be used to estimate social and environmental values of on-farm water storage technology. Similarly, the study has contributed to the general body of knowledge by identifying gaps in policies and interventions necessary to improve sustainable utilization of water resources and uptake of the on-farm water storage technology. It also provides an understanding of social and environmental benefits of on-farm water storage technology. It appears that this is the first on-farm water storage valuation to highlight the importance of water resource conflicts in farmer WTP for improved irrigation water supply. On practical contribution to policy and practice, the study has developed a model governance framework for improved uptake of on-farm water storage technology.

5.2 Conclusions

This study has examined the governance arrangements for sustainable utilization of water resources and uptake of on-farm water storage technology among smallholder irrigators in the Tsavo sub-catchment. Based on key findings of the study, the water governance arrangements are insufficiently supportive to the proposed on-farm water storage technology and sustainable practices in water resources management. This finding is important in policy development that intensify awareness and target a range of support services such as extension, technical, communication and financing in the uptake of the technology. Specific conclusions of the study are discussed below.

5.2.1 Knowledge and practices in water management

The study shows that awareness and extension programmes have not been targeted to improve sustainable practices in water management, and neither have they been associated with social, economic and environmental benefits of on-farm water storage technology. It appears that current awareness campaigns are largely focused on enhancing cooperation and compliance with water abstraction permit. This finding is useful to policy-makers and water managers in their attempt to better target awareness campaigns and extension services. Improving awareness and understanding of water policies, and farmer' participation in water management decision-making processes would be a logical starting point for any intervention on sustainable water management. Key messages of awareness campaigns should focus on sustainable utilization of water resources and uptake of on-farm water storage technology. This finding provides evidence base for rethinking water resource policies and strategies to improve their acceptability. Water policies focusing on balancing irrigation water supply with the necessity to safeguard ecosystems are most likely to get wide support among farmers in the Tsavo sub-catchment. In light of these findings, policy-makers need to develop adapted water policies that take into consideration underlying socio-economic contexts.

5.2.2 Farmers' willingness to pay for on-farm water storage technology

The study indicates that irrigators in the Tsavo sub-catchment value the attributes of on-farm water storage technology. A reduction of water resource conflict, year-round water availability for irrigation and improvement of water quality for domestic use and for environmental flows generated great impact on farmers' WTP for on-farm water storage technology. The strong preferences and WTP for these attributes suggest that any strategy geared towards addressing water resource conflicts and uncertainty of irrigation water supply, and improving water quality for domestic use and for environmental flows need to incorporate on-farm surface water storage technology. Moreover, awareness and extension programmes on sustainable water management would have greater impact on innovation uptake if they incorporate the preferred attributes of the proposed on-farm water storage technology. While the receptivity to on-farm water storage attributes is high, initial cost of investment poses serious threats to its adoption. Overall, the study provides basis for developing policies and strategies that recognize the importance of on-farm water storage technology in enhancing agricultural productivity and environmental sustainability.

5.2.3 Water governance arrangements

The sub-catchment water governance arrangements created a context that is less supportive to effective water policy implementation. This has hindered sustainable utilization of water resources and the realization of on-farm water storage goal as set by the Water Resources Management Rules (2007). The multiplicity of diverse actors in the sub-catchment water governance is a constraint to integration and participatory decision-making. Their competing perspectives and ambitions constrained efforts to co-produce contextual governance structures that are appropriate to local needs and capacities. Further efforts to promote social learning and communication were hindered by inadequate institutional and technical capacities among local water governance institutions. These findings can assist policy makers to understand stakeholders' positions in sub-catchment water governance and design tools for engagement based on their interactions, perspectives, mandates and resources.

5.2.4 Governance framework for adoption of on-farm water storage technology

On-farm water storage adoption initiatives are constrained by low levels of knowledge on water management, high initial cost of investment and inadequate policy and institutional support mechanisms. The adoption initiatives in the sub-catchment have not benefitted from institutional commitment and support in terms of publicly-funded research, demonstration trials, awareness and extension programmes and financing schemes on scaling up the proposed on-farm water storage technology. The proposed governance framework for uptake of on-farm water storage technology provides the basis for development and deployment of the technology aligned to farmers' priorities and capabilities. The framework has incorporated socio-institutional aspects associated with innovation uptake such as awareness and extension programmes and institutional support mechanisms, and emphasized the importance of actors' relations and interactions in defining technology design and diffusion.

5.3 Recommendations

The findings of this study are of policy relevance in enhancing governance of water resources for improve uptake of on-farm water storage technology. The specific policy recommendations are provided below.

i. Improve awareness on sustainable water resource management practices

Water policy should make provisions for awareness and extension programmes on sustainable water management. Targeted awareness and extension support services can create interest, responsibility and new norms for sustainable practices. While there is a variety of dissemination pathways, the government should support interpersonal communication strategies, such as farmer educational meetings and local engagement forums, and establish partnership with traditional media to enhance awareness and understanding of water management issues.

ii. Integrate on-farm water storage technology into water and agriculture policies and strategies

Agriculture and water policies should make provisions for adoption of on-farm water storage technology. This is particularly so if policy choices and actions are geared towards improving water availability for smallholder irrigation systems, reducing water resource conflicts and safeguarding environmental flows. Moreover, there is need, within intergovernmental framework, to support the adoption and utilization of RWH at the farm level through appropriate incentives and sanctions.

iii. Develop appropriate incentive mechanisms to enable the uptake of on-farm water storage technology.

Finance is a key element in the adoption of agricultural technologies. However, institutional weaknesses limit the prospects to benefit from available financial resources and mobilize additional ones. A review of water policy, and amendments of Water Act (2016) and Irrigation Act (2019) are necessary to provide for economic instruments such as subsidies and rebates for RWH products. Such measures could reduce credit risks and farmers' averseness, and increase credit for scaling-up market-oriented on-farm water storage technology.

iv. Strengthen capabilities of local water governance institutions (e.g. WRUAs) for sustainable practices

Water policy should make provisions for adequate financial and technical support to strengthen capabilities of WRUAs. While the Water Act (2016) has expanded the responsibilities of WRUAs in water resources management, it has not matched such responsibilities with resource allocation. In addition to financing, WRUAs would require additional capacities to foster collaboration and partnerships and demand accountability on water policy and regulatory decision-making processes. Strong partnerships and collaborations with research institutions, civil society organizations, private sector and governments can facilitate social learning and communication and provide leverage for resource mobilization.

v. Strengthen research-extension-farmer linkages in the development and implementation of policy decisions on water resources management

Water and agriculture policies should make provisions for coordinated and cooperative research to support the design of on-farm water storage technology. This would ensure the development of flexible technological package that is technically and socially acceptable and applicable to a wider range of biophysical and socio-economic contexts. Further, there is need for county agriculture policy to make provisions for the establishment of demonstration centres at local levels to serve as a "one-stop-shop" for knowledge and information transfer, and farmers' capacity building and technical support.

vi. Support collaborative and coherent multi-level governance systems

Water resources management cuts across sectors such as agriculture, wildlife, environment, forestry, land use and energy. Yet, the overall responsibility for water resources management lies with the Ministry of Water and Irrigation, which creates institutional conflicts. The water policy should make provisions for effective coordination between the national government, its agencies and county governments in the implementation of sustainable management practices and the uptake of on-farm water storage technology. Moreover, the policy should enhance better understanding of the needs of water-related sectors in the development and implementation of policy decisions on water resources management. Overall, a network of multi-level actors and stakeholders would be required to facilitate the uptake of innovative technologies and sustainable practices in water management.

5.4 Further research

Further studies on RWH should expand the scope of this research by:

i. Developing a cost benefit model for on-farm water storage technology under different cropping systems. For example, future studies should investigate the cost-benefits of specific cropping systems.
ii. Compare preferences for attributes of on-farm storage technology and practices under different socio-ecological contexts. For example, case studies research can compare preferences among heterogenous farmers' groups under different agro-ecologies.
iii. Examine conditions under which local governance institutions (e.g. WRUAs) can effectively support sustainable utilization of water resources and uptake of alternative water resource use technologies in the sub-catchment.

REFERENCES

Adamowicz, W. & Boxall, P. C. (2001). *Future directions of stated choice methods for environmental valuation.* Paper prepared for: Choice experiments: A new approach to environmental valuation. London, England

Adamowicz, W., Louviere, J., & Williams, M., (1994). Combining revealed and stated preference methods for valuing environmental amenities. *J. Environ. Econ. Manage*. *26*, 271–292.

African Technology Policy Studies (ATPS). (2013). Indigenous Rain Water Harvesting Practices for Climate Adaptation and Food Security in Dry Areas: The Case of Bahi District [Deusdedit Kibassa]. ATPS Research Paper No. 22

African Union (AU). (2015). *AGENDA 2063: The Africa we want - First Ten-Year Implementation Plan*, (April), 140. Retrieved from www.agenda2063.au.int

African Union (AU). (2003). *Maputo Declaration on Agriculture and Food Security. Assembly of The African Union*, Second Ordinary Session 10 - 12 July 2003

Agrawal, A. (2001). Common Property Institutions and Sustainable Governance of Resources. *World Dev. 29(*10), 1649-1672.

Agricultural and Consumer Economics (ACE). (accessed 2015). Research Collaborations: Department of Agricultural and Consumer Economics, http://ace.illinois.edu/sierraleone/research (accessed January 20, 2015).

Akuffobea-Essilfie, M., Williams, P. A., Asare, R., Damman, S., & Essegbey, G. O. (2019). Promoting rainwater harvesting for improving water security: Analysis of drivers and barriers in Ghana. African Journal of Science, Technology, Innovation and Development, 0(0), 1–9.

Alcon, F., Tapsuwan, S., Brouwer, R., & de Miguel, M. D. (2014). Adoption of irrigation water policies to guarantee water supply: A choice experiment. *Environmental Science and Policy*, *44*, 226–236.

Alexandratos, N., & Bruinsma, J. (2012). World agriculture towards 2030/2050: the 2012 revision. *ESA Working Paper*, *No. 12-03*(12), 147. Rome, FAO

Ali, A., Okeyo, B., Tewodros, T., Handa, C., Wanzala, W., Gerd, … Neema M. (2014, November). Water use conflicts in East Africa: Lessons Learnt from International DAAD Alumni Expert Seminars on Integrated Water Resources Management within Tsavo River Catchment. *African Academy of Sciences*, *Vol. 18*, pp.11

Alpizar, F., Carlsson, F., & Martinsson, P. (2001) Using choice experiments for non-market valuation. Department of Economics, *Working Papers in Economics Series, No. 52*. Goteborg University, Goteborg.

Altobelli, F., Lall, U., Dalla Marta, A., Caracciolo, F., Cicia, G., D'Urso, G., & Del Giudice, T. (2018). Willingness of farmers to pay for satellite-based irrigation advisory services: A southern Italy experience. Journal of Agricultural Science, 156(5), 723–730.

