ASSESSING THE STATUS OF CROP FARMING AND STRATEGIES USED TO SCALE-UP YIELDS FOR ENHANCED FOOD SECURITY IN TURKANA COUNTY, KENYA

BY

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DECLARATION

This thesis is my original work and has not been presented for the award of a degree in any other university or any other award.

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Supervisors' Approval

We confirm that the work reported in this thesis was carried out by the candidate under our supervision and submitted with our approval as the University Supervisors.

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DEDICATION

I dedicate this work to my mother Sophia Sang, my wife Sofia Mutai, and the children: Clement, Patricia, Brian, Pascal and Sixtus for their moral support and understanding they accorded me during the course of my Studies.

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LIST OF ABBREVIATIONS AND ACRONYMS

ADESO	African Development Solutions
ALRMP	Arid Lands Resources Management Project
ANOVA	Analysis of Variance
ASAL	Arid and Semi-Arid Lands
ASDSP	Agriculture Sector Development Support Programme
CA	Conservation Agriculture
FAO	Food and Agriculture Organization
FEG	Food Economy Group
FEWS NET	Famine Early Warning Systems Network
FSTP	Food Security Thematic Project
GDP	Gross Domestic Product
GEA	Green Economy Assessment
ILRI	International Livestock Research Institute
IPAR	Institute of Policy Analysis and Research
IPM	Integrated Pests Management
KALRO	Kenya Agriculture and Livestock Research Organization
KARI	Kenya Agriculture Research Institute
KNALS	Kenya National Adult Literacy Survey
KNBS	Kenya National Bureau of Statistics
MDGs	Millennium Development Goals
MoA	Ministry of Agriculture
NACOSTI	National Commission for Science, Technology and Innovation
NGO	Non-Governmental Organization
NPK	Nitrogenous (N), Phosphorous (P) and Potassium (K)
RCBD	Randomized Complete Block Design
SDGs	Sustainable Development Goals
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNESCO	United Nations Education Scientific and Cultural Organization
VSF	Veterinaires sans Frontieres

ABSTRACT

Despite being a culture-centred livelihood activity, pastoralism alone has not guaranteed food and nutrition security for households in Turkana, Kenya. The frequency of droughts and their negative impact on livestock production in the County translate into reduced purchasing power of the pastoral households; causing perennial food insecurity and consequent human indignity. As a growing response to this perennial situation, rain-fed crop production has been introduced in the County at subsistence level. Most pastoralists however still tend to shy away from crop farming largely due to cultural factors and not their technical feasibility. This study assessed the current status of crop farming and analyzed factors limiting diversification to crop farming. Further it appraised measures towards increased adoption of viable crop production systems within households in five locations purposively selected from two Sub-counties of Turkana Central and Loima. A cross-sectional descriptive survey design targeting 357 respondents was used in this study. In addition data was collected from a few key respondents from sub-County Agricultural Extension Offices. Primary data was collected using questionnaires and interview schedules. On farm experimentation on crop performance under different treatments (drip & bucket irrigation methods) was done in order to demonstrate the potential inherent in crop farming under appropriate crop and land husbandry practices. Data was analyzed using descriptive statistics. Experimental data was subjected to analysis of variance. Results showed that an increasing number of pastoralists are now venturing into crop farming for survival purposes; of which seventy three percent (73%) of the respondents were agro-pastoralists. With a change in attitude away from cultural pastoralism, this percentage can increase with more deliberate and targeted extension service at the County level. Annual average yield of maize in Turkana County was twelve 90kg-bags per acre, while its annual cost of production was Ksh 12,600/acre and the annual revenue was Ksh 32,400/acre. The annual average yield of sorghum in the County was relatively the same as that of maize, and its annual cost of production was Ksh 6,800/acre, while the annual revenue was Ksh 43,200/acre. The study concluded that there is potential and opportunity to improve crop farming under proper land and crop husbandry practices including water use efficiency in Turkana County. Currently, there is a shift from pastoralism to agro-pastoralism. However, this shift is still slow and adoption levels low leading to poor crop yields. The main challenges that constrain crop farming include general lack of knowledge in crop farming and low adoption levels of modern agricultural practices such as use of manure and fertilizer. The study established that drip irrigation had good crop yields, though not used due to high initial costs. Where irrigation is being used, increasing salinity problem was noted. On farm trials with spinach (*Spinacia oleracea*) as the test crop demonstrated the superiority of water use efficiency under drip irrigation than under bucket method of irrigation. The use of inorganic fertilizers is not common in Turkana County because of the combined reasons of costs and knowledge on fertilizer use under water scarcity conditions. Some farmers use farmyard manure, which readily available from the large herds and flocks kept, but the level of use is low. The study recommended a more deliberate and targeted extension service to introduce improved crop agriculture which can be integrated with the cultural way of life of pastoralists which would ensure improved livelihoods and food security

CHAPTER 1: INTRODUCTION

1.1 Background Information

Agriculture has remained the mainstay of Kenya's economy since independence in 1963 (Kenya, 1997). Although its contribution to the GDP decreased from 35% in 1963 to 25% in 1996 (Nyangito H. and Okello J., 1998), agricultural sector still employs about 75% of the labour force, provides most of the food requirements for the nation and earns the country about 60% of the foreign exchange (Kenya, 1997). According to Kenya Economic Report (2016) crop agriculture contributed 72% of the GDP in 2014 while livestock contributed about 18% of the GDP. As per the Green Economic Assessment (GEA) report (UNEP, 2014), Agriculture contributed to 24% of national GDP valued at Ksh 342 billion in 2014; and another 27% indirectly valued at Ksh 385 billion in 2012 (GoK, 2012). Despite the importance of the agricultural sector in Kenya, its performance has been poor for most years since 1970 (World Bank, 1981; Chibber, 1988; Mosley and Smith, 1989). As per the Performance of Kenya's Agriculture Report by Oluoch-Kosura (2017), agriculture has been declining steadily at 21.41% p.a. Much of the blame for the poor performance of the sector is attributed to the policies used, as stated in the Kenya's Agricultural Policy Occasional Paper No OP/04/98 (Nyangito H. and Okello J., 1998). Kenya's experience of using unsuccessful approaches to deliver service to farmers has taught policy makers that in order to be effective; extension agents should avoid top-down planning and implementation of intervention to farmers' problems in favour of demand-driven and farmer-led participation approaches (Republic of Kenya, 2004). The linkage between policy and practice in the agricultural space remains a key concern for the sector, as most of these policies are not translated into a language that the ordinary Kenyan citizen can understand and relate to (Njenga, 2017).

Turkana County's economic activity is traditionally oriented to livestock production (Ocra Company Ltd Technical Team, 2013). However, constant loss of livestock in the County due to drought, disease or raiding has caused perennial food insecurity in the County (Diocese of Lodwar *et al*, 2012). Herds become prone to raiding during drought when they wander away from secure areas and to the well-vegetated zones bordering communities that are hostile to the Turkana (Dyson-Hudson and MacCabe, 1985). There is potential to develop other existing livelihoods into this economic activity including crop farming (ADESO, 2013). This is one of the gaps this study proposed to explore. The crop agriculture has been introduced along the Turkwel and Kerio rivers mainly on rain fed and some irrigation (Akal; 2014). Hence agro-pastoralism would be preferred; a lifestyle in which livestock keepers obtain more than 25% but less than 50% of agricultural income from livestock keeping on communal lands in areas with annual rainfall between 400 and 600 mm and length of growing period of 75 to 90 days, where cropping millet and sorghum is possible (Nikola, 2006). The crops mainly maize, sorghum, green grams, cowpeas, mangoes, pawpaw, watermelons and vegetables are grown on subsistence basis whose levels of production have not been quantified (Diocese of Lodwar *et al*; 2012). The actual crop yield obtained per hectare is very low mainly due to poor agronomic practices such as inadequate means to maintain crop soil moisture requirements (Ocra Company Ltd Technical Team; 2013).

1.2 Statement of the Problem

Livestock keeping has not adequately provided for food security in Turkana County. The recurrence of drought and its impact on livestock production in the County ultimately translate into reduced purchasing power of the pastoral households due to stock deaths and or emaciation that result into very low prices. This has caused perennial food insecurity and human indignity in the area. Although rain-fed farming in the area has been a risky undertaking due to erratic rainfalls,

integrating irrigated crop farming with pastoralism would greatly enhance food security and options for income generation, and thus enhance human well-being. The pastoralists however tend to shy away from crop farming largely due to cultural factors and not technical feasibility. This is compounded by little or no promotion of crop farming by the public extension service.

1.3 Study Justification

Promotion of crop farming in Turkana County through irrigation and water use efficiency approaches will diversify livelihood options and reduce the risks communities must endure due to persistent droughts that often result into livestock deaths (Ebei et al, 2007). Investment in food security is both a national development agenda and also global agenda as evidenced by Millennium Development Goal (MDG) and sustainable development goals (SDGs) 1 and 2 (Roger, 2008). While few non-governmental organizations and faith-based organizations have attempted to demonstrate the viability of crop farming in the area (Diocese of Lodwar *et al*; 2012), much needs to be done to maximize on the number of households that are likely to see and adopt crop farming (Speca, 2013). On-farm demonstrations under water scarcity conditions are needed to convince pastoralists on the County's potential in crop farming (Nicol *et al*, 2015). This study sought to fill this gap and to provide baseline data on the status of crop farming and what could be done to scale it up and out in Turkana Central and Loima Sub-counties of Turkana County.