Anderson, A, Karar, E., & Farolfi, S. (2008). Synthesis: IWRM Lessons for Implementation. *Water SA 34*(6):665-669

Araral, E. (2009). What Explains Collective Action in the Commons? Theory and Evidence from the Philippines. *World Dev. 37(3),* 687-697.

Asfaw, D., & Neka, M. (2017). Factors affecting adoption of soil and water conservation practices: The case of Wereillu Woreda (District), South Wollo Zone, Amhara Region, Ethiopia. *International Soil and Water Conservation Research, 5*(4), 273–279.

Assefa, N. (2012). *Valuing the Economic Benefit of Irrigation Water : Application of Choice Experiment and Contingent Valuation Methods to Ribb Irrigation and Drainage Project in South Gonder, Ethiopia* (Unpublished doctoral dissertation). Addis Ababa University, Ethiopia

Ayashola, A., Sule, B., & Salami, A. (2013). Evaluation of will Willingness to pay for reliable and sustainable Household water use in ilorin, Nigeria. *Ethiopian Journal of Environmental Studies and Management, 6,* 754–762.

Aydogdu, M. H., & Bilgic, A. (2016). An evaluation of farmers ' willingness to pay for efficient irrigation for sustainable usage of resources : the GAP-Harran Plain case , Turkey. *Journal of Integrative Environmental Sciences, 13*(2-4*),* 175–186.

Aydogdu, M. H. (2019). Farmers ' Attitudes to the Pricing of Natural Resources for sustainability: GAP Sanliurfa Sampling of Turkey. *Water, 11*, 1772.

Aydogdu, M. H., & Yenigun, K. (2016). Willingness to pay for sustainable water usage in Harran Plain-Gap Region, Turkey. *Applied Ecology and Environmental Research, 14*(3), 147–160.

Baldwin, E., Evans, T., Washington-Ottombre, C., Dell'Angelo, J., & Cole, D. (2016). Polycentric Governance and Irrigation Reform in Kenya. *Governance*, *29*(2), 207–225.

Baldwin, E., McCord, P., Dell'Angelo, J., & Evans, T. (2018). Collective action in a polycentric water governance system. *Environmental Policy and Governance, 28*(4), 212–222.

Barbosa, M. C., Alam, K., & Mushtaq, S. (2016). Water policy implementation in the state of São Paulo, Brazil: Key challenges and opportunities. *Environmental Science & Policy, 60,* 11–18.

Bertule, M., Glennie, P., Bjørnsen, P. K., Lloyd, G. J., Kjellen, M., Dalton, J., … Harlin, J. (2018). Monitoring water resources governance progress globally: Experiences from monitoring SDG indicator 6.5.1 on integrated water resources management implementation. *Water (Switzerland), 10*(12), 1–20.

Beveridge, R. & Monsees, J. (2012). Bridging parallel discourses of Integrated Water Resources Management (IWRM): Institutional and political challenges in developing and developed countries. *Water International 37*(7), 727-743.

Biazin, B., Sterk, G., Temesgen, M., Abdulkedir, A., and Stroosnijder, L. (2012). Rainwater harvesting and management in rainfed agricultural systems in sub-Saharan Africa – A review. *Physics and Chemistry of the Earth 47–48* (2012) 139–151.

Birol, E., & Koundouri, P. (2008). *Introduction. In Birol, E. and Koundouri, P. (Eds), Choice Experiments Informing Environmental Policy*. Edward Elgar Publishing Limited, UK

Biswas, A. K. (2004). Integrated Water Resource Management: A Reassessment. *Water International 29*(2): 248-256.

Bo, A., Friis, K., Osborne, R., & Maindal, H. T. (2014). *National indicators of health literacy: ability to understand health information and to engage actively with healthcare providers*—a population-based survey among Danish adults.

Bockstael, N. E. & McConnel, K. E. (2007). *Environmental and Resource Valuation with Revealed Preferences: A Theoretical Guide to Empirical Models*. Springer, The

Netherlands

Boer, C. L. (2012). Contextual water management: a study of governance and implementation processes in local stream restoration projects. Enschede: Universiteit Twente.

Boone, C., Dyzenhaus, A., Manji, A., Gateri, C. W., Ouma, S., Owino, J. K., … Klopp, J. M. (2019). Land law reform in Kenya: Devolution, veto players, and the limits of an institutional fix. *African Affairs*, *118*(471), 215–237.

Boulanger, P., Dudu, H., Ferrari, E., Mainar, A. J., Balié, C. J., Battaglia, L., … Balié, J. (2018). *Policy options to support the Agriculture Sector Growth and Transformation Strategy in* Kenya A Computable General Equilibrium (CGE) analysis. Publication Office of the European Union, Luxembourg.

Bouma, J.A., Hegde, S. S., & Lasage R. (2016). Assessing the Returns to Water Harvesting: A Meta-Analysis. *Agricultural Water Management 163* (2016) 100-109.

Bozorg-haddad, O. (2016). Estimation of farmers' willingness to pay for water in the agricultural sector. *Agricultural Water Management, 177*, 284–290

Bressers, H., Bressers, N., & Larrue, C. (2016). *Governance for drought resilience: Land and water drought management in Europe*. *Governance for Drought Resilience: Land and Water Drought Management in Europe*. Springer International Publishing.

Bressers, H., de Boer, C., Lordkipanidze, M., Özerol, G., Vinke-de Kruijf, J., Farusho, C., ... Browne, A. (2013). Water governance assessment tool: with an elaboration for drought resilience. INTERREG IVb DROP project.Cole, D. H., Carpenter, S., & Baldwin, E. (2017). The polycentric turn: A case study of Kenya's evolving legal regime for irrigation waters. Natural Resources Journal, 57(1), 101–137

Bressers, N. (2015). DROP Partners. Benefit of Governance in Drought Adaptation. A Handbook for Regional Water Authorities; DROP Project: Almelo, The Netherlands, 2015; Available online: http://www.dropproject.eu/publications (accessed on 1 December 2015).

Brown, R. R., & Keath, N. A. (2007). Drawing on social theory for transitioning to sustainable urban water management: Turning the institutional super-tanker. *Australian Journal of Water Resources*, *12*(1), 73–83.

Bunclark, L., Gowing, J., Oughton, E., Ouattara, K., Ouoba, S., & Benao, D. (2018). Understanding farmers' decisions on adaptation to climate change: Exploring adoption of water harvesting technologies in Burkina Faso. *Global Environmental Change*, *48*(November 2017), 243–254.

Buriti, R., Al-Saidi, M., & Ribbe, L. (2018). Challenges of multi-level water governance at micro-watershed level – A case from Rio de Janeiro , Brazil Challenges of multi-level water governance at micro- watershed level – A case from Rio de Janeiro , Brazil.

Caribbean Institute of Media and Communication (CIMC). (2012). Report on Climate Change Knowledge, Attitude and Behavioural Practice Survey. *Univeristy of the West Indies, Jamaica*, 1–157.

Cascetta, E. (2009). *Transportation Systems Analysis*. Springer Science & Business Media. Vol.29, 89-167

Choice Metrics, (2014). *Ngene 1.1.2. user manual and Reference Guide: The Cutting Edge in Experimental Design.* Available at: www.choice-metrics.com

Cody, K. C., Smith, S. M., Cox, M., & Andersson, K. (2015). Emergence of Collective Action in a Groundwater Commons: Irrigators in the San Luis Valley of Colorado. *Society and Natural Resources, 28*(4), 405–422.

Cole, D. H., Carpenter, S., & Baldwin, E. (2017). The polycentric turn: A case study of Kenya's evolving legal regime for irrigation waters. *Natural Resources Journal, 57*(1), 101–137.

Cox M, Arnold G, Villamayor-Tomas, S. (2010). A review of design principles for community-based natural resource management. *Ecology & Society 15(4),* 1–19

Critchley, W. & Siegert, K. (1991). *Water Harvesting*. FAO, Rome, Italy. pp. 33.

D'Agostino, D. D., Borg, M., Hallett, S. H., Sakrabani, R. S., Thompson, A., Papadimitriou, L., & Knox, J. W. (2019). Multi-stakeholder analysis to improve agricultural water management policy and practice in Malta. *Agricultural Water Management, (January),* 105920.

Daniel, K., Coombes, P., & White, I. (2014). Politics of innovation in multi-level water governance systems. *Journal of Hydrology 519 (2014),* 2415–2435.

Dean, A. J., Fielding, K. S., Lindsay, J., Newton, F. J., & Ross, H. (2016). How social capital influences community support for alternative water sources. Sustainable Cities and Society, 27, 457–466. https://doi.org/10.1016/j.scs.2016.06.016

Dean A. J, Lindsay J, Fielding K. S., & Smith L. (2016). Fostering water sensitive citizenship –Community profiles of engagement in water-related issues. *Environ Sci Policy*. *55*(1), 238–47.

De Boer, C., Bressers, H. (2011). Complex and Dynamic Implementation Processes: The Renaturalization of the Dutch Regge River; University of Twente, in Collaboration with the Dutch Water Governance Centre: Enschede, The Netherlands, 2011.

De Boer, C. Contextual Water Management: A Study of Governance and Implementation Processes in Local Stream Restoration Projects. Ph.D. Thesis, Universiteit Twente, Enschede, The Netherlands, 2012.

De Fraiture, C., Molden, D., & Wichelns, D. (2010). Investing in water for food, ecosystems, and livelihoods: An overview of the comprehensive assessment of water management in agriculture. *Agricultural Water Management*, *97*(4), 495–501.

De Fraiture, C., Wichelns, D., Kemp Benedict, E., & Rockstrom, J. (2007). *Scenarios on water for food and environment*. Earthscan, London and International Water Management Institute, Colombo

De Graaf, R. (2009). *Innovations in Urban Water Management to Reduce the Vulnerability of Cities* (Published Doctoral Thesis). Delft University of Technology, Netherlands.

Dellapenna, J. W. & Gupta (2009). The Evolution of Global Water Law. In Dellapenna, J. W. & Gupta, J. (eds.), *The Evolution of the Law and Politics of Water*. Springer.

Dell'Angelo, J., McCord, P. F., Gower, D., Carpenter, S., Caylor, K. K., & Evans, T. P. (2016). Community Water Governance on Mount Kenya: An Assessment Based on Ostrom's Design Principles of Natural Resource Management. *Mountain Research and Development, 36*(1), 102–115.

De Trincheria, J., Oduor, A., Ngigi, S., Oremo, F.O., Ngondi, J., van Steenbergen, F.,… Leal Filho, W. (2017). *Advanced training materials on rainwater harvesting irrigation management in arid and semi-arid areas of sub-saharan Africa: Technical capacity* *building on the use of rainwater for off-season smallscale irrigation in Ethiopia, Kenya, Mozambique and Zimbabwe.* AFRHINET Project. Hamburg University of Applied Sciences, Hamburg, Germany.

Dolnicar, S., & Hurlimann, A. (2010). Australians' water conservation behaviours and attitudes. *Australian Journal of Water Resources, 14*(1), 43–53.

Falkenmark, M., Finlayson, M., Gordon, L. J., Bennett, E. M., Chiuta, T. M., Coates, D., … Wasson, R. (2007). Agriculture, water, and ecosystems: avoiding the costs of going too far. In Molden, David (Ed.), *Water for food, water for life: a Comprehensive Assessment of Water Management in Agriculture* (pp. 233-277). London, UK: Earthscan; Colombo, Sri Lanka: International Water Management Institute (IWMI).

FAO, 2016. Food Security Indicators. ⟨http://www.fao.org/economic/ess/ess-fs/essfadata/en/#.WJmu-2_hCUk⟩.

FAO. 2017. *The future of food and agriculture – Trends and challenges*. Rome.

FAO. (2018). Food Security and Nutrition in the World. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing. https://doi.org/10.1109/JSTARS.2014.2300145

FAO. (2015). State of Food Insecurity in the World 2015. *Meeting the 2015 international hunger targets: taking stock of uneven progress*. Rome, FAO.

Fisher, B, Christie, M. (2010). Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation. In Kumar P (ed.) *TEEB: the economics of ecosystems and biodiversity. Ecological and Economic Foundations*. Earth Scan, London. Chapter 1, p 1–40

Flores, C., Vikolainen, V., & Bressers, H. (2016). Water Governance Decentralisation and River Basin Management Reforms in Hierarchical Systems : Do They Work for Water Treatment Policy in Mexico.

Freeman, A. M. (1993). *The Measurement of Environmental and Resource Values: Theory and Methods, Resources for the Future*. Washington, DC.

Fujiie, M., Hayami, Y., & Kikuchi, M. (2005). The Conditions of Collective Action for Local Commons Management: the Case of Irrigation in the Philippines. *Agric. Econ.33*(2), *179-189.*

Gachenga, E. (2018). Kenya's Water Act (2016): real devolution or simply the 'same script, different cast. In Kameri-Mbote, P., Paterson, A., Ruppel, O., Orubebe, B., & Kam Yogo, Law, Environment, Africa, Publication of the 5th Symposium, 4th Scientific Conference of the Association of Environmental Law Lecturers from African Universities in cooperation with the Climate Policy and Energy Security Programme for Sub-Saharan Africa of the Konrad-Adenauer-Stiftung and UN Environment.

Gachenga, E. (2015). Customary law system for water governance in Kenya. In P. Martin et al., the search for environmental justice. The IUCN Academy of Environmental Law Series, Edward Elgar Publishing, UK.

Gan, C., & Luzar, E.J., (1993). A Conjoint Analysis of Waterfowl Hunting in Louisiana. J. *Agric. Appl. Econ. 25,* 36–45.

García Soler, N., Moss, T., & Papasozomenou, O. (2018). Rain and the city: Pathways to mainstreaming rainwater harvesting in Berlin. *Geoforum*, *89*(January), 96–106.

Garg, K.K., Wani, S.P., Barron, J., Karlberg, L., Rockström, J. (2012). Up-scaling potential impacts on water flows from agricultural water interventions: opportunities and trade-offs in the Osman. *Hydrol. Process.*

Gilbertson, M., Hurlimann, A., & Dolnicar, S. (2011). Does water context influence behaviour and attitudes to water conservation? *Australasian Journal of Environmental Management, 18*(1), 47–60.

Giordano, M., & Fraiture, C. De. (2014). Small private irrigation : Enhancing benefits and managing trade-offs. *Agricultural Water Management, 131*, 175–182.

Global Water Partnership. (2005). *Catalyzing Change: A Handbook for Developing IWRM and Water Efficiency Strategies*

Global Water Partnership (GWP). (2000). *Integrated Water Resources Management. Technical Advisory Committee*. Background Paper No. 4. Stockholm: Global Water Partnership Secretariat.

Global Water Partnership (GWP). (2017). The need for an integrated approach. Retrieved from. http://www.gwp.org/en/About/why/the-need-for- an-integrated-approach (accessed 15 May 2019)

Glover, D., Sumberg, J., Ton, G., Andersson, J., & Badstue, L. (2019). Rethinking technological change in smallholder agriculture. *Outlook on Agriculture, 48*(3), 169–180.

Haigh, R, Amaratunga, D., Pathirage, C. (2007) 'The Role of Philosophical Context in the Development of Research Methodology and Theory', *The Built and Human Environment Review,* 1,1- 5

Haiyan, Yu., Anna, L., Mike, E. & Dave, T. (2013). Villagers' Perceptions of Water Crises and the Influecing Factors of Local Perceptions: A case Study in the Shiyang River Basin, Northwest China. *The Journal of Transdisciplinary Environmental Studies 12, (2).*

Hanley, N. Shogren, J. F. & White, Ben (2007). *Environmental Economics in Theory and Practice*. Palgrave Macmilan, UK

Hardin, R. (1982). Collective action: *A book from resources for the future*. Baltimore, MD, USA: The Johns Hopkins University Press.

Hatibu, N., & Mahoo, H. F. (2000). *Rainwater harvesting for natural resources management. A planning guide for Tanzania*. Technical Handbook No. 22.RELMA, Nairobi.

Hellegers P. & Lefaive, X. (2015) Water allocation reform: what makes it so difficult? *Water International, 40*(2), 273–285

Hidalgo-Toledo, Arturo, J., Hernández-Arce, C., & Vargas-Velázquez, S. (2019). River Basin Organisation, the Best Path Towards Integrated Water Resources Management. In H. R. Guerrero García Rojas (ed.) *Water Policy in Mexico, Global Issues in Water Policy* 20,

Hilimire, K., & Greenberg, K. (2019). Water conservation behaviors among beginning farmers in the western United States. *Journal of Soil and Water Conservation 74*(2), 138–144.

Hoekstra, A. Y., Chapagain, A. K., & van Oel, P. R. (2019). Progress in water footprint assessment: Towards collective action in water governance. *Water (Switzerland), 11*(5).

Hole, A. (2013). *Mixed logit modeling in Stata - an overview United Kingdom Stata Users.* Group Meetings 2013 23. Stata Users Group.

Hughes, L. (2005). Malice in Maasailand: The historical roots of current political struggles. *African Affairs*, *104*(415), 207–224.

Hussain, I. & Giordano, M. (Eds). (2004). *Water and Poverty Linkages: Case Studies from Nepal, Pakistan and Sri Lanka. Colombo, Sri Lanka*: International Water Management Institute (Project Report).

International Conference on Water and Environment (ICWE). (1992). *Dublin Statement, International Conference on Water and Environment.* Dublin, 29-31 December 1992.

Intergovernmental Panel on Climate Change. (2014). *Climate Change 2014 Synthesis Report - IPCC. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*.

Intergovernmental Panel on Climate Change. (2012). *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, NY, USA

International Water Association (IWA). (2016). *Global Trends & Challenges in Water Science, IWA Specialist Group*. London

Ison, R., Roling, N., & Watson, D. (2007). Challenges to science and society in the sustainable management and use of water: investigating the role of social learning. *Environmental Science and Policy 10* (6), 499-511

Israel, G.D. (1992). *Determining Sample Size.* University of Florida Cooperative Extension Service Institute of Food and Agriculture Sciences, EDIS.

Jacobs, M. H., & Buijs, A. E. (2011). Understanding stakeholders' attitudes toward water management interventions: Role of place meanings. *Water Resources Research*, *47*(1), 1–11.

Jaetzold, R., & Schmidt, H. (1983). *Farm Management Handbook of Kenya*. Vol. 2. Nairobi: Ministry of Agriculture

Jägermeyr, J., Gerten, D., Schaphoff, S., Heinke, J., Lucht, W., & Rockström, J. (2016). Integrated crop water management might sustainably halve the global food gap. *Environmental Research Letters*, *11*(2).

Jägermeyr, J., Pastor, A., Biemans, H., & Gerten, D. (2017). Reconciling irrigated food production with environmental flows for Sustainable Development Goals implementation. *Nature Communications*, *8*(May), 1–9.

Janssen, M. A., Anderies, J. M., Perez, I., & Yu, D. J. (2015). The effect of information in a behavioral irrigation experiment. *Water Resources and Economics*, *12*, 14–26

Jarvie C. I, Bonilla- Z.J. (2011). "The Sage Handbook of the Philosophy of Social Sciences", London, Sage Publications Ltd: pg. 521

Jeffrey, P. & Seaton, R. (2004). A Conceptual Model of 'Receptivity' Applied to the Design and Deployment of Water Policy Mechanisms. *Environmental Sciences, 1*(3), 277-300.

Juma, C.& Ojwang, J. B. (1996). In land we trust: Environment, private property and constitutional change. Nairobi: Initiatives Publishers

Keating, M. and Porta, D. (2008). "Approaches and Methodologies in the Social Sciences: A Pluralist Perspective". Cambridge, Cambridge University Press, pp. 19 – 38.

Kameri-Mbote, P. (2006). Land Tenure, Land Use, and Sustainability in Kenya: Toward Innovative Use of Property Rights in Wildlife Management. In N. Chalifour, P. Kameri-Mbote, L. Lye, & J. Nolon (Eds.), Land Use Law for Sustainable Development (IUCN Academy of Environmental Law Research Studies, pp. 132-160). Cambridge: Cambridge University Press.

Kameri-Mbote, P. (2008) "Land Tenure and Sustainable Environmental Management in Kenya." In Okidi, C., Kameri-Mbote, P. Akech, M. *Environmental Governance in Kenya: Implementing the Framework Law*. East Africa Educational Publishers.

Kattel, R. R. (2015). *Rainwater Harvesting and Rural Livelihoods in Nepal*. South Asian Network for Development and Environmental Economics (SANDEE).

Karp, D. S., Chaplin-Kramer, R., Meehan, T. D., Martin, E. A., DeClerck, F., Grab, H., … Zou, Y. (2018). Crop pests and predators exhibit inconsistent responses to surrounding landscape composition. *Proceedings of the National Academy of Sciences*, *115*(33), E7863–E7870.

Kassie, M., Stage, J., Teklewold, H., & Erenstein, O. (2015). Gendered food security in rural Malawi: why is women's food security status lower? *Food Security 7*, 1299–1320

Khan, I., & Zhao, M. (2019). Water resource management and public preferences for water ecosystem services: A choice experiment approach for inland river basin management. *Science of the Total Environment*, *646*, 821–831.

Kenya Wildlife Services. (2008). *Tsavo conservation Area Management Plan 2008-2018.*

Koissaba, B. O. (2016). Elusive Justice: The Maasai Contestation of Land Appropriation in Kenya : A Historical and Contemporary Perspective. In Kithinji, M., Koster, M., & Rotich J (Eds.), Kenya After 50: African Histories and Modernities (pp. 189-219). Palgrave Macmillan, New York

Kuks, S., Bressers, H., Boer, C. de, Vinke, J., & Özerol, G. (2012). Governance assessment tool - Institutional capacity, (April), 6–9.