1.4 Research Questions

This study was guided by the following questions:-

i. What is the current status of crop farming systems and technologies used in the County?
ii. Why is adoption of crop farming in the area generally very low?
iii. How has crop farming influenced food security within households and the community?
iv. Which measures can be taken to enhance crop farming in such dryland agro-ecosystem?

1.5 Objectives

1.5.1 General Objective

The overall objective of this study was to assess the status of crop farming in dryland pastoral area of Turkana County in order to promote options for livelihood diversification for enhanced survivability during difficult times occasioned by drought events.

1.5.2 Specific Objectives

The specific objectives were:

i. To assess the status of crop production and factors limiting diversification to crop farming in Turkana County
ii. To analyse adoption level of crop farming and its influence on food and nutrition security within households practicing it
iii. To appraise measures towards increased adoption of viable crop production systems in the County

1.6 Research Hypothesis

The study was guided by the following research hypothesis:

i. There is a negative relationship between diversification of crop farming and culture in Turkana County
ii. Households practicing crop farming are more food secure than those dependent on only pastoralism
iii. Attitude among land users is more critical for increased adoption of crop farming than technical acumen

1.7 Significance of the Study

The accomplishment of this study and implementation of its findings would provide significant impacts to a number of beneficiaries as outlined below:

- **The dryland Agro-pastoralists**- The production level of crop agriculture in Turkana County was quantified; and the gross margins obtained from cultivated crop would be expected to motivate agro-pastoralists to improve on their adoption to crop production.
- **The agricultural policy makers**- The identified appropriate methods for soil moisture conservation that help to scale up crop yields would be considered as useful materials for policy formulation in favour of dryland ecosystem management and human survival.
- **The government extension officers-** The results from the study would be used by the agricultural extension officers as resourceful information for their work towards enhancing food and nutrition security that would address chronic malnutrition among the children and adults throughout Turkana County.
- **The non-governmental agencies** involved in promotion of food security in dryland areas of Kenya would use the research results to enhance their efforts towards food security in Turkana County and inform investment initiatives towards crop farming economy that would complement pastoralism.

1.8 Conceptual Framework

In this study food security (FS) is a function of multiple factors collectively grouped into three main categories: production (PN), purchase (PE) and distribution (DN), thus, FS = f (PN, PE, DN) as indicated in Figure 1.1.

Traditionally food production in Turkana has focused on livestock production and consumption of the same (Dyson-Hudson and MacCabe, 1985). However, livestock farming is constrained by

adverse weather particularly drought; cases of prolonged droughts leading to livestock deaths are widely documented (Ebei *et al*, 2007). Financial poverty on the other hand limits people's ability to purchase food from elsewhere (Diocese of Lodwar *et al*; 2012). Similarly the remoteness, isolation and low density of motorable roads in the area makes distribution of food products difficult (Ocra Company Ltd Technical Team, 2013). To provide alternative yet supplementary livelihood options, this study explored the potential of crop farming (PN) through farmer friendly drip irrigation and how to scale it up within this livestock centric community. In the context of integrated community development plan, other studies can be done on food security options of purchases hence alternative income options within the community and how to increase feeder roads to enhance food distribution.

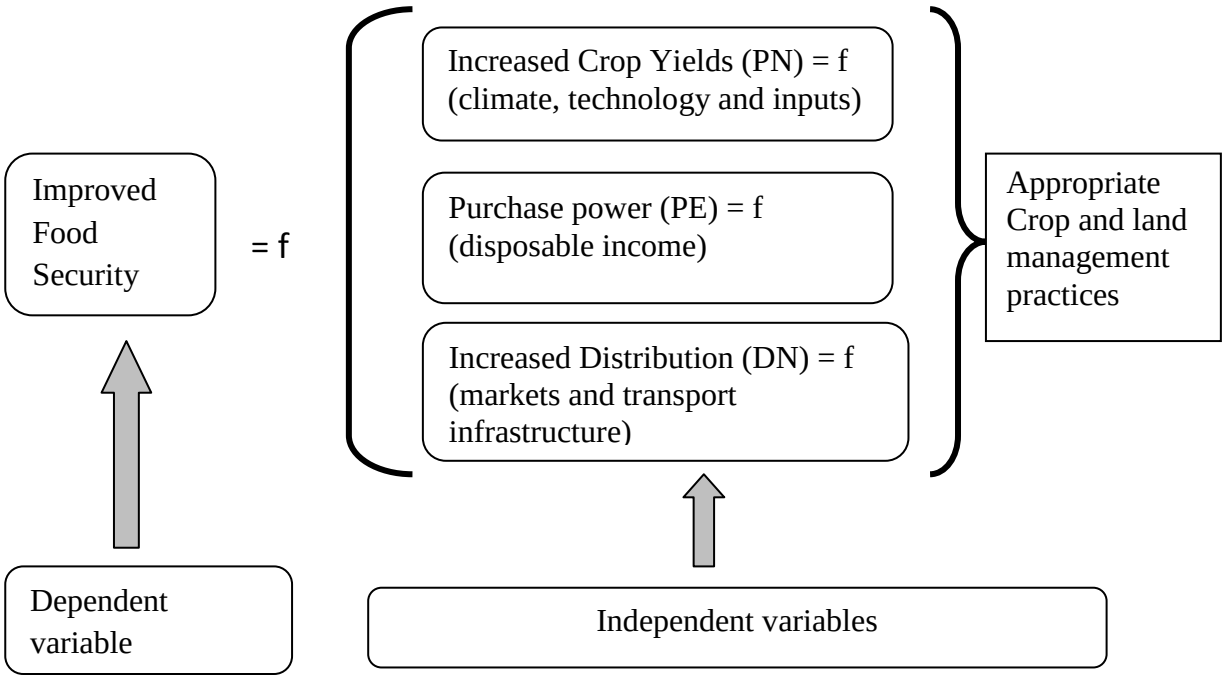

Figure 1.1: Conceptualization of Food Security through Promotion of Crop Farming in a Livestock Economy of Turkana County, Kenya

1.9 Definition of Terms

The definition of "food security" as per the World Food Summit (1996) is that, 'Food Security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life'. This definition points to the following dimensions of food security (FAO, 1983):

Food Availability: The availability of sufficient quantities of food of appropriate quality, supplied through domestic production or imports. In Turkana County, this can be facilitated through enhancing food supply to the most vulnerable and improving rural food production by the farmers which can lead to increased crop yields (PN) (Figure 1.1); and investing in rural infrastructure and markets leading to increased distribution (DN) and purchase power (PE) of foodstuff (Figure 1.1).

Food Access: Access by individuals to adequate resources for acquiring appropriate foods for a nutritious diet. This can be facilitated through re-establishing rural institutions that ensure access to land and assets, and strengthening the labour market; thus enabling appropriate crop and land management practices (Figure 1.1) in the County.

Utilization: Utilization of food through adequate diet, clean water, sanitation and health care to reach a state of nutritious well-being where all physiological needs are met. In Turkana, this can be facilitated through mechanisms such as nutrition intervention programmes that ensure safe food; and re-establishing rural financial systems that lead to increased purchase power (PE) (Figure 1.1).

Stability: To be food secure, a population, household or individual must have access to adequate food at all times. This stability concept refers to both the availability and access dimensions of food security; hence it can be facilitated through diversifying agriculture and employment to increase crop yields (PN), monitoring food security and vulnerability through increased distribution (DN), dealing with the structural causes of food insecurity and re-establishing access to credit system and savings mechanisms that increase purchase power (PE) (Figure 1.1) in the County.

CHAPTER 2: LITERATURE REVIEW

2.1 Overview of Livestock Economy in Turkana County

Turkana County is classified as arid and semi-arid with pastoralism being the main economic activity (Ministry of Pastoral Economy and Fisheries, 2013). Although livestock is part and parcel of almost all the social interaction, from neighbourhood meat feasts, through ritual uses, the bride wealth to legal compensation in social disputes as well as being source of food and income, there are occasions when drought or pestilence can render individuals livestock-less (Ocra Company Ltd Technical Team, 2013 and Notenbaert A. *et al*, 2006). The lost wealth is nowadays replaced mainly by growing and selling crop produce, so as to get back the lost herd. A common term used for those who grow crops is "pastoralist drop-outs" (Ocra Company Ltd Technical Team, 2013).

Most pastoralists use the free-range system with migrations determined by availability of water and pasture; and livestock sector in the County though ranked as most important, experiences various challenges ranging from production to marketing and consumption (Diocese of Lodwar *et al*; 2012). The present situation of markets is that of inefficient market chains due to low productivity in the sector as a result of transaction and processing costs (Ebei *et al*, 2007). Cattle rustlings from neighbouring communities (Pokot and Merile people) challenge livestock production besides climate change and cultural practices (Diocese of Lodwar *et al*; 2012). Cultural practices highly affect the livestock sector in that it is a social status to hold large herds of cattle; herds are not sold even when the pastoralist can foresee a disaster, or slaughtered despite the Turkana having their indigenous knowledge of meat preservation in time of plenty for time of scanty, slaughtering is the last resort. Women and children starve and malnourish in presence of huge herds (Ebei *et al*, 2007).