Kumar, R. (2014). Research Methodology, A step by Step guide for Beginners. London, Sage Publications, pp. 10 – 25.

Kumar, S., Ramilan, T., Ramarao, C. A., Srinivasa, C., & Whitbread, A. (2016). Farm level rainwater harvesting across different agro climatic regions of India : Assessing performance and its determinants. *Agricultural Water Management, 176*, 55–66.

Kumar, S., Ramarao, C. A., Patan, E. K., Paresh, S., & Whitbread, A. M. (2018). Potential of farm level rainwater harvesting for enhancing resilience of dryland farming systems in India. In: *Global Water Security Conference for Agriculture and Natural Resources*, 3-6 Oct, 2018, Hyderabad, India.

Lacroix, K. E. M. (2016). Building Common Ground for Environmental Flows using Traditional Techniques and Novel Engagement Approaches. Environmental Management, 57(4), 912–928.

Lasage, R., & Verburg, P.H. (2015). Evaluation of Small Scale WHTs for Semi-Arid Environments. *Arid Environ. 118*, 48-57

Leeuwis, C., Pyburn, R., & Röling, N. G. (2002). *Wheelbarrows full of frogs: social learning in rural resource management : international research and reflections.* Assen: Koninklijke Van Gorcum.

Liang, X., & Dijk, M. P. Van. (2011). Resources , Conservation and Recycling Economic and financial analysis on rainwater harvesting for agricultural irrigation in the rural areas of Beijing. *Resources, Conservation & Recycling 55*(11), 1100–1108.

Lienert, J., Schnetzer, F., & Ingold, K. (2013). Stakeholder analysis combined with social network analysis provides fine-grained insights into water infrastructure planning processes, 125, 134–148.

Lordkipanidze, M., Bressers, H., & Lulofs, K. (2019). Governance assessment of a protected area: the case of the Alde Feanen National Park. *Journal of Environmental Planning and Management*, *62*(4), 647–670.

Lyytinen, K., & Damsgaard, J. (2001). What ' s Wrong with the Diffusion of Innovation Theory? The case of a complex and networked technology. https://doi.org/10.1007/978-0-387-35404-0

Macvaugh, J., & Schiavone, F. (2010). Limits to the diffusion of innovation: A literature review and integrative model. *European Journal of Innovation Management, 13,* 197 – 221

Mahmoud, N., Hogland, W., Sokolov, M., Rud, V., & Myazin, N. (2018). Assessment of rainwater harvesting for domestic water supply in palestinian rural areas. MATEC Web of Conferences, 245, 06012.

Malesu, M., Black, J., Oduor, A., Cheregony K., & Nyabenge, M. (2012). *Rain Water Harvesting Inventory of Kenya*. The World Agroforestry Centre

Malik, R P S, Giordano, M., & Sharma, V. (2014). Examining farm-level perceptions , costs , and benefits of small water harvesting structures in Dewas , Madhya Pradesh. *Agricultural Water Management, 131*, 204–211.

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), 515–536. https://doi.org/10.1016/j.foodpol.2006.10.002.

Mati B.M. (2007). *100 ways to manage water for small holder agriculture in East and Southern Africa*. SWMnet Working Paper 13. Improved Management in Eastern and Southern Africa (IMAWESA).

McCord, P., Dell'Angelo, J., Baldwin, E., & Evans, T. (2017). Polycentric Transformation in Kenyan Water Governance: A Dynamic Analysis of Institutional and Social-Ecological Change. *Policy Studies Journal*, *45*(4), 633–658.

McCord, P., Waldman, K., Baldwin, E., Dell'Angelo, J., & Evans, T. (2018). Assessing multi-level drivers of adaptation to climate variability and water insecurity in smallholder irrigation systems. *World Development*, *108*, 296–308.

McDuff M. M, Appelson G. S, Jacobson S. K., & Israel G. D. (2008). Watershed management in North Florida: public knowledge, attitudes and information needs. *Lake Reserv Manage. 2008; 24*(1), 47–56.

Mees, H., Suykens, C., & Crabbé, A. (2017). Evaluating Conditions for Integrated Water Resource Management at Sub-basin Scale. A Comparison of the Flemish Sub-basin Boards and Walloon River Contracts, 73(January), 59–73.

Mehta, L., Movik, S., Bolding, A., Derman, B., & Manzungu, E. (2017). Introduction - Flows and practices: The politics of integrated water resources management (IWRM) in eastern and Southern Africa. Flows and Practices: *The Politics of Integrated Water Resources*

Management in Eastern and Southern Africa, *9*(3), 1–29.

Mehta, L. and Movik, S. (2014). *Flows and practices: Integrated Water Resources Management (IWRM) in Africa Contexts*. Institute of Development Studies (IDS).London, UK.

Meijer, S. S., Catacutan, D., Ajayi, O. C., Sileshi, G. W., & Nieuwenhuis, M. (2015). The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa. *International Journal of Agricultural Sustainability*, *13*(1), 40–54.

Meinzen-Dick, R., Janssen, M. A., Kandikuppa, S., Chaturvedi, R., Rao, K., & Theis, S. (2018). Playing games to save water: Collective action games for groundwater management in Andhra Pradesh, India. *World Development*, *107*, 40–53.

Mekdaschi, S. R. & Liniger, H. (2013). *Water Harvesting: Guidelines to Good Practice. Centre for Development and Environment (CDE*). Bern; Rainwater Harvesting Implementation Network (RAIN), Amsterdam; MetaMeta, Wageningen; The International Fund for Agricultural Development (IFAD), Rome.

Menga, F. (2016). Domestic and international dimensions of transboundary water politics. *Water Alternatives, 9*(3),704–723.

Mersha, A. N., Masih, I., de Fraiture, C., Wenninger, J., & Alamirew, T. (2018). Evaluating the impacts of IWRM policy actions on demand satisfaction and downstream water availability in the Upper Awash Basin, Ethiopia. *Water (Switzerland), 10*(7).

Mills, J., Gaskell, P., Ingram, J., Dwyer, J., Reed, M., & Short, C. (2017). Engaging farmers in environmental management through a better understanding of behaviour Theory of Planned Behaviour. *Agric Hum Values*, 34, 283–299

Nkonya, E., Pender, J., Kaizzi, C, Kato, E., Mugarura, S., Ssali, H., & Muwonge J. (2008). Linkages Between Land Management, Land Degradation, and Poverty in Sub-Saharan Africa: The Case of Uganda. IFPRI Research Report No. 00159. International Food Policy Research Institute, Wasington D.C.

Molden, D., Oweis, T., Steduto, P., Bindraban, P., Hanjra M., & Kijne, J. (2010). Improving Agricultural Water Productivity: Between Optimism and Caution. *Agricultural Water Management*, *97*(4), 528-535

Mottaleb, K. A. (2018). Perception and adoption of a new agricultural technology: Evidence from a developing country. *Technology in Society*, *55*(April), 126–135.

Mott, L. K. & Megdal, S. B. (2016). Explore, synthesize, and repeat: Unraveling complex water management issues through the stakeholder engagement wheel. Water 8(4)

Mukhopadhyay, P., In Nawn, N., & In Das, K. (2017). *Global change, ecosystems, sustainability: Theory, methods, practice*. New Delhi, India, Thousand Oaks, California: SAGE Publications India

Murase, M. (2009). Innovative Rainwater Museum in Japan. *The 8th International Conference on Urban Drainage Modelling and the 2nd International Conference on Rainwater Harvesting and Management.* 7-12th September. Tokyo, Japan.

Mutabazi, K., Hatibu, N., Senkondo, E. Mbilinyi, B., & Tumbo, D. (2005). *Economics of Rainwater Harvesting for Crop Enterprises in Semi-Arid Areas: The Case of Makanya Watershed in Pangani River Basin, Tanzania.* Soil-Water Management Research Group.

Mwihaki, N. J. (2018). Decentralisation as a tool in improving water governance in Kenya, 1–14. https://doi.org/10.2166/wp.2018.102

Ncube, B., Magombeyi, M., Munguambe, P., Mupangwa, W. & Love, D. (2008). Methodologies and case studies for investigating upstream-downstream interactions of rainwater water harvesting in the Limpopo Basin. *Proceedings of the Workshop on Increasing the Productivity and Sustainability of Rainfed Cropping Systems of Poor, Smallholder Farmers, Tamale, Ghana, 22-25 September 2008*

Ndeketeya, A., & Dundu, M. (2019). Maximising the benefits of rainwater harvesting technology towards sustainability in urban areas of South Africa: a case study in urban areas of South Africa : a case study. *Urban Water Journal*, *16*(2), 163–169.

New Partnership for Africa's Development (NEPAD). (2015). *Synthesis of the Malabo Declaration on African Agriculture and CAADP*, 1(June 2014), 2–5.

Ngigi, S.N. & G. Denning. (2008). Assessment of water resources management for smallholder farming systems adaptation of African agriculture to climate change in sub-Saharan Africa. *World Scientific and Engineering Academy and Society (WSEAS).*

Ngigi, S. N., Mutui, Ngeno, F., & Mwaura, J. (2015). *Proceedings of the Regional Stakeholders' Knowledge Sharing and Networking Workshop, KCB Training and Leadership Centre, Karen, Nairobi, Kenya. Kenya Rainwater Association*. August 24–26, 2015.

Ngigi, S.N. (2003). *Rainwater harvesting for improved food security: Promising technologies in the Greater Horn of Africa*. Greater Horn of Africa Rainwater Partnership (GHARP), Kenya Rainwater Association (KRA), Nairobi, Kenya. pp.266

Ngigi, S. N., Rockstrom, J., & Savenije, H.G., (2006). Assessment of rainwater retention in agricultural land and crop yield increase due to conservation tillage in Ewaso Ng'iro river basin, Kenya. *Physics and Chemistry of the Earth, Parts A/B/C, 31*(15-16): 910-918.

Ngigi, S. N., Savenige, H.G., Rockstrom, J., & Gichuki, F.N., (2008). Hydrological Impacts of Food Storage on Irrigation Water Abstraction in Upper Ewaso Ng'iro river basin, Kenya. *Water Resources Management, 22*,1859-1879

Ngigi, S. N. (2018). Towards optimizing the performance and cost-Effectiveness of farm pond technology for small-scale irrigation in sdemi-arid farming systems. In W. Leal Filho and J. De Trincheria Gomez, *Rainwater-Smart Agriculture in Arid and Semi-Arid Areas.* Springer International Publishing

Ngigi, S.N., Warui, P.G., & Korir, C.C. (2014). *Rainwater Harvesting and Utilization. Final Project Report*. USAID-funded Kenya Horticulture Competitiveness Project, Partner Fund Award No. 6 for (May 2011 - June 2014). Kenya Rainwater Association, KRA Secretariat, Nairobi, Kenya

Nguyen, D. C., & Han, M. (2018). Rainfall-storage-utilization-discharge model for flood mitigation and water conservation. *Water Science and Technology: Water Supply*, *18*(4), 1252–1260.

Nhemachena, C., & Hassan, R. (2007). *Micro-level analysis of farmers' adaptation to climate change in Southern Africa*. IFPRI Discussion Paper No. 00714. International Food Policy Research Institute, Washington, D.C.

Nicol, A., Langan, S., Victor, M., & Gonsalves, J. (Eds.) (2015). *Water-smart agriculture in*

East Africa. Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Research Program on Water, Land and Ecosystems (WLE); Kampala, Uganda: Global Water Initiative East Africa (GWI EA). 352p.

Nkomoki, W., Bavorová, M., & Banout, J. (2018). Adoption of sustainable agricultural practices and food security threats: Effects of land tenure in Zambia. *Land Use Policy, 78*(July), 532–538.

Oates, B. J. (2006) Researching information systems and computing. Sage Publications Limited.

Obando, J. A., Luwesi, C. N., Förch, N., Opiyo, A. O., Shisanya, C., & Förch, G. (2018). Kenya Success Story in Water Resources Management: Participatory Capacity Building in Integrated Watershed Management. In C. Ondieki, & J. Kitheka (Eds.), *Hydrology and Best Practices for Managing Water Resources in Arid and Semi-Arid Lands* (pp. 185-208). Hershey, PA: IGI Global.

Ochoa-García, H., & Rist, S. (2018). Water Justice and Integrated Water Resources Management: Constitutionality Processes Favoring Sustainable Water Governance in Mexico. *Human Ecology, 46*(1), 51–64.

OECD. (2015). *OECD Principles on Water Governance*. Draft for consulation at the 7th World Water Forum. Report, (May), 1–23.

Ogada, J. O., Krhoda, G. O., Van Der Veen, A., Marani, M., & van Oel, P. R. (2017). Managing resources through stakeholder networks: collaborative water governance for Lake Naivasha basin, Kenya. *Water International, 42*(3), 271–290.

Oguge, N. & Oremo, F. (2017). Fostering the use of rainwater for off-season small-scale irrigation in arid and semi-arid areas of Kenya, In W. Leal Filho and J. De Trincheria Gomez (eds.), *Rainwater-Smart Agriculture in Arid and Semi-Arid Areas*. Springer International Publishing.

Okello, M. M., & Kioko, J. M. (2011). A Field Study in the Status and Threats of Cultivation in Kimana and Ilchalai Swamps in Amboseli Dispersal Area , Kenya. *Natural Resources 2*, 197–211.

Okoth-Ogendo, H. W.O. (1995). Terminalogy and land tenure in Customary law: An exercise in linguistic theory. In Woodman, G. & Obilade, A. O. (Eds.), *African law and legal theory.* New York University Press, New York.

Okumah, M., Yeboah, A. S., Nkiaka, E., & Azerigyik, R. A. (2019). What Determines Behaviours Towards Water Resources Management in a Rural Context ? Results of a Quantitative Study.

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

Orlendo, E. V. (2019). *Master Thesis: Behind the Tap: An analysis of Kenya's Water Act 2016.* Swedish University of Agricultural Sciences, Faculty of Natural Resources and Agricultural Sciences Department of Urban and Rural Development

Ostrom, Elinor. (1990). *Governing the Commons: The Evolution of Institutions for Collective Action.* Cambridge: Cambridge University Press.

Ostrom, Elinor. 2005. *Understanding institutional diversity*. Princeton: Princeton University Press.

Oweis, T. Y., Prinz, D., & Hachum, A. Y. (2012). *Rainwater harvesting for agriculture in the* *dry areas*. *Rainwater Harvesting for Agriculture in the Dry Areas*.

Oweis, T., Prinz, D. & Hachum, A. (2001) *Water Harvesting: Indigenous Knowledge for the Future of the Drier Environments*. International Centre for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria.

Pahl-Wostl, C. & Knieper, C. (2014). The Capacity of Water Governance to Deal with the Climate Change Adaptation Challenge: Using Fuzzy Set Qualitative Comparative Analysis to Distinguish between Polycentric, Fragmented and Centralized Regimes. Global Environmental Change 29, 139–154.

Pahl-Wostl, C., Lebel, L., Knieper, C., & Nikitina, E. (2012). From applying panaceas to mastering complexity: Toward adaptive water governance in river basins. *Environmental Science and Policy*, *23*, 24–34.

Paneque, P., Lafuente, R., & Vargas, j. (2018). Public Attitudes toward Water Management. *Water*, 1–15. https://doi.org/10.3390/w10040369

Pearce, D., Atkinson, G., & Mourato, S. (2006). *Cost-Benefit Analysis and the Environment: Recent developments.* Organisation for Economic Co-operation and Development

Penning de Vries, F.W.T., Mati, B., Khisa, G., Omar, S. & Yonis, M. (2005). Lessons Learned from Community Successes: A case for Optimism. In: Bright Spots: Demonstrate Community Successes in African Agriculture. Colombo, Sri Lanka: International Water Management Institute (IWMI). *Working Paper 102: 1-6*

Pluchinotta, I., Pagano, A., Giordano, R., & Tsoukiàs, A. (2018). A system dynamics model for supporting decision-makers in irrigation water management. Journal of Environmental Management, 223(June), 815–824.

Porcher, S., & In Saussier, S. (2019). Facing the challenges of water governance. Cham, Switzerland: Palgrave Macmillan.

Power, A. G. (2010). Ecosystem services and agriculture: Tradeoffs and synergies. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *365*(1554), 2959–2971.

Price, J. I., Janmaat, J., Sugden, F., & Bharati, L. (2016). Water storage systems and preference heterogeneity in water-scarce environments: A choice experiment in Nepal's Koshi River Basin. *Water Resources and Economics*, *13*, 6–18.

Quentin, G, R. (2017). Responding to the 'Wicked Problem' of Water Insecurity. *Water Resources Management 31*, 3023.

Rahaman, M. (2009). Integrated Water Resources Management: *Constraints and Opportunities with a focus on the Ganges and the Brahmaputra river basins*. Retrieved from http://lib.tkk.fi/Diss/2009/isbn9789512298754/ (accessed on 26 April 2019)

Rahaman, M. M. & Varis, O. (2005). *Integrated Water Resources Management: Evolution, Prospects and Future Challenges.* Sustainability: Science, Practice, & Policy 1 No. 1:15-21.

Recha, C. W., Mukopi, M. N., & Otieno, J. O. (2015). *Socio-Economic Determinants of Adoption of Rainwater Harvesting and Conservation Techniques in Semi-Arid Tharaka*, *773* (October 2014), 765–773.

Reed, M. S., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., … Stringer, L. C. (2009). Who' s in and why? A typology of stakeholder analysis methods for natural resource management. *Journal of Environmental Management*, *90*(5), 1933–1949.

Repko, F.A. (2012). Interdisciplinary Research Process and Theory, USA, Sage Publications, pp. 5 -135

Republic of Kenya (2010c). *Agricultural Sector Development Strategy 2010-2020*. Nairobi, Kenya.

Republic of Kenya (2019). *Agricultural Sector Transformation and Growth Strategy 2019-2029.* Nairobi, Kenya

Republic of Kenya (2010a). *The Constitution of the Republic of Kenya, 2010*. Nairobi, Kenya Government Printer

Republic of Kenya (2019). Irrigation Act 2019. Nairobi, Kenya, Government Press

Republic of Kenya. (2008). *Kenya Vision 2030*. Government Press, Nairobi, Kenya

Government of Kenya (2017), Kenya Climate Smart Agriculture Strategy-2017-2026. Available at: https://www.adaptation-undp.org/sites/default/files/resources/kenya_climate_smart_agriculture_strategy.pdf. Accessed on 15 July 2019.

Republic of Kenya. (2016). *Kenya National Adaptation Plan 2015-2030.* Ministry for Environment, Natural Resources and Regional Bodies

Republic of Kenya. (2013a). *National Climate Change Action Plan (NCCAP). 2013-2017.* Nairobi: Ministry of Environment and Mineral Resources.

Republic of Kenya (2010b). *National Climate Change Response Strategy*. Nairobi; Government Press

Republic of Kenya. (2013c). *National Environment Management Authority (NEMA): State of Environment Reports.* Government Press, Nairobi, Kenya

Republic of Kenya (1999). *The National Policy on Water Resources Management and Development, Sessional Paper No. 1 of 1999*. Nairobi

Republic of Kenya (2013b). *The Project on the Development of the National Water Master Plan 2030.* Final Report. Japan International Cooperation Agency.

Republic of Kenya (2009). *Sessional Paper No.3 of 2009 on National Land Policy* (Nairobi: Ministry of Lands, August 2009)

Republic of Kenya (2017). *Sessional Paper No.1 of 2017 on National Land Use Policy* (Nairobi: Ministry of Lands and Physical Planning, October 2017)

Republic of Kenya (2004). *Strategy for Revitalizing Agriculture.* Nairobi, Kenya Government Printer

Republic of Kenya (2016). *Water Act 2016*. Nairobi, Kenya, Governnment Press

Republic of Kenya (2002). *Water Act 2002*. Nairobi, Kenya, Governnment Press

Ricart, S., Kirk, N., & Ribas, A. (2019). Ecosystem services and multifunctional agriculture: Unravelling informal stakeholders' perceptions and water governance in three European irrigation systems. Environmental Policy and Governance, 29(1), 23–34.

Ricart, S., Rico, A., Kirk, N., Bülow, F., Ribas-palom, A., Ricart, S., … Ribas-palom, A. (2018). How to improve water governance in multifunctional irrigation systems ? Balancing stakeholder engagement in hydrosocial territories. *International Journal of Water Resources Development, 0627*, 1–34.

Richards, K. (2003). Qualitative inquiry in TESOL. New York, NY: Palgrave Macmillan.

Richard, N. (2019). Water Users Associations in Tanzania: Local Governance for Whom? *Water, 11*, 2198

Richter, B. D., Mathews, R., Harrison, D. L., & Wigington, R. (2003). Ecologically Sustainable Water Management: Managing River Flows for Ecological Integrity. *Ecological Applications, 13*(1), 206–224.

Rockström, J., & Falkenmark, M. (2015). Agriculture: Increase water harvesting in Africa. *Nature*, 519(7543), 283–285.

Rockstrom, J., Folke, C., Gordon, L., Hatibu, N., Jewitt, G., Penning de Vries, F., … Schulze, R. (2004). A watershed approach to upgrade rainfed agriculture in water scarce regions through Water System Innovations: an integrated research initiative on water for food and rural livelihoods in balance with ecosystem functions. *Physics and Chemistry of the Earth 29*(2004), 1109–1118

Rogers, E.M. (2003) *Diffusion of Innovations*, 5th ed. New York: Free Press

Rogers, E. M. (1995). *Diffusion of Innovations*. The Free Press, New York.