2.2 Livestock Economy, Food and Nutrition Nexus

Ninety per cent of livestock in Turkana County are acquired through non-commercial means such as dowry, fines for eloping young girls for marriage or breaching social norms, rustling and 10% are bought (Diocese of Lodwar *et al*; 2012). The livestock's value, however, goes beyond the production of meat; it is based on the full set of services they supply (milk, meat, blood, hides), their asset value as a form of savings, and their cultural symbols; and the severity of droughts and their impact on livestock production translate into reduced purchasing power of pastoral households (ILRI, 2006 and Ebei *et al*, 2007). A special report by the Famine Early Warning Systems Network (Grobler-Tanner C., 2006), cited three underlying and overlapping causes of malnutrition in Northern Kenya (Turkana and Mandera Counties): firstly, Inadequate household food security – livestock holdings for a significant number of pastoralists are insufficient to support household food security in both the immediate and long-term due to high livestock mortality rates, as a result of recurrent and lengthy droughts coupled with a rapidly degrading environment; secondly, Inadequate care and feeding practices – which have led to lack of food for pregnant and lactating mothers and have shortened breastfeeding period to two months or less with infants often fed water, milk from cows, camels or goats within a few days of birth, and by three months most infants are given other foods; and thirdly, Poor public health access and environment as it was statistically analysed in the report that high rates of illness and acute malnutrition are associated.

2.3 Livestock Economy and Sustainable Development Goals

The stakeholders in livestock sub-sector have recognized the role of livestock industry to reverse poverty levels and contribute to Turkana County's economic growth (Ministry of Pastoral Economy and Fisheries, 2013). This is normally the case whenever drought has not stricken the area (ILRI, 2010). The intervals of drought in the area have shortened of late as stated by the Ministry of

Pastoral Economy and Fisheries (2013). This recognition of the important role of livestock industry is emphasized in various interventions which are envisaged in national and global goals: Agriculture Sector Development Support Programme (ASDSP), Millennium Development Goals (MDGs), Sustainable Development Goals (SDGs), Kenya Vision 2030 and National Livestock Policy (Ministry of Pastoral Economy and Fisheries, 2013).

2.4 History of Crop Agriculture in Turkana County

Vulnerability of the pastoralists in Turkana County could be alleviated by integrating crop farming with pastoralism in order to diversify their livelihoods; crop agriculture in the County has been practiced mainly by the settled Turkana communities (Akall, 2014). The survey that was carried out by Pro-Water International together with the Diocese of Lodwar (2012) reported that there is much latent wealth from natural resources of water, arable land and will of locals to be self-sufficient.

As a result of unreliable rainfall, drought and resultant famine is recurrent due to poor harvests from rain fed farming sites (Diocese of Lodwar *et al*; 2012); existing irrigation projects have contributed to food security and incomes. The Ocra Company Ltd Technical Team (2013) estimated that Turkana food requirement for the population of 855,399 people is between 106,000 to 117,000 metric tons per year; out of which 25% is provided through famine relief and about 12,035 metric tons of grains per year are produced in the areas presently under irrigation along Turkwel and Kerio rivers with 1,753 and 913 hectares respectively. The irrigation schemes support 16,609 households with plot sizes of 0.16 to 0.4 hectare (Ocra Company Ltd Technical Team, 2013).

2.5 Types of Crops Grown in Turkana County

The main crops grown in the irrigation schemes in Turkana County are maize and sorghum (Diocese of Lodwar *et al*, 2012). The estimated yield levels for crops were as shown in Table 2.1.

Table 2.1: Dominant crops and the estimated yield levels in Turkana

Crop Type	Potential (Hectares)	Actual (Hectares)	Potential Yield/Hectare	Actual Yield/Hectare
Maize	8,000	3,450	28-36 bags @ 90kg	18 bags @ 90kg
Sorghum	5,000	3,155	16-40 bags @ 90kg	13 bags @ 90kg
Mangoes	100	2.5	10 metric tonnes	5.3 metric tonnes
Bananas	80	10	20 metric tonnes	11.5 metric tonnes
Green grams	2,000	75	10-14 bags @ 90kg	8 bags @ 90kg
Cowpeas	4,000	216	6-14 bags @ 90kg	4.5 bags @ 90kg

Source: Diocese of Lodwar *et al*, 2012

The other Potential crops for expansion are guavas, grapes, lemons, oranges, dates, coconuts and aloe vera (Diocese of Lodwar *et al*; 2012); the actual crop yield obtained per hectare as shown above is about half the expected yield. This is mainly due to poor agricultural practices such as inadequate means to maintain crop soil moisture requirements, inadequate soil fertility management, poor means to control soil salinity in some cultivated areas; limited agricultural extension services; and lack of commercialization (Ocra Company Ltd Technical Team, 2013). The irrigation potentials for the Turkwel and Kerio rivers have been estimated at 16,600 hectares which if fully exploited may increase grain production to 232,615.8 metric tons (Ocra Company Ltd Technical Team, 2013).

2.6 Farming Systems in the Turkana Community

The Turkana Agro-Pastoralists practice mainly rain-fed and some irrigation types of farming system at subsistence level, growing crops mainly maize and sorghum which are in many cases intercropped with cowpeas and green grams (Ocra Company Ltd Technical Team, 2013); maize occupies on average 75% of the cultivated area while 24% is under sorghum, and pulses mainly cowpeas and green grams occupy 1% of the areas. Cowpeas are commonly grown for their leaves which are used as vegetables. Production of other vegetable crops is limited by the long irrigation intervals that are common in most of the irrigation schemes. However, vegetables such as kales, tomatoes and traditional vegetables are produced in small proportions. Poor agricultural practices and lack of commercialization have resulted to low productivity and therefore low income to farmers (Ocra Company Ltd Technical Team, 2013); most of the food products marketed in the County is sourced from areas such as Kitale, West Pokot, Eldoret and Marakwet.

2.7 Irrigation Projects in Turkana County

The key locations of irrigated agriculture in Turkana County lie along the Turkwel and Kerio rivers covering irrigation schemes such as Turkwel, Kangalita, Lochokobo, Katilu, Juluk, Kalemnyang, Kaptir, Kapelibok and Nakwamoru along River Turkwel; and Lokori, Lokui, Morulem and Lokubae irrigation schemes along River Kerio (Watson *et al*, 2008). Irrigation also covers major seasonal rivers such as the Tarach in Turkana West, where cereals such as maize and sorghum; pulses such as green-grams and cowpeas; and fruit trees such as mangoes, oranges, bananas and guavas are grown (Ocra Company Ltd Technical Team, 2013). Other irrigation schemes in Turkana West, are Lelea/Loritit, Lokangae, Lopur, Nanam, Loreng, Lopwarin and Songot; and other irrigation scheme in Loima include Lochor Emeyan, Koono, Puch, Urum, Lorengippi, Napeikar, Nabuin, Nadapal,

while Turkana Central has all the areas along River Turkwel, Lorengelup, Chokchok, Napuu and Naotin among others (Turkana-guardian; June 2014).

The soils across the County are fertile and suitable for irrigation (Diocese of Lodwar *et al*; 2012); farmers in most schemes practice flat basin methods for applying water onto their farms; however they realize some cases of soil fertility deterioration. The basins are of different sizes with no relation to the stream flow for irrigation; and so the farmers realize isolated cases of high salinity levels and try to address the problem by burning vegetation trash on the affected areas to moderate the effect of salts (Ocra Company Ltd Technical Team, 2013). Food Security Master Plan for Turkana County (Diocese of Lodwar *et al*; 2012) states that amongst all the irrigated crops, maize and sorghum, which comprise 80% in the county are preferred.

According to the Ocra Company Ltd Technical Team (2013), the estimate of the current flow of River Turkwel water is about $15m^3/s$. With the assumption that half of the flow is left for domestic use, livestock use and ecological maintenance, the balance of $7.5m^3/s$ is available for irrigation. With peak water requirement of 0.75 l/s/ha, the estimated area for irrigation is 10,000 ha and the area presently under irrigation here is 1,753 ha which leaves 8,200 ha for further development. The mean discharge for Kerio River water at Lokori is $10.5m^3/s$. Assuming that half of this is available for irrigation while the other half is reserved for domestic, livestock and environment water requirements, then about $5m^3/s$ is available for irrigation. With peak water requirement of 0.75 l/s/ha, the estimated area for irrigation is 6,600 ha and the area presently under irrigation here is 913 ha which leaves 5,700 ha for further development (Ocra Company Ltd Technical Team, 2013).

2.8 Challenges in Crop Agriculture in Turkana County

According to the Ocra Company Ltd Technical Team (2013), challenges to crop agricultural development in Turkana County are mainly climatic and anthropogenic causes. There is often inadequate water to meet the moisture requirements for crop production as annual rainfall ranges between 120 to 600 mm which is also erratic in time and space. This is worsened by high temperatures ranging between 24 to 38^0C, with high evaporation rates which lead to soil moisture deficits and therefore high irrigation water requirements. This also puts the soils at risk of salinity due to accumulation of salts as the water evaporates (Ocra Company Ltd Technical Team, 2013).

Turkana County is prone to flooding due to localized rains or bursting of the Kerio and Turkwel rivers, which are the main rivers in the County (Diocese of Lodwar *et al*., 2012). This causes crop loss and extensive damage to irrigation infrastructure. High silt load of Turkwel and Kerio rivers which limits the choice of irrigation water application technologies to surface irrigation as sprinkler and drip irrigation methods may require expensive water filtration systems to reduce clogging of their nozzles and emitters. This also causes high cost of system maintenance due to the need for frequent desilting of the intake works and canals (Diocese of Lodwar *et al*; 2012).

Felling trees of high socio-economic importance to give room for irrigation may have a significant impact on the livelihood of the community. The expansion of irrigated agriculture is likely to have significant impact on wildlife and wildlife-related industries. Irrigation development in Turkana County reduces the area of dry season grazing and livestock corridors through encroachment into the riverine areas. This may result in conflicts between farmers and livestock keepers/pastoralists, as livestock graze on crops or damage irrigation infrastructure in attempt to access water and pasture.