Rolston, A., Jennings, E,. & Linnane S. (2017). Water matters: An assessment of opinion on water Management and community engagement in the Republic of Ireland and the United Kingdom. *PLoS ONE 12*(4): *e0174957*

Rouillard, J., Reeves, D., Heal, K., & Ball, T. (2014). The role of public participation in encouraging changes in rural land use to reduce flood risk. *Land Use Policy 38,* 637–645

Roy, J. (2004). *Willingness to Pay Studies: A Policy Tool*. Paper Presented at the conference on Market Development of Water & Waste Technologies through Environmental Economics, 28th-29th May 2004, Paris.

Ryan, M., Gerard, K., & Amaya-Amaya, M. (2008). *Using Discrete Choice Experiments to Value Health and Health Care, The Economics of Non-Market Goods and Resources.*

Saunders, M., Lewis, P. and Thornhill, A. (2009). Understanding Research Philosophies and Approaches. Research Methods for Business Students., Pearson Education.

Saravanan, V.S. (2009). Critical Review of Integrated Water Resources Management; Moving Beyond Polarized Discourse. *Natural Resources Forum 33*(1), 76 – 86

Schuetze, T. (2013). Rainwater harvesting and management - Policy and regulations in Germany. Water Science and Technology: *Water Supply*, *13*(2), 376–385.

Sarkera, A., Baldwin, C., & Rossa, H. (2009). Managing groundwater as a common-pool resource: an Australian case study. *Water Pol. 11* (5), 598–614.

Sharma, A. (2019). Sizing of Domestic Rainwater Harvesting Systems Using Economic Performance Indicators to Support Water Supply Systems. *Water*, *11*, 783.

Shikuku, K. M., Winowiecki, L., Twyman, J., Eitzinger, A., Perez, J. G., Mwongera, C., & Läderach, P. (2017). Climate Risk Management Smallholder farmers ' attitudes and determinants of adaptation to climate risks in East Africa. *Climate Risk Management*, 16, 234–245.

Sombroek, W.G., Braun, H.M.H. and van der Pouw, B.J.A. (1982). Exploratory Soil Map and Agro-Climatic Zone Map of Kenya, 1980. Scale: 1:1'000'000. Exploratory Soil Survey Report No. E1. Kenya Soil Survey Ministry of Agriculture - National Agricultural

Laboratories, Nairobi, Kenya.

Spiegel, A., Britz, W., & Finger, R (July 28 – August 2018). Risk aversion and agricultural technology adoption – a combination of real options and stochastic dominance. 10th International Conference of Agricultural Economists, Vancouver.

Srivastava, R., Kannan, K., Mohanty, S., Nanda, P., Sahoo, N., Mohanty, R., & Das, M. (2009). Rainwater management for smallholder irrigation and its impact on crop yields in eastern India, Water Resour. Manag. 23, 1237–1255.

Stanbury P, Lynott J (1994, June). Irrigation Management and Conflict Resolution. Paper presented at the Workshop in Political Theory and Policy Analysis at North Park, Indiana University, 1994, June.

Steffen, J., Jensen, M., Pomeroy, C. A., & Burian, S. J. (2013). Water supply and stormwater management benefits of residential rainwater harvesting in U.S. cities. *Journal of the American Water Resources Association*, *49*(4), 810–824.

Stijn, S., & Chellatan, V. P. (2012). Comparing the scope for irrigation water rights reforms in India and South Africa. *Selected Paper Prepared for Presentation at the International Association of Agricultural Economists (IAAE) Triennial Conference, Foz Do Iguaçu, Brazil, 18-24 August, 2012.*

Stoneman, P L. (1985). Technological Diffusion: The Viewpoint of Economic Theory. The Warwick Economics Research Paper Series (TWERPS) 270, University of Warwick, Department of Economics.

Streimikiene, D., Balezentis, T., Alisauskaite-seskiene, I., Stankuniene, G., & Simanaviciene, Z. (2019). A Review of Willingness to Pay Studies for Climate Change Mitigation in the Energy Sector. *Energies(Switzerland),* 1-38.

Sullivan, A., White, D. D., & Hanemann, M. (2019). Designing collaborative governance: Insights from the drought contingency planning process for the lower Colorado River basin. *Environmental Science and Policy*, 91(October 2018), 39–49.

Susilo, G., & Jafri, M. (2019). The analysis of rainwater harvesting carrying capacity on water domestic supply for dwelling areas in Indonesia. Civil and Environmental Science, 2(1), 067–075.

Tang Z., Nan Z., & Liu, J. (2012). The Willingness to Pay For Irrigation Water: A case Study in Northwest China. *Global NEST Journal, 15* (1), 76-84.

Thomas, E., Riley, M., & Spees, J. (2020). Land Use Policy Knowledge fl ows : Farmers ' social relations and knowledge sharing practices in ' Catchment Sensitive Farming .' *Land Use Policy, 90(August 2019),* 104254.

Tran, H., Nguyen, Q., & Kervyn, M. (2018). Land Use Policy Factors in fl uencing people's knowledge , attitude , and practice in land use dynamics : A case study in Ca Mau province in the Mekong delta , Vietnam. *Land Use Policy*, *72*(December 2017), 227–238.

Trujillo-Barrera, A., Pennings, J. E. & Hofenk, D. (2016). Understanding producers' motives for adopting sustainable practices: the role of expected rewards, risk perception and risk tolerance. *European Review of Agricultural Economics 43 (3)*:359–82.

Twerefou, D. K., Osei-Assibey, E., & Agyire-Tettey, F. (2011). Land tenure security, investments and the environment in Ghana. *Journal of Development and Agricultural Economics*, *3*(6), 261–273.

United Nations Environment Programme (UNEP) (2012). *Status Report on the Application of Integrated Approaches to Water Resources Management*; UNEP: Nairobi, Kenya

United Nations. (1992). *Report of the United Nations Conference on Environment and Development (Rio de Janeiro, 3–14 June 1992),* United Nations General Assembly Document A/CONF.151/26. New York: United Nations.

United Nations. 1977. *Report of the United Nations Water Conference, Mar del Plata*. 14-25 March 1977, E/CONF.70/29; United Nations: New York, NY, USA

United Nations (2015). *Transforming our world: the 2030 agenda for Sustainable Development. Sustainable Development Knowledge Platform*

Usher, Tara. (2008). Adjudication of Socio-Economic Rights: One Size Does Not Fit All', *UCL Human Rights Review, 1.1*, 154-171.

Valizadeh, N., Bijani, M., Hayati, D., & Haghighi, N. (2019). Social-cognitive conceptualization of Iranian farmers ' water conservation behavior. *Hydrogeology Journal*

Van Koppen, B. (2007). *Community Based Water Law and Water Resource Management Reform in Developing Countries*. Wallingford, UK: CABI Publishing.

Van Oel, P. R., Odongo, V. O., Mulatu, D. W., Muthoni, F. K., Ndungu, J. N., Ogada, J. O., & van der Veen, A. (2014). Supporting IWRM through spatial integrated assessment in the Lake Naivasha basin, Kenya. *International Journal of Water Resources Development*, *30*(3), 605–618.

Velasco-Muñoz, J. F., Aznar-Sánchez, J. A., Batlles-delaFuente, A., & Fidelibus, M. D. (2019). Rainwater harvesting for agricultural irrigation: An analysis of global research. *Water (Switzerland),* 11(7).

Villanueva, A., Guerrero-Baena, M. D., Gomez-Limon, J., & Glenk, K. (2018, August). Valuing the Willingness To Pay for Improving Irrigation Water Supply Reliability: An Approach Based on Probability Density Functions. XI Congreso de La Asociación Española de Economía Agraria (pp. 138–141).

Vorosmarty, C. J, Mcintyre, P. B., Gessner, M. O., Dudgeon, D., Prusevich, A., Green, P., … Davies, P. M. (2010). Global threats to human water security and river biodiversity. *Nature*, *467*(7315), 555–61.

Wanessa, D., Márcia, M., & Simone, R. (2020). Multi-level governance application to a shared river basin. *Brazilian Journal of Water Resources*. 1-16

Walker, J., & Ostrom, E. (2009). Trust and reciprocity as foundations for cooperation. In K. Cook, M. Levi, & R. Hardin (Eds.), *Whom can we trust? How groups, networks, and institutions make trust possible*. USA: Russell Sage Foundation, New York, NY.

Ward, S. L. (2010). *PhD Thesis: Rainwater harvesting in the UK: a strategic framework to enable transition from novel to mainstream*. Quality, 1–521.

Warner, L. A., Lamm, A. J., & Kumar, A. (2018). Landscape and Urban Planning Florida residents ' perceived role in protecting water quantity and quality through landscape practices. Landscape and Urban Planning, 171(November 2017), 1–6.

Water Resources Authority (WRA) - *Athi Catchment Area. (2017). Rombo River Sub Catchment Water Abstraction and Pollution Survey*.

Water Resources Management Authority (WRMA) (2007). The Water Resources

Management Regulations. Nairobi, Kenya, 2007

Wesson, M. (2011). Reasonableness in Retreat? The Judgment of the South African Constitutional Court in Mazibuko v City of Johannesburg. *Human Rights Law Review 11*(2), 390 – 405

Whitty, J. A., & Kauf, T. L. (2013). Turning the Spotlight on Experimental Design in Discrete Choice Experiments—A Focus on Pragmatic Approaches in Health. *Value in Health*, *16*(1), 1–2.

World Bank. (2018). Poverty and Shared Prosperity 2018: Piecing Together the Poverty Puzzle. Washington, DC: World Bank. License: Creative Commons Attribution CC BY 3.0 IGO

World Commission on Dams. (2000). Dams and Development: A New Framework for Decision-Making; Earthscan: London.

World Economic Forum (WEF). (2016). *The global risks report 2016*. (11th Edition) Cologny: World Economic Forum

Woodhouse, P., Muller, M. (2017). Water Governance – an historical perspective on current debates. *World Development., 92, 225–241.*

World Health Organisation (WHO). (2008). *Advocacy, Communication and Social Mobilization for TB Control: A Guide to Developing Knowledge, Attitude and Practice Surveys*. World Health Organization, Switzerland.

World Summit on Sustainable Development (WSSD). (2002). *Report of the World Summit on Sustainable Development.* New York: United Nations.

World Water Assessment Programme (WWAP). (2015). *The United Nations World Water Development Report 2015*: Water for a Sustainable World. Paris, UNESCO

Xavier Vollenweider, S. D. (May 2011). *Risk preferences and voluntary agri-environmental schemes: does risk aversion explain the uptake of the Rural Environment Protection Scheme?* Grantham Research Institute on Climate Change and the Environment, Working Paper No. 48.

Yang, L. E., Ka, F., Chan, S., & Scheffran, J. (2018). Climate change , water management and stakeholder analysis in the Dongjiang River basin in South China. *International Journal of Water Resources Development*, *34*(2), 166–191.

Yosef, B. A., & Asmamaw, D. K. (2015). Rainwater harvesting : An option for dry land agriculture in arid and semi-arid Ethiopia. *International Journal of Water Resources and Environmental Engineering 7*(785), 17–28.

Zhuo, L., Hoekstra, A. Y., Wu, P., & Zhao, X. (2019). Monthly blue water footprint caps in a river basin to achieve sustainable water consumption: The role of reservoirs. *Science of the Total Environment*, *650*, 891–899.

LIST OF APPENDICES

Appendix 1: Supplimentary Data

Evaluation of actors' interests in and influence on the Tsavo sub-catchment water governance (**Figure 4.11**)

Category	**Institutions**	**Influence** (scores)	**Interest** (scores)
Government agencies and departments	WRM	10	10
	Basin water resources committees (BWRCs)	7	7
	NEMA	8	4
	KWS	8	9
	KFS	6	5
	KWTA	3	4
	WSB	5	5
	NIDA	7	5
	County government	8	6
	National government administration (NGA)	9	9
Resource users	WRUAs	9	10
	Farmers	4	10
	Pastoralists	3	10
	WRUA council	8	7
NGOs & CBOs	CESPAD	5	6
	Wetlands International	4	6
	Amboseli Ecosystem trust	5	6
	Kimana wetland association	7	8
	Faith Based Organizations	4	4
Private/business sector	Hoteliers	6	7
	WSPs	4	9
	Group ranches	4	7
Research institutions	School for Field Studies (SFS)	4	5
	Universities	2	3

Appendix 2: Informed Consent

(The following statement must be read to every respondent)

CONSENT FORM

Hello Sir/ Madam,

My name is **Francis Oremo**. I am a PhD student in Environmental Policy programme at the Centre for Advanced Studies in Environmental Law and Policy (CASELAP), University of Nairobi. I am undertaking a research study titled: ***Enhancing Governance of Water Resources for Improved Uptake of On-Farm Water Storage Technology Among Smallholder Irrigators in Tsavo Sub-Catchment, Kenya.*** The study will provide the basis for developing a framework for uptake of on-farm Rainwater Harvesting (RWH) technology among smallholder farmers in the Tsavo sub-catchment.

I assure you that the information you share with us will not be disclosed to any other party and will strictly be used for this assignment. Every effort will be made to ensure that the information you share will not be traceable back to you. The interview will take approximately 30 minutes.

By agreeing to be interviewed you are confirming consent to participate in this assignment voluntarily having been fully informed of the nature and purpose of this study. Further, it shows that you have not been influenced or forced to participate based on any consideration.

For more information about this study, please contact the researcher on 0721 739 033 or email at oremo2007@gmail.com

[Ask the respondent for consent: Your household has been selected for this study and we wish to have permission to interview you. May we proceed? ___Yes ___No].

Appendix 3: Household Questionnaires

(Note to interviewer: 97 = other (specify), 98 =no answer provided, 99 = don't know).

*** Indicates more than one response**

N°	QUESTIONS	ANSWERS
Section 1: General Perception and Observation of Tsavo Sub-Catchment		
101.	What is your general perception of the current environmental status of Tsavo sub-catchment?	01 = Very good 02 = Good 03 = Degraded |___||___| 04 = Very Degraded 99 = Don't know
102.	Rank environmental problems in Tsavo sub-catchment in order of their severity, listing the most severe first (1) and the least severe last (8).	[___] Water scarcity [___] Loss of biodiversity [___] Water resource use conflicts (human vs. human, wildlife vs. human) [___] Over-abstraction of water resources [___] Pollution [___] Floods [___] Encroachment of riparian areas [___] Overgrazing
103.	What is your general perception of the availability of water in Tsavo sub-catchment?	01 = Very good 02 = Good 03 = Satisfactory 04 = Bad |___||___|
104.	What is your general perception of the quality of water in Tsavo sub-catchment?	01 = Very good 02 = Good 03 = Satisfactory |___||___| 04 = Bad 97 = Others (specify) ____________________
105.	Has your farm been affected by water scarcity in the last 12 months?	01 = No 02 = Yes |___||___|

N°	QUESTIONS	ANSWERS
106.	If Yes, how many times?	|___||___|
107.	*In your opinion, what are the causes of water scarcity?	[ ] Deforestation. [ ] Poor agricultural practices, e.g. over-abstraction of surface. conversion of wetlands, etc. [ ] Population growth. [ ] Insufficient rainfall [ ] Other_______________________________
Section 2: Knowledge, Attitudes and Practices in Relation to Water Resources Management		
201.	Before this interview, had you heard about the term integrated water resources management (IWRM)? (Explain in case the terms are unfamiliar) *IWRM seeks to promote coordinated development and management of water, land and related resources, in order to maximize the socio-economic welfare in an equitable manner without compromising the sustainability of vital ecosystems*	01 = No 02 = Yes |___||___|
202.	If YES, how would you rate your understanding on Integrated Water Resource Management (IWRM)?	01 = Very good 02 = Good 03 = Satisfactory |___||___| 04 = Poor
What are your thoughts about the following statements about water resources in Tsavo sub-catchment? (I will read a sentence, and then please tell me whether you agree, disagree or are unsure)		
203.	Fresh water is finite and vulnerable resource	01 = Agree 02 = Disagree 03 = Unsure |___||___|
204.	Farmers are included in water resources management decision-making	01 = Agree 02 = Disagree 03 = Unsure |___||___|
205.	Water conservation actions by farm irrigators can save local rivers and wildlife	01 = Agree 02 = Disagree 03 = Unsure |___||___|

N°	QUESTIONS	ANSWERS
206.	Do you make use of any of the following media at home//work?	01 = Radio 02 = TV 03 = Newspapers 04 = Internet 05 = None
207.	*****Through which media have you heard about integrated water resources management?	[ ] Radio [ ] TV [ ] Newspapers [ ] Internet [ ] Workshops/seminar [ ] Local baraza [ ] Posters [ ] Others ______________________________
208.	*****By which of the following methods would you like to receive information about integrated water resources management?	[ ] Radio [ ] TV [ ] Newspapers [ ] Internet [ ] Workshops/seminar [ ] Local baraza [ ] Posters [ ] Others ___________________________________
209.	Have you recently attended a workshop on integrated water resources management?	01 = No 02 = Yes |___||___|

N°	QUESTIONS	ANSWERS
210.	***If "yes" who organized the events?**	[ ] National government e.g. WRA [ ] County government [ ] NGO e.g. WWF [ ] Church [ ] Local Chief [ ] Others __________________________________
211.	*** What did you learn about integrated water resources management (IWRM)? (Repeat "IWRM" definition)**	[ ] Soil and water conservation [ ] Pollution control [ ] Everyone needs to cooperate in water resources management [ ] Water resource use conflict resolution [ ] Protection of wetlands and water harvesting [ ] Promotion of drip irrigation [ ] Reduction of illegal abstraction and over abstraction [ ] Reduction of charcoal burning [ ] Other ____________________________________
212.	If you learnt new information/skills about water resources management, would you be prepared to share with other water users in the area?	01 = No 02 = Yes |___||___|
213.	What barriers are hindering you from implementing the ideas you learnt in the workshop?	01 = Inadequate knowledge on IWRM 02 = Lack of financial resources 03 = Lack of political will
214.	How concerned are you about declining water resources in the area?	01 = very concerned 02 = Just concerned 03 = Not concerned at all 04 = Not sure

N°	QUESTIONS	ANSWERS
215.	*What have you done ALREADY to conserve and protect water resources in the area?	[ ] Engaged in collaborative management of water resources [ ] Construct farm ponds for supplemental irrigation [ ] Abstract river water within permitted levels [ ] Nothing [ ] Other ________________________________
216.	***Are you incline to take up any of these measures in future i.e. next one year to improve water resources management in the area?	[ ] Soil conservation measures [ ] Water pollution control [ ] Construct farm ponds to supplement water for irrigation [ ] Nothing [ ] Other_________________________________

Section 3: Choice Experiment

Introduction

The Tsavo sub-catchment provides a number of services both to humanity and the overall ecosystem, e.g. water for irrigation, wildlife (both plants and animals) domestic and livestock needs. Essentially, it means that in order for the community to enjoy better ecosystem services of the sub-catchment, there is need for more balanced use of the resources available to ensure their perpetuity. However, in reality this may not be the case of because of resource constraints and other competing needs.

This section therefore is assessing your willingness to pay for various option of harnessing the water resources for farming purposes in light of the various purpose of water resource utilization, the need for enhanced livelihood and economic development, and resources constraints

I will show you a sequence of cards. Each card has three options, A, B and C. Each option has the levels of potential benefits you, the community, and the ecosystem may get from Tsavo sub-catchment based on the kind of irrigation technology you may adopt. On the cards, you will also see the cost of the initial construction of a particular technology you may adopt so that both you, the society and ecosystem may continue to draw the water services from the sub-catchment. Remember that option C (*Status quo* *option)* which is the most prevalent water abstraction method where farmers fully draw their water either from the streams or the springs does not change in each set of cards).

Consider the details on the cards to be able to understand the services better.

[Show the overview card and explain the attributes and their levels]

You will be first shown an example card.

[Show the respondent the example card and explain the process.]

On this card you see technology options A, B and C (status quo) in which there are different costs of initial construction of on-farm rainwater storage structure (in Ksh.), quality of water available for domestic use, quantity of water available for irrigation, quantity of water available for ecosystem services, water use conflict, water abstraction fees.

Here you will be required to make choices on the kind of technology options you will be willing to adopt given the costs implications and the associated benefits.

Choice Experiment Responses

Answers for Cards

Card Number	**Tick box below the chosen option**		
	Option A	**Option B**	**Option C (Business as usual)**
Card 1			
Card 2			
Card 3			
Card 4			

Debriefing questions

I would like to understand how you made your choices in the cads for questions in section 3

A. When answering questions, did you always choose option C (status quo)?	
Yes	
No	go to Question C

B. If you always chose options C, which of the following statements best describe your main reason for doing so? (Please tick one box only)		
i.	I don't believe that ecosystem services will increase under new technology.	
ii.	I support new technology, but I am not the only one who will benefit from the improved water resources in the sub-catchment.	
iii.	I was looking for the least cost of setting up the irrigation technology	
iv.	I don't believe that quantity of water from streams and springs will decline with continuous abstraction	
v.	I don't believe that there will be increased conflict over the water resource	
vi.	Some other reason (please specify) …………………………………………….	