Dependency syndrome caused by General Food Distribution, coupled with endemic poverty and low literacy levels amongst members of Turkana communities also cause challenges to crop agricultural development in Turkana County (Diocese of Lodwar *et al*; 2012). Inadequate resources for efficient extension service delivery may result into rampant crop pests and diseases which are not efficiently and effectively controlled.

2.9 Opportunities of Enhanced Crop Agriculture in Turkana County

According to the Food Security Master Plan for Turkana County (Diocese of Lodwar *et al*; 2012), there is much latent wealth for crop agricultural development in Turkana County especially from natural resources of water, arable land and will of locals to be self-sufficient. Irrigated agriculture using the Turkwel and Kerio rivers has indicated that diversified household livelihoods can be enhanced in the County. Underground water harvesting for irrigation is possible through various means such as bucket/drip irrigation, generator water pumps, solar panels or windmills (Diocese of Lodwar *et al*; 2012). Potential crops for the irrigated agriculture include introduced drought tolerant cereal crops such as green-grams, cowpeas, sorghum, and PH4 or DH04 series of maize; and intensive cultivation of high value vegetables such as improved varieties of tomatoes, capsicum, kales, spinach, onions, eggplants, okra and traditional vegetables (Ocra Company Ltd Technical Team, 2013). Also expanding fruit and vegetable market in Lodwar and neighbouring towns provide excellent opportunity for enhanced crop agriculture (KNBS, 2015).

Good textured and structured soils for fruit farming and other field crops; vast land for farming with inherent soil fertility along rivers Turkwel and Kerio; rain water harvesting for crop farming; and linkage of the interior areas of the County to the readily available markets in the growing towns enable crop agriculture development in Turkana County (Ocra Company Ltd Technical Team, 2013). The possibility of growing more than two crops in a year creates an opportunity for the agro-

pastoralists to keep a few animals within the vicinity of the irrigation scheme, which are fed with weeds as well as crop residues; especially during dry spells (Diocese of Lodwar *et al*; 2012). Crop agriculture's main roles in the County span from solving problems of food security, acting as a source of income to the households and providing the local residents with alternative livelihoods through adopting crop farming and reducing overreliance on livestock keeping (Akall, 2014).

2.10 Research Gaps

A number of research activities that have been done have caused many challenges of contemporary pastoralism in Turkana. Such activities include establishment of national frontiers that have tended to severely restricted long distance opportunistic movements of livestock between what now Uganda, South Sudan and Ethiopia (Blench, 2000). Convergence of large numbers of animals on certain pastures, especially around wells causing degradation of environment that has led into long-term impoverishment among pastoralists, since they must sell their emaciated animals cheaply and cannot afford to re-buy them when the drought ends (Blench, 2000 and ILRI, 2006). Food relief mechanisms which have been put in place by the government and other agencies have resulted in maintaining unsustainable levels of human and livestock populations in Turkana (Blench, 2000).

A new alternative strategy to diversify livelihoods could be investing more on crop farming under irrigation using rivers Turkwel and Kerio water, and exploitation of the recently discovered huge quality of ground water in Turkana County (Diocese of Lodwar *et al*; 2012). This research is aimed at exploring this new alternative strategy; and to evaluate crop agriculture in dryland pastoral area so that household food security and livelihoods can be diversified in Turkana County. Developing appropriate irrigation systems in the County to invest on crop farming would provide adequate means to maintain crop soil moisture that would raise actual crop yields to the potential levels per hectare as stated in Table 2.1.

CHAPTER 3: METHODOLOGY

3.1 Study Area Characteristics

3.1.1 Location

Turkana County is situated in North Western Kenya, covering an area of 68,680.3 Km^2 and it borders Uganda to the West, South Sudan to the North and Ethiopia to North-East (Figure 3.1); it lies between Longitudes $34^0$30' and $36^0$40' East and between Latitudes $1^0$30' and $5^0$30' North (Turkana County Government, 2015). The County is one of the arid and semi-arid land (ASAL) areas of Northern Kenya that has been severely impacted by drought over the years (Akall, 2014).

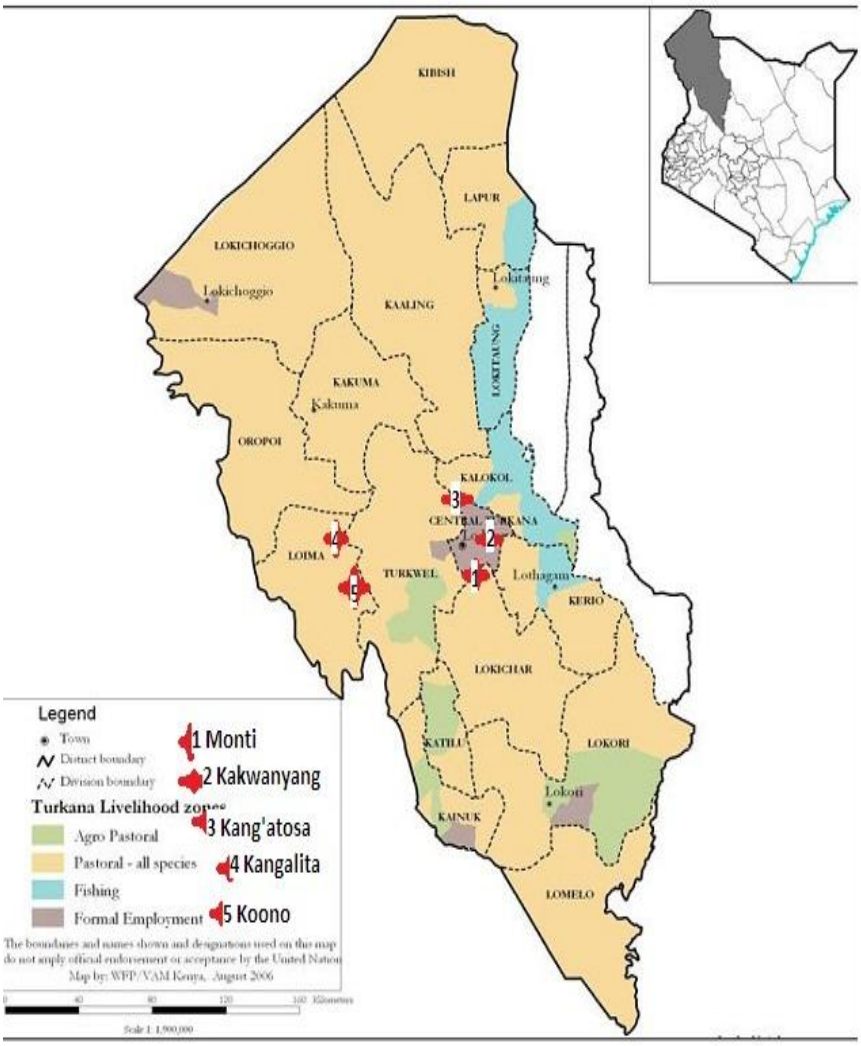

Figure 3.1: Map of Turkana County - Livelihood zones and Study sites (Source: Map of Turkana County extracted from the Map of Kenya; Akall, 2014).

The Turkana County also borders West Pokot and Baringo Counties to the South, Marsabit County to the East and Samburu County to the South-East (Turkana County Government, 2015). The research targeted three locations: Monti, Kakwanyang and Kang'atosa in the Central Turkana Sub-county and two other locations: Koono and Kangalita in Loima Sub-county; shown on Figure 3.1.

3.1.2 Topography and Climate

The County's landscape consists mainly of low lying plains with isolated mountains and hill ranges with vegetation ranging from barren land, annual grassland to evergreen forest (Diocese of Lodwar *et al*; 2012); unreliable and erratic rainfall ranging from 120mm-450mm annually with seasons March to May the long rains fall, whereas the short rains are from October to December with frequent droughts; and annual temperatures range from 24^0C to 46^0C. Woody vegetation with tall and less herbaceous plants is present in the target study areas; with sandy soils of moderate water holding capacity; and alluvial materials deposited on riverine areas (Diocese of Lodwar *et al*; 2012).

According to the Master Document for Strategic Food Security Plan by the Diocese of Lodwar *et al* (2012), droughts and occasional floods have a major impact: herds of livestock are decimated during periodic droughts. The interval between these events is shortening, so recovery time for farmers and herdsmen is decreasing. Run-off of rain water in the neighbouring countries' high hills results in dry riverbeds filling up downstream in Turkana, closing off access roads and causing flooding. Encroaching deserts are damaging farm land and changing semi-arid regions to arid lands thereby reducing pastureland. Such events may be the effects of climate change (Ebei *et al*, 2007).

3.1.3 Population, Land use and Economic Activities

The Turkana County total population was estimated at 855,399 (KNBS, 2009). Based on a population growth rate of 6.4%, the County is projected to have a total population of 1,036,586 in 2012 and 1,427,797 in 2017 (Turkana County Government, 2015). The households in Turkana practice pastoralism (62%), agro-pastoralism (14%), fishing (8%), and Urban/Peri-urban formal and informal employment (16%); as in Figure 3.1 above (Akall, 2014 and ALRMP, 2011). The research area (Figure 3.1) has 4,943 households with a total population of 29,658 comprising males (14,381), females (15,277), adults (9,710) and children (19,948); and the study targeted the adults population. Turkana County is the poorest in Kenya with the poverty index of 94.9% (Ministry of National Planning and Development, 2013); this is characterized by low and highly variable rainfall patterns, poor soils, geographical isolations, food insecurity and general marginalization.

3.2 Research Design

Cross sectional survey design was used in this study to collect data that determine level and cost of crop production; and appraise crop production systems and technologies used in Turkana County. On-farm experimentation design was used to assess cost effectiveness of gravity-drip irrigation technology for Spinach (*spinacia oleracea*) vegetable production in the target five areas of Turkana County. On-farm experimentation was conducted in farmers' fields, the place where production occurs and farmers make their major production decisions. Treatments based on the randomized Complete Block Design used were arranged as shown in Table 3.1; where two experimental units randomly selected in each block and represented by T_{d1} and T_{d2} to test effectiveness of drip irrigation, and other two represented by T_{b1} and T_{b2} for bucket micro-basin irrigation were used.

The experiment was designed such that each of the two farmers in each block used each of the treatments; where the bucket micro-basin irrigation acted as a control experiment.

Table 3.1 Treatments and layout of plots

	Block 1 Monti				Block 2 Kakwanyang				Block 3 Kang'atosa				Block 4 Kangalita				Block 5 Koono			
Farmer	1		2		3		4		5		6		7		8		9		10	
Plot	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Trt	T_{d2}	T_{b1}	T_{d1}	T_{b2}	T_{b2}	T_{d2}	T_{d1}	T_{b2}	T_{b2}	T_{d1}	T_{d2}	T_{b1}	T_{b2}	T_{d1}	T_{b1}	T_{d2}	T_{d2}	T_{b2}	T_{d1}	T_{b1}

Where: Trt = treatment

3.3 Sample Sizes and Sampling Procedure

Purposive selection was used to select two Sub-counties (Turkana Central and Loima) in which five locations of mainly agro-pastoralists were identified for the study. With confidence level at 95% and a total farm household population of 4,943, a sample size of 357 was computed for this work (Table 3.2). This sample was distributed proportionately among the target five locations. The formula used to determine the sample size was as per a Creative Research System http://www.surveysystem.com/sscalc.htmthe Sample Size Calculator that has the following inbuilt formula:

Sample size (Ss) = Z 2 * (p) * (1-p)/c 2;

Where:

Z = (1.96 for 95% confidence level); p = percentage picking a choice, expressed as decimal (0.5 used for sample size needed); c = confidence interval, expressed as decimal; (0.05 for 5% confidence interval)

Correction for Finite Population: New SS = Ss/1+ (Ss-1/pop), where pop = population.

The proportionate random sampling (Hunt N. *et al*, 2001) was used to get a representative sample from each of the five locations as given in Table 3.2; generated as percentage of the target total household study population.

Table 3.2: Sample Size distribution per Target Location

Location Name	**Area Population**	**Adult Study Population**	**Household Study Population**	**As % of total Study Population**	**Sample Size**
Monti	4,562	1,480	760	15	55
Kakwanyang	2,479	823	413	8	30
Kang'atosa	11,833	3,903	1,972	40	142
Kangalita	4,955	1,605	826	17	60
Koono	5,829	1,899	972	20	70
TOTAL	**29,658**	**9,710**	**4,943**	**100%**	**357**

Systematic random sampling was then used to randomly select, at every 13th case in the population frame, the number of cases from each location to answer questionnaires. All sampled members of the target locations (Monti, Kakwanyang, Kang'atosa, Kangalita and Koono) were involved when selecting the household heads who answered the questionnaires when the baseline survey was being conducted.

3.4 Data Collection Method

3.4.1 Baseline Survey – Questionnaire

The semi-structured questionnaires were administered by the researcher to the sampled farm household heads from each of the five communities of the target locations: Monti, Kakwanyang, Kang'atosa, Kangalita and Koono. The information collected was on demographic data, type and level of crop production and any farming technologies used.

3.4.2 Baseline Survey – Key Informant Interviews

The focused interview schedule was used to collect and record responses from the key informants. The key informants met comprised Agricultural Officers from the two Sub-county Agricultural Offices: Turkana Central and Loima Sub-counties, and the Turkana County Director of Agriculture. The information collected was on the types of crops and farming technologies already introduced to the farmers, the farmers' crop adoption behaviour and the expected and actual levels of crop production.

3.4.3. On-Farm Experiment

Two of the farm household heads who answered the questionnaires at each of the target five study areas were randomly selected to participate in demonstrating the gravity-drip irrigation during the Spinach's cropping season. The total ten selected farmers from the five study areas were then trained on the characteristics and application of the gravity-drip irrigation technology, and were supported to carry out farmer-managed demonstrations and promotion of the gravity-drip irrigation technology. Each of the two selected farmers in every study area was also asked to cultivate Spinach using the conventional bucket micro-basin irrigation on an equal plot size as that of drip irrigated plot so that the outputs could be compared to provide information on current production capacity. Drip laterals (20m length) having 20cm emitter spacing manufactured by the Amiran

Kenya were provided to the ten farmers demonstrating the use of drip irrigation technology. Water storage tanks having 200-litre capacity, were used to store water extracted from the solar-powered water-harvesting shallow wells; with culvert walls. The storage tanks were placed about 1m above the ground surface so as to gain sufficient gravitational energy for drip emitters to discharge the required amount of water uniformly along the laterals which are directly connected to the tanks. The farmers were required to fill the tanks before starting irrigation, to check the uniformity of water discharged by emitters, and to clean clogged emitters.

The amount of water applied per irrigation was determined by the soil-water available prior to irrigation using the feel method (Nicol A. *et al*; 2015). Initially, the participant farmers were guided to demonstrate the shape of the squeezed moist soil under different soil moisture content. They were oriented to apply water when they obtain the similar shape of sample moist soil squeezed at critical water content. All these farmers who used drip and bucket methods of irrigation were asked to record in tables the amount of labour, water applied and the yield obtained from the plots; so that costs and benefits could be compared.

The study adopted Type 2 of On-farm experiment classified by Coe D. *et al* (1997) where the researcher designs the experiment and farmers manage; the researcher consults farmers on the design and each farmer agrees to follow the same procedures to enable comparisons; the researcher evaluates performance of a practice on representative farms, and also facilitates analysis of costs and returns while farmers conduct all operations.

3.5 Data Analysis Methods

Social survey data was analyzed using descriptive statistics, particularly the means and proportions. Experimental data from on-farm research was analyzed using the analysis of variance (ANOVA) on Randomized Complete Block Design (RCBD), particularly the means and significant levels.

3.6 Ethical Considerations

Research approval and clearance was sought Kenyatta University Ethical review, Graduate School; and National Commission for Science, Technology and Innovation (NACOSTI). The respondents did not have to indicate their names on the questionnaires and interview schedules, so as to assure confidentiality of the data.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the findings and their implications in the context of the research problem statement. These findings have been sequenced based on the specific objectives.

4.2 Respondents' Background Information

Table 4.1 summarizes the main demographic aspects that were considered in this study, thus: gender, age, education level, family size and occupation. Among the 30 farm household heads that completed the questionnaire 53% were female while 47% were male. This may imply that women dominate crop farming as compared to their male counterparts who are traditionally engaged in herding livestock away from the farms in search of pasture and water in time of droughts. This concurred with explanation by the Ocra Company Ltd Technical Team (2013) that men in Turkana County are traditionally engaged in herding livestock away from the farms in search of pasture and water in time of droughts; and according to Akall (2014) many of them die due to raids.

The majority of the respondents (73%) were agro-pastoralists; and 27% of them comprised entrepreneurs, pastoralists and farmers. This implies that integrating crop farming and livestock rearing can provide sustainable livelihood in Turkana County. This concurred with an explanation by Akall (2014) that vulnerability of the pastoralists in Turkana County could be alleviated by integrating crop farming with pastoralism in order to diversify their livelihoods. Furthermore, 25 (83%) respondents were at the age bracket of 31-36 years and above; implying that they were the ones who practised crop farming alongside livestock keeping as a means to cater for the needs of their families whose reported average size was 6; and it may also imply that they are the group mostly hit by food insecurity. Respondents in Koono and Kangalita were all above 36 years of age.

The majority 27 (90%) respondents reported none level of education. This implies that the rate of illiteracy is high in Turkana County attributed to the fact that Turkana people are pastoral based, and perhaps parents prefer assigning their children the responsibility of looking after livestock to sending them to school; and also it has been reported that Turkana County has the highest illiteracy levels (KNALS, 2007, KNBS, 2015 and Save the Children, 2016).

Table 4.1: Demographic aspects contributing to the status of crop farming in Turkana County

Sub-County		**Turkana Central**						**Loima**					
Location		**Kang'atosa**		**Kakwanyang**		**Monti**		**Koono**		**Kangalita**		**Total**	
Number of Respondents		n	%	n	%	n	%	n	%	n	%	n	%
Age	20-25			1	33	1	20					2	7
	26-30	2	18			1	20					3	10
	31-36	3	27	1	33	2	40					6	20
	> 36	6	55	1	33	1	20	6	100	5	100	19	63
Gender	Male	6	55	2	67	2	40	2	33	2	40	14	47
	Female	5	45	1	33	3	60	4	67	3	60	16	53
Education Level	None	11	100	1	33	5	100	6	100	4	80	27	90
	Primary			1	33					1	20	2	7
	Secondary			1	33							1	3
Family Size	3			1	33							1	3
	4	3	27	1	33	1	20					5	17
	5	1	9	1	33							2	7
	6	4	36			2	40			1	20	7	23
	> 6	3	27			2	40	6	100	4	80	15	50
Occupation	Entrepreneur	1	9	1	33	1	20					3	10
	Farmer					2	40					2	7
	Pastoralist	1	9	1	33	1	20					3	10
	Agro-pastoralist	9	82	1	33	1	20	6	100	5	100	22	73

Table 4.2 summarizes the main activities contributing to the status of crop farming in the County, thus: land usage, crop farming practices used, farming skills learnt and crop types grown.

A small number of the respondents (33%) had learnt some farming skills such as conservation agriculture in Monti and Koono; intercropping in Kangalita, Koono and Kakwanyang; and tree planting and crop rotation in Kang’atosa. This implies that the farmers have not been exposed to the

use of proper agronomic practices, as was also reported by the Ocra Company Ltd Technical Team (2013). Accordingly, 25 (83%) respondents reported that they use their own land ranging from ¼ to 1 acre under crop farming mainly in Koono and Kangalita. This implies that majority of Turkana are beginning to embrace crop farming as alternative means of survival. The reported land acreage cultivated per household that ranges from ¼ acre to 1 acre may imply that the irrigation system in most arable places in Turkana County has not been fully developed to supply quantities of water that provide adequate crop soil moisture; as evidenced in the same Table 4.2 by only 43% respondents who reported that they use rain-fed and some irrigation systems to grow the crops; only in Kangalita are crops fully under irrigation and crops in Koono are purely rain-fed (Table 4.2). This is because the County's annual rainfall ranges between 120 and 600 mm which is erratic in time and space; and temperatures ranging between 24 and 38^0C, with high evaporation rates which lead to soil moisture deficits (Ocra Company Ltd Technical Team, 2013 and KNBS, 2015). Underdeveloped irrigation system is a problem that needs to be addressed so as to scale up crop yields to improve household food security in the County.

Furthermore, 25 (83%) respondents reported that the main types of crops grown in Turkana County are sorghum, maize, cowpeas and green grams. These are drought tolerant crops implying that such types of crops are grown in Turkana County. However, the yields of these crops are relatively low as per the prevailing amount of soil moisture and the types of agronomic practices used (Diocese of Lodwar *et al*, 2012 and Speca A., 2013). Other introduced crops are tomatoes, capsicum, spinach, kales and onions (Table 4.2); as also reported by the Ocra Company Ltd Technical Team (2013).

Table 4.2: Main activities contributing to the status of crop farming in Turkana County

Sub-County		Turkana Central						Loima					
Location		Kang'atosa		Kakwanyang		Monti		Koono		Kangalita		Total	
Number of Respondents		n	%	n	%	n	%	n	%	n	%	n	%
Land Usage	Crop farming	10	91	1	33	3	60	6	100	5	100	25	83
	Livestock keeping			1	33							1	3
	Both crops & livestock					1	20					1	3
	Housing	1	9	1	33	1	20					3	10
Crop Farming Practices Used	Rain-fed & Irrigation	10	91			3	60					13	43
	Rain-fed only							6	100			6	20
	Irrigation only			1	33					5	100	6	20
	Undecided	1	9	2	67	2	40					5	17
Farming Skills Learnt	Conservation Agric					3	60	3	50			6	20
	Tree planting and crop rotation	10	91									10	33
	Intercropping			1	33			3	50	5	100	9	30
	Undecided	1	9	2	67	2	40					5	17
Crop Types Grown	Undecided	1	9	2	67	2	40					5	17
	Sorghum / Maize	10	91	1	33	3	60	6	100	5	100	25	83
	Cowpeas / Green-gram	10	91	1	33	3	60	6	100	5	100	25	83
	Tomatoes / Capsicum	6	55			3	60	6	100	3	60	18	60
	Kales / Spinach	6	55			2	40	3	50	3	60	14	47
	Onions	6	55			1	20	3	50	2	40	12	40

4.3 Status of Crop Production and Factors limiting Diversification in the Area

4.3.1 Crop production systems and technologies used in Turkana County

Majority (73%) respondents reported that mostly subsistence and small commercial farming systems were used in Turkana County (Table 4.3). Poor agricultural practices in maintaining soil moisture for crops requirement and lack of commercialization in the County have resulted to low productivity, hence low income to the farmers (Ocra Company Ltd Technical Team, 2013 and KNBS, 2015). Shifting from crop subsistence to commercial farming in the County can be a factor that could motivate the agro-pastoralists to increase crop productivity. This echoed the World

Bank's findings (2007) which emphasized on getting the prices right through structural adjustment programmes which saw market and institutional fixes as the recent most promising driver of agricultural development; when market access, favourable prices and well-functioning institutions are believed to encourage smallholders to invest in enhanced productivity.

Table 4.3: Status of Crop Production Systems used in Turkana County

	Statement	**Dissatisfied**		**Neutral**		**Satisfied**	
		n	%	n	%	n	%
1	Mostly subsistence and small commercial farming systems are used	4	13	4	13	22	73
2	Mostly rain-fed and some irrigation farming systems are used in Turkana	9	30	0	0	21	70
3	Appropriate techniques to manage soil and water salinity in most parts of Turkana County are used	17	57	9	30	4	13
4	Appropriate measures are taken in the county to mitigate Climate Change so as to impact positively on crop production	23	77	5	17	2	7

Furthermore, 21 (70%) respondents reported that mostly rain-fed and some irrigation farming systems were used in the County. This implies that rain-fed farming system was used in most parts of the County. In addition, 17 (57%) respondents disagreed that appropriate techniques are used to manage soil and water salinity in most parts of Turkana County. This may imply that very little effort is made to manage soil and water salinity in the County.

Furthermore, 23 (77%) respondents disagreed that appropriate measures were taken in the County to mitigate Climate Change so as to impact positively on crop production. This implies that awareness creation on means to mitigating climate change has not adequately been sensitized to the

Turkana farmers by the agriculture extension officers. This agreed with the Diocese of Lodwar *et al* (2012) which reported that felling trees of high socio-economic importance to give room for irrigation may have a significant impact on the livelihood of Turkana community.

However, 15 (50%) respondents reported that irrigation system had been developed for use in some parts of Turkana County (Table 4.4). High silt load of Turkwel and Kerio rivers limits the choice of irrigation technologies to surface irrigation as sprinkler and drip irrigation methods may require expensive water filtration systems to reduce clogging of their nozzles and emitters (Ocra Company Ltd Technical Team, 2013 and KNBS, 2015). Furthermore, Sustainable Land Management practices such as Organic farming practices; Integrated Soil Fertility Management and Conservation Agriculture (CA) that can improve soil fertility were reported by 11 (37%) respondents as being used in some parts of Turkana Loima Sub-County; thus most farmers may have not been sensitized.

Table 4.4: Crop Production Technologies used in Turkana County

	Statement	**Dissatisfied**		**Neutral**		**Satisfied**	
		n	%	n	%	n	%
1	Mostly irrigation and some rain-fed farming systems are used in Turkana	9	30	6	20	15	50
2	Sustainable land management practices that can improve soil fertility, such as Organic farming practices, Integrated Soil Fertility Management practices and Conservation Agriculture are used	16	53	3	10	11	37
3	Adequate access to high value and drought tolerant crops, and integrated pests & diseases control	20	67	3	10	7	23

This also implies that very few farmers had adopted using sustainable land management practices to improve soil moisture required by the crops and maintain soil fertility in the County. This calls for intensive extension services by the agricultural extension officers in Turkana County. The available research shows that CA is more likely to be adopted by well-to-do-male smallholder farmers than poor smallholder farmers, who are also often women (Wekesah F.M., et al, 2019). Conservation Agriculture (CA) is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment; it is characterized by three principles which are linked to each other, namely: continuous minimum mechanical soil disturbance, permanent organic soil cover, and diversified crop rotations in the case of annual crops or plant associations in the case of perennial crops (FAO, 2010).

In addition, 67% of the respondents disagreed that farmers have adequate access to high value and drought tolerant crops and integrated pests & diseases control. This could mean that the seeds for high value and drought tolerant crops and chemicals for integrated pests & diseases control are not fully accessible for purchase within the County. This echoed the findings by the Diocese of Lodwar *et al*, (2012) which established that inadequate resources for efficient extension service delivery in Turkana County may result into rampant crop pests and diseases which are not efficiently and effectively controlled.

4.3.2 Farm household head responses on farming types:

In Table 4.5, all (100%) respondents reported that women in Turkana County do all farm activities such as crop planting, weeding, channelling irrigation water to the farms, scaring away birds and monkeys, and controlling crop pests and diseases; while 26 (87%) respondents reported men doing the same farm activities with the women. This may imply that some men are fully engaged in

herding livestock away from the homesteads and farms, in search of pasture and water in time of droughts; as was explained by the Ocra Company Ltd Technical Team (2013).

Further, all (100%) the respondents reported the use of farmyard manure to maintain soil moisture and fertility. This implies that majority of the respondents keep livestock which provide farmyard manure for the crops; though the farmers still experience poor crop yields. This may imply poor quality manure due to poor storage since farmers in Turkana use old manure which has been left in the open where plant nutrients might have been lost through leaching and volatilization. Farms with both crops and livestock have the potential to recycle a large portion of the nutrients used by crops back to the soil, since about 75% or more of the NPK consumed in animal feed is excreted in manure or urine; and efficient recycling of the nutrients depends upon storage, handling, and application methods that minimize losses, and an effective nutrient management plan that applies farmyard manure to fields in amounts matching crop needs with nutrient content of the manure (Pretty *et al*., 2010).

No report on the use of inorganic fertilizers was given by the farmers (Table 4.5). This may imply that most farmers in the County do not use inorganic fertilizers either due to high costs of fertilizers (KNBS, 2015) or low adoption of new crop farming methods by the Turkana Agro-pastoralists. This echoed the findings by Mugwe et al. (2008) on a research entitled "*Determinants of The Decision to Adopt Integrated Soil Fertility Management Practices by Smallholder Farmers in The Central Highlands of Kenya"* which called for adequate knowledge of farmers' adoption behaviour towards the new technologies. The study was done in the then Meru South District in the Central Highlands of Kenya.

Table 4.5: Farm household head responses on farming types in Turkana County

Questions		Responses	Respondents	
			n	%
Prevailing gender roles in crop agriculture	Male	Plant & sometimes weed and scare birds, monkeys & other pests & water channelling	26	87
	Female	Plant, Weed and scare away birds, monkeys & other pests & water channelling	30	100
Whether organic manure or inorganic fertilizers are applied		Organic types: - Farmyard manure	30	100
		Organic types: - Green manure & mulch	5	17
		Inorganic types:		0
Methods used to control pests and diseases		Cultural & Biological: Resistant varieties, Crop rotation, uprooting, ashes, scarecrow	29	97
		Chemical: Pesticides & fungicides/ IPM	9	30
Types of irrigation methods used		Basin	19	63
		Drip		0
		Flood	4	13
		Furrow	10	33
		Sprinkler		0

Further, 29 (97%) respondents reported use of cultural and biological methods, mainly crop rotation and ashes to control crop pests and diseases; and 9 (30%) respondents reported the use of chemicals mainly pesticides and fungicides. This may imply that cultural and biological methods are more accessible for use by the farmers to control crop pests and diseases than using chemicals that include application of Integrated Pest Management (IPM) methods. This is echoed by Pretty's findings (2010) which explained that application of IPM is lagging despites its successes and multiple benefits to farmers and to society.

Integrated Pest Management (IPM) means the careful consideration of all available pest control techniques, and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified, and reduce or minimize risks to human health and the environment (FAO, 2010 and

Meinzen-Dick *et al*., 2004). Good Agricultural Practices and Integrated Pests Management, implemented in programmes as a tool for farmers to acquire access to global markets that offer a better price (Kusnandar *et al*., 2019) could be the case in Turkana County.

The main irrigation methods used in Turkana County were reported by 19 (63%) and 10 (33%) respondents as basin and furrow types respectively (Table 4.5). This may imply that majority of initially introduced Irrigation Schemes in the County have used these two methods of irrigation. This echoed the findings by the Ocra Company Ltd Technical Team (2013) which explained that high silt load of Turkwel and Kerio rivers limits the choice of irrigation water application technologies to surface irrigation as sprinkler and drip irrigation methods may require expensive water filtration systems to reduce clogging of their nozzles and emitters. Thus, none of the respondents reported the use of drip irrigation, implying that it is not commonly used in Turkana; though it is viewed as the best option because it works in all types of slopes and can use both clean and salt water with efficiency of 80-90% (Michael, 2008). Salt water is common in Turkana County (Table 4.3); and with the use of drip irrigation the water is directed to wet only around the plant roots; pushing salt to accumulate away from the root zones when water evaporates.

4.3.3 Key Informants' responses on farming types in Turkana County:

Both irrigated and rain-fed agriculture were reported as the main crop production systems used in Turkana County (Table 4.6); with surface types of irrigation mainly used. This implies that surface irrigation provides adequate soil moisture for use by the crops and compensate for the water loss through high rates of evapotranspiration in the County. This confirmed the same report from the farm household heads (Table 4.5). However, all the Key Informants prefer promoting furrow irrigation and no mention of basin which is one of the surface types of irrigation used. This could be

due to the amount of work involved in basin ground levelling for uniform water distribution and prevention of salt accumulation (Table 4.3). Only 1 Key informant from Loima Sub-county reported the Drip (conservational) type of irrigation being used in the new irrigation schemes. This implies that drip type of irrigation is currently being introduced in the County to boost crop yields.

The Key informants agreed that better crop production techniques be introduced in the County. This implies that better techniques that would increase crop yields should be introduced in Turkana County. Moreover, all (100%) the key Informants (Table 4.6) reported that farmers in Turkana County use farmyard manure to maintain soil fertility, thus confirming what the farm household heads (Table 4.5) reported; and only 1 key informant reported the use of inorganic fertilizers, that is nitrogenous fertilizers (CAN) for topdressing the crops in his area of work, Loima Sub-county. Thus, the use of inorganic fertilizers is not common in Turkana County as was also reported by the farm household heads (Table 4.5).

All the key informants reported the use of chemicals to control crop pests and diseases (Table 4.6) in Turkana County, though only 30% of the farm household heads (Table 4.5) reported the use of this chemical method. This could imply that the supply of such chemical to farmers by the Ministry of Agriculture may not have been enough for all the farmers in the County (Ocra Company Ltd Technical Team, 2013 and KNBS, 2015). Furthermore, all the key informants reported that farmers in Turkana County use cultural methods to control crop pests and diseases; which concurred with the farm household heads (Table 4.5); and only 1 key informant reported the use of Integrated Pest Management (IPM) method. Thus, application of IPM is lacking despites its successes and multiple benefits to farmers and to society as it is established in the Pretty's findings (2010).

Table 4.6: Key Informants' responses on farming types in Turkana County

Questions	Responses	Turkana Central Sub-county Agric Officer	Turkana Loima Sub-county Agric Officer	County Director of Agriculture Turkana County	Respondents n
Which are the main crop production techniques that are used in Turkana County?	Irrigated agriculture	1	1	1	3
	Rain-fed agriculture	1	1	1	3
	Drip (conservational) Irrigation		1		1
	Flood (non-conservational) Irrigation		1		1
	Furrow (surface) Irrigation			1	1
	Basin (surface) Irrigation			1	1
Should better crop production techniques be introduced in Turkana County?	Yes	1	1	1	3
	Spate Irrigation (flood-based farming techniques		1	1	2
	Shade nets/Greenhouses	1		1	2
	Smart Drip Irrigation Systems	1			1
Do you apply organic manures or inorganic fertilizers in the farms?	Organic - Farmyard manure	1	1	1	3
	Inorganic - Nitrogenous (CAN)		1		1
Which methods do farmers use to control crop pests and diseases in the area?	Chemical control methods	1	1	1	3
	Cultural methods	1		1	2
	Biological methods			1	1
	Integrated Pests Management (IPM) methods		1		1
Which types of irrigation are used in Turkana County?	Basin Irrigation	1	1	1	3
	Drip Irrigation		1		1
	Flood Irrigation	1	1	1	3
	Furrow Irrigation	1	1	1	3
	Sprinkler Irrigation		1		1
	Others - Spate Irrigation			1	1
Which one among the above irrigation methods should be promoted?	Furrow Irrigation	1	1	1	3
	Flood Irrigation		1		1
	Drip Irrigation		1		1
	Spate Irrigation			1	1

4.4 Adoption level of Crop Farming and its influence on Household Food Security

4.4.1 Level of crop production in Turkana County and its influence on food security:

Table 4.7 indicates all (100%) respondents agreed that crop agriculture acts as a source of income and provides alternative livelihoods to Turkana people. This implies that adopting crop farming has generated income through sale of crop produce and provided alternative livelihoods to Turkana people. This was echoed by the Diocese of Lodwar *et al* (2012) which explained that crop agriculture's main roles in Turkana County span from solving problems of food security, acting as a source of income to the households and providing the local residents with alternative livelihoods through adopting crop farming and reducing overreliance on livestock keeping.

Table 4.7: How level of crop production influences food security status in Turkana County

No.	Statement	Agree (A)		Not agree (NA)		Undecided (UD)	
		n	%	n	%	n	%
1	Crop agriculture has more benefits in terms of food security to the Turkana households than livestock keeping	**27**	90	**3**	10		0
2	Crop agriculture acts as a source of income and provides alternative livelihoods to Turkana people	**30**	100		0		0
3	The possibility of growing more than two crops in a year enables the agro-pastoralists to keep a few animals within the vicinity of the irrigation scheme, which are fed with weeds as well as crop residues	**22**	73	**7**	23	**1**	3
4	Currently there is higher crop adoption rate by the people living in Turkana County than it was in the last five years.	**28**	93	**2**	7		0
5	There is improved road linkage of interior areas of the county to the expanding fruit and vegetable markets in Lodwar and neighbouring growing towns	**24**	80	**5**	17	**1**	3

Accordingly, 28 (93%) respondents agreed that currently there is higher crop adoption rate by the people living in Turkana County than it was in the last five years. This may imply that the Turkana people are currently changing their lifestyle at high rate from pure pastoralism to agro-pastoralism. This was also reported by the Diocese of Lodwar et al. (2012) that some households drop out of pastoralism to settle as farmers along the rivers or around underground water points since crop irrigation brings more benefits than pastoralism in Turkana County. Furthermore, 27 (90%) respondents reported that crop agriculture has more benefits in terms of food security to the Turkana households than livestock keeping. This implies that Turkana households have benefited in terms of food security from crop farming than livestock keeping which is traditionally a symbol of prestige to the society. This was echoed by VSF Belgium (2013) which identified diversification of alternative livelihood activities by the Turkana Pastoralists to be one of the options in minimizing effects of drought.

In addition, 24 (80%) respondents agreed that there is improved road linkage of interior areas of Turkana County to the expanding fruit and vegetable markets in Lodwar and neighbouring growing towns. This may imply that the improvement of roads linking the interior areas of the County to the vegetables and fruits markets in Lodwar and other towns can stimulate the development of crop agriculture in Turkana County. Linkage of the County interior areas to the readily available markets in Lodwar and other growing towns enable crop agriculture development in Turkana County (Ocra Company Ltd Technical Team, 2013).

Further, 22 (73%) respondents agreed that the possibility of growing more than two crops in a year enables the agro-pastoralists to keep a few animals within the vicinity of the irrigation scheme,

which are fed with weeds as well as crop residues. This implies that Turkana people value integrating crop farming with livestock keeping as a way of diversifying their livelihoods. Vulnerability of the pastoralists in Turkana County could be alleviated by integrating crop farming with pastoralism in order to diversify their livelihoods (Akall, 2014).

4.4.2 Farm household head responses on crop production's contribution to food security:

Table 4.8 indicates that the majority 14 (47%) respondents get 3-5 90kg bags of cereal crop per acre per growing season while 4 (13%) of them get over 10 bags per acre per season; and they have three growing seasons per year. This implies that on average the Turkana farm household gets as low yields as 12 bags @ 90 kg per acre annually. This may call for further research on improved cereal yield growth in rain-fed environments which could be done by extending the research downstream to farmers and upstream to the use of tools derived from biotechnology to assist conventional breeding (Rosegrant *et al.*, 2002).

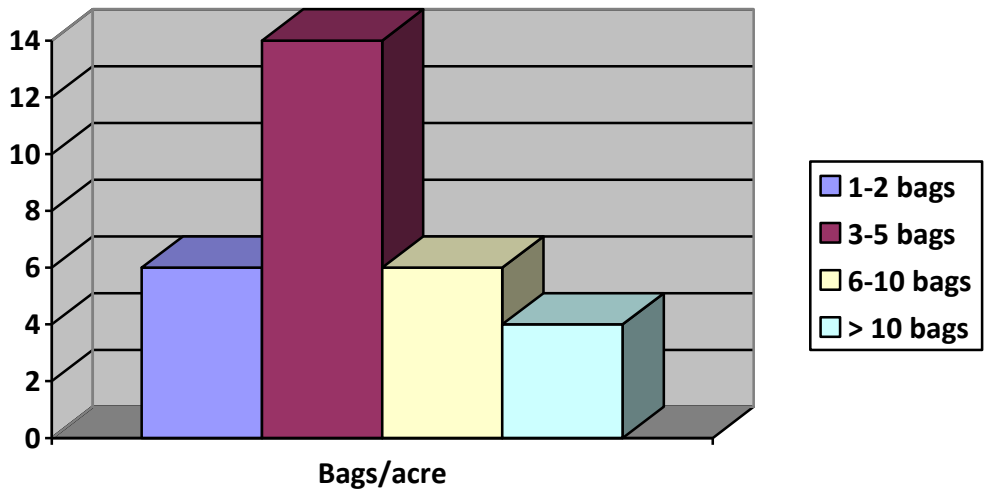

Figure 4.1: Cereal crop yields in 90 kg-bags per acre per growing season

Although this shows that the farmers get very low yields from their farms, as illustrated in Figure 4.1, Table 4.8 indicates 28 (93%) respondents reported that crop farming has significant impact to the life of Turkana people. This may be because average costs of crop production in the County were much lower than the proceeds from sales of farm produce as reported by the majority 12 (40%) respondents on labour spent in land preparation and other operations (Table 4.8), and 18 (60%) respondents on the seeds used during planting that amounted to Ksh 12,600.00 for maize and Ksh 6,800.00 for sorghum per acre; since sorghum's land preparation was done once and the subsequent harvesting seasons were from ratoon crops.

One bag of maize in the County at harvest time was Ksh 2,700.00 as reported by 14 (47%) majority respondents, and that of sorghum was Ksh 3,600.00 as reported by the 14 (47%) respondents. Thus, the revenue that could be collected from sale of the 12 bags per acre per year of each of maize and sorghum was Ksh 32,400.00 and Ksh 43,200.00 respectively; which are far much more than the costs of production that amounted to Ksh 12,600.00 for maize and Ksh 6,800.00 for sorghum per acre. This was echoed by the Ocra Company Ltd Technical Team's findings (2013) which explained that expected crop revenue in Turkana County is far much more than the annual cost of crop production. The yields of maize on smallholder farms are often limited because farmers have acute shortage of improved seed varieties (Sitch *et al*., 1996).

Table 4.8: Crop Production Contribution to Food Security status in Turkana County

Questions	Responses				Respondents	
					n	**%**
Cereal crop yields in 90 kg-bags per acre	1-2 bags @ 90kg				6	20
	3-5 bags @ 90kg				14	47
	6-10 bags @ 90kg				6	20
	> 10 bags @ 90kg				4	13
Does crop farming have significant impact to the life of Turkana people?	Yes				28	93
	No				2	7
What quantities & prices of various crop variable inputs per each main crop per acre?	Crop	Quantity (Kg)	Price (Ksh)	Costs (Ksh)	**n**	**%**
	Maize	18	200	3600	18	60
	Sorghum	4	250	1000	18	60
	Maize	Not sure			12	40
	Sorghum	Not sure			12	40
	Greengram	3	300	900	7	23
Amount of labour used in terms of man-days per main crop grown per acre	Crop	(Man-days)	Price (Ksh)	Costs (Ksh)	**n**	**%**
	Maize	24 (land preparation)	200	4800	12	40
		21 (other operations)	200	4200	12	40
		Not sure			6	20
	Sorghum	8 (land preparation)	200	1600	12	40
		21 (other operations)	200	4200	12	40
		Not sure			6	20
Quantities and prices of various crop outputs per each main crop per acre	Crop	Quantity (Kg)	Price (Ksh)	Revenue (Ksh)	**n**	**%**
	Maize	150	30	4500	10	33
		90	30	2700	14	47
		50	30	1500	12	40
	Sorghum	150	40	6000	9	30
		90	40	3600	14	47
		50	40	2000	13	43

These figures are similar to the ones given by the Ocra Company Ltd Technical Team's findings (2013) which explained that revenue per hectare in crop irrigated areas of Turkana was Ksh 54,895.00 and the annual cost of production per hectare was Ksh 44,900; showing that expected revenue was far much more than the annual cost of crop production. This goes with the findings by

Mazonde (1993) which established that higher crop yields, which lead to sustained development of the arable sector because they reduce cost per unit of output, should form a major technological challenge for Sub-Saharan African countries.

The figures in Table 4.8 for costs of production, the yields and prices of the produce were used in calculating the gross margins for maize and sorghum as shown in Table 4.9. Thus the annual gross farm profit of maize was calculated as Ksh 19, 800.00 and that of sorghum was Ksh 36, 400.00. Hence, promoting crop farming in Turkana County would diversify livelihood options and reduce the risks communities must endure due to persistent droughts that often result into livestock deaths (Ebei *et al*, 2007). The farmers should be encouraged to intercrop the cereal crops with legumes to increase the yields for consumption and get surplus for sale to earn income; thus increases farmers' options to grow crops based on market demand which improves agricultural activities and productivity (Muoni *et al*, 2019).

Table 4.9: Gross Margin calculation for Maize and Sorghum

	Details	Maize	Sorghum
Gross Output		Ksh	Ksh
	Sales of 12 90kg-bags per acre per year @ 2,700sh maize; and 12 90kg-bags per acre per year @ 3,600sh sorghum	32,400.00	43,200.00
A	Total Gross Output per acre per year	**32,400.00**	**43,200.00**
Variable Cost			
	Land preparation – 24 labourers @ 200sh for maize per acre; and 8 labourers @ 200sh for sorghum per acre	4,800.00	1,600.00
	Seeds – 18 kg @ 200sh/acre maize; and 4 kg @ 250sh/acre sorghum	3,600.00	1,000.00
	Planting – 7 labourers @ 200sh per acre	1,400.00	1,400.00
	Weeding – 7 labourers @ 200sh per acre	1,400.00	1,400.00
	Harvesting – 7 labourers @ 200sh per acre	1,400.00	1,400.00
B	Total Variable Cost per acre per year	**12,600.00**	**6,800.00**
C	Total Gross Margin = A - B	***19,800.00***	***36,400.00***

4.4.3 Key informants' responses on crop production's contribution to food security:

Table 4.10 indicates the majority (67%) key informants who reported that most households in Turkana County cultivate up to ¼ acre of land. This may imply that households in the County can cultivate to approximately ¼ acre of land due to inadequate supply of water for crop irrigation. This echoed the Ocra Company Ltd Team's findings (2013) which established that irrigation schemes along Turkwel and Kerio rivers support 16,609 households with plot sizes of 0.16 to 0.4 hectare. Accordingly, all the 3 (100%) Key informants reported that majority of farm households in the County get cereal crop yields of 6-10 bags @ 90 kg per acre per season; while 33% of them reported the yields of 3-5 bags, just the much which was reported by majority of the respondent farmers (Table 4.9). This may imply that the right yields can be that of 3-5 bags per acre per season since these were reported twice by the majority respondents, thus giving an average of 4 bags per acre per season, hence the annual yield of 12 bags per acre; though the agricultural officers (the Key Informants) might have given far projected estimates.

Furthermore, 67% of the key informants gave the reason for obtaining the low yields as inadequate water for irrigation and inadequate use of certified seeds. This implies that in addition to inadequate water for irrigation, the farmers use inadequate certified dry-land seeds as they have limited access to most of the crop farm inputs in the County. The