C. Which characteristics did you consider when making choices? (Please tick one box only)	
01. I considered all characteristics	
02. I considered the cost of establishing the technology	
03. I considered the highest benefit for the ecosystem	
04. I considered the highest benefit for perpetual availability of water for irrigation	

05. I considered the highest benefit of avoiding water use conflict	
06. Some other reason (please specify) ………………………………………………	
D. Was there any characteristic that you considered not important?	
01. yes	
02. No	
E. If YES to part D above. please tick the characteristic that you considered not important	
01. Cost of setting up irrigation technology	
02. Quality of water available for domestic use	
03. Quantity of water available for irrigation	
04. Water resource use conflict	
05. Water user fees	
F. How confusing was it for you in making choices	
01. Very easy	
02. Easy	
03. Neither Easy nor confusing	
04. confusing	
05. Very confusing	

N°	QUESTIONS	ANSWERS
Section 4: Socio-Demographic Characteristics of Respondents		
401.	**Record sex of the respondent**	01 = Male 02 = Female |___||___|
402.	How old are you? **Record age in years**	Record number of years 99 = Don't Know |___|___|
403.	How long have you lived in this community?	01 = Less than 1 year 02 = 1 -10 years 03 = 11 - 20 years 04 = 21- 30 years |___||___| 05 = 0ver 30 years

404.	What is the highest level of schooling you have attained?	00 = None 01= Some primary education 02 = Completed Primary 03 = Secondary 04 = College 05 = University 97=Other(specify)--------------------	|___||___|
405.	What is your main source of income? ***(Only one answer is possible. Record the principal income sector.)***	01 = Crop farming 02 = Business 03 = Pastoralism 04 = formal employment 05 = Casual employment 97 = Other (Specify) ………………………………………	|___||___|
406.	What is your marital status?	01 = Single 02 = Married 03 = Divorced/Separated 04 = Widow/ Widower 98 = No answer	|___||___|
407.	How many people currently live in your household including yourself?	**Record exact number**	|___||___|
408	Do you belong to any network/group?	01 = yes 02 = no	|___||___|
409	If yes, which one?	01 = Environmental/conservation group 02 = Economic group e.g. savings and credit 03 = Social groups (church, sports, etc.)	|___||___|
410	Do you have to access to credit?	01 = Yes 02 = No	|___||___|
Section 5: Land Ownership and Utilization			
501.	What is the size of your land?		|___||___|
502	What is the total area under cultivation?	RECORD ACTUAL IN ACRES	|___||___|

503.	What is the total area of the cultivated land under irrigation?	RECORD ACTUAL IN ACRES |___||___|
504.	How long have you been a farmer?	|___||___|
505.	What is the type of land ownership	01 = Private property with title deed 02 = Communal land 03 = Leasehold |___||___| 97 = Other (specify)………………………………………………...
506.	What is the distance from your farm to the nearest river/stream?	01 = Less than 1 km 02 = 1 – 3 km 03 = 4 – 5 km |___||___| 04 = Over 5 km
507.	***What problems do you experience in accessing water?	[ ] Conflict with neighbours and wildlife [ ] Long distance [ ] Other (specify)______________________________
508.	***What do YOU do when there is less/no water in the river/springs to support irrigation on your farm?	[ ] Extract water from boreholes/wells [ ] Use water from farm ponds [ ] Reduce the farm size under irrigation [ ] Suspend irrigation activities [ ] Other ____
509.	Who makes decision over land management	01 = Head of household 02 = The entire family |___||___| 97 = Other (specify) _____________________________
510.	Where do you normally sell your products?	---
511.	What is the main source of extension services	00 = None 01 = Government 02 = Private 03 = NGOs |___||___| 97 = Other (Specify)
512.	What is the frequency of extension services	01 = Weekly 02 = monthly 03 = Quarterly 04 = Occasional (specify the interval) ______________ |___||___|
513.	What is your mean monthly household?	01 = up to Ksh. 10,000 02 = 10,001 - 30,000 03 = 30,001 - 50,000 04 = over 50,000 |___||___|

514.	* Does your household possess any livestock? Indicate the type of livestock you possess.	None |___||___| Cattle |___||___| Sheep |___||___| Goats |___||___| Poultry |___||___| Donkeys |___||___| Other, Specify and provide the number ___________________
515.	How do you normally feed your livestock?	01 = Open range grazing 02 = Zero grazing
Thank You Very Much for Your Cooperation		

Appendix 4: Key Informant Interview Schedule

Name of the Key Informant: ……………………………………………………………………

Position: ……………………………………………………………………………….………

Name of the organization: …………………………………………………………….……

Interview schedule

1. Introduction

(a) You are the [position] of [name of organisation]. What do you do in this position?

(b) What are the key aims/objectives of your organisation?

(c) Are you involve in water resources management? If YES, please describe the activities of your organisation.

2. Water users

(a) Who are the main users of water resources in the sub-catchment?

(b) What is the economic status and literacy level of the water users in the area?

(c) Does the literacy level affect the use and management water resources?

(d) What are the main activities carried out in the sub-catchment and what are their impacts on sustainable water resources management?

3. Water resource use conflicts

(a) Have there been any disputes/conflicts related to water resource use in this area? If YES, please explain the cause(s) of these disputes/conflicts.

(b) Apart from the disputes, list any other problems associated with water resources management in the sub-catchment.

4. Water resources governance

(a) Other than your organisation, who are other stakeholders in water resource management? What role do they play in the management of water resources?

(b) Are the community actively involved in water resources management? If NO, are there efforts to elicit their participation in water resource management issues?

(c) Looking at the current use of existing water resources, would you say that their use is sustainable? Kindly explain.

(d) Are there measures to ensure sustainable abstraction of water resources? If YES, which ones?

(e) Does the sub-catchment have a management plan? If YES, how was it formulated?

(f) Who is implementing the management plan? And how is it coordinated?

(g) Please explain from your perspective the top priority initiatives required to support sustainable management of water resources in the Tsavo sub-catchment.

5. Practices in relation to water resources

(a) Has the local community (including irrigators) taken any measures to conserve and protect water resources in area? If YES, please list and describe the measures?

(b) From your point of view, what measures should the smallholder irrigators consider in future to conserve and protect water resources?

(c) Are these efforts to integrate these measures in the catchment management plans? If YES, please explain.

(d) What is the status of uptake of on-farm water storage technology among irrigators? Are there any constraints or enablers to its uptake? If YES, what are the constraints and enablers?

(e) Do you think national and county governments has put in place any measures to enable uptake of on-farm water storage technology? If YES, what are these measures?

5. Environmental Aspects

(a) Has your organisation gathered any information on the status of water resources in this area in the past 2 years? If YES, what is the status of water resources in the sub-catchment (in terms of availability and quality)?

(b) Are there policies and laws regulating land and water management in the sub-catchment?

(c) If yes, which policies/laws? How are they being enforced?

(d) What are main challenges encountered during the enforcement of water-related laws and regulations?

Appendix 5: Focus Group Discussion Checklist

1. Institutional contexts
   - (a) Do local institutions play a role in water resources management? If YES, what are these roles?
   - (b) Do they encounter challenges in undertaking their roles? What are these challenges?
   - (c) How do they engage with other actors in water governance, such as the WRA, KFS, KWS, etc?
   - (d) What measures can be undertaken to strengthen capacities of community-based governance institutions, such as WRUAs?
2. Knowledge of water issues
   - (a) What is farmers' level of knowledge of water resource management issues?
   - (b) Are there gaps in knowledge of water issues? If YES, does it affect farmers' practices in water management.
   - (c) How can gaps in knowledge of water resource management issues be narrowed?
3. Benefit and costs of on-farm water storage technology
   - (a) What are the benefits of on-farm water storage technology?
   - (b) What are the constraints to the uptake of technology?
   - (c) How can these constraints be addressed?
   - (d) Do other water actors and institutions have a role in the uptake of the technology? What are these roles?

Stakeholder analysis
NB:

Interests in water management relates to how stakeholder use water resources as input for productive uses; or the statutory role of specific stakeholders in ensuring efficiency, equity and sustainability in water resource allocation and use.

Influence is the scale of resources – human, financial, technological, or political – available to a stakeholder and its ability to mobilize them. This may determine the level of power with which a stakeholder can support or oppose a

1. What is/are the main interest(s) of the following water actors in the Tsavo sub-catchment?

Water actors		**Main interests**
Government agencies & Department	WRM	
	Basin water resources committee (BWRC)	
	NEMA	
	KWS	
	KFS	
	WSBs e.g. Tanathi	
	Ministry of Agriculture	
	County government	
	National Irrigation Development Authority	
	Ewaso Nyiro South Development Authority (ENSDA)	
	National government administration	
Water resource users	WRUAs	
	Farmers	
	Pastoralists	
	Fishermen	
	WRUA council	
NGOs	AWF	
	CESPAD	
	Amboseli Ecosystem trust	
CBOs	Kimana wetland association	
	Faith Based Organizations (Catholic Diocese)	
Private sector	Hoteliers	
	Group ranches	
	Water service providers	
	Research institutes e.g. School for Field Studies	
	Universities	

2. Based on the engagement of these stakeholders in water governance in the Tsavo sub-catchment, how would you rate their level of influence on a scale of 0–10, where 0 denotes **No Influence**, and 10 **Very High Influence**

Water actors		**Level of influence**										
		0	1	2	3	4	5	6	7	8	9	10
Government agencies & Dept.	WRM											
	Basin water resources committee											
	NEMA											
	KWS											
	KFS											
	WSBs e.g. Tanathi											
	Ministry of Agriculture											
	County government											
	Department of Irrigation											
	Ewaso Nyiro South Development Authority (ENSDA)											
	National government administration											
Water resource users	WRUAs											
	Conservation group											
	Farmers											
	Pastoralists											
	Fishermen											
	WRUA council											
NGOs	AWF											
	CESPAD											
	Amboseli Ecosystem trust											
CBOs	Kimana wetland association											
	Faith Based Organizations											
	Farmers and farmer' groups											
Private sector	Hoteliers											
	Water service providers											
	Group ranches											
Research institutes	Pwani University											
	Taita Taveta University											
	JKUAT											

1. Based on the engagement of these stakeholders in water governance in the sub-catchment, how would you rate their level of interest a scale of 0 – 10; where 0 denotes **No interest**; and 10 denotes **Very High Interest**?

Water actors		**Level of interest**										
		0	1	2	3	4	5	6	7	8	9	10
Government agencies & Dept.	WRM											
	Basin water resources committee											
	NEMA											
	KWS											
	KFS											
	WSBs e.g. Tanathi											
	Ministry of Agriculture											
	County government											
	Department of Irrigation											
	Ewaso Nyiro South Development Authority (ENSDA)											
	National government administration											
Water resource users	WRUAs											
	Conservation group											
	Farmers											
	Pastoralists											
	Fishermen											
	WRUA council											
NGOs	AWF											
	CESPAD											
	Amboseli Ecosystem trust											
CBOs	Kimana wetland association											
	Faith Based Organizations											
	Farmers and farmer' groups											
Private sector	Hoteliers											
	Water service providers											
	Group ranches											
Research institutes	Pwani University											
	Taita Taveta University											
	JKUAT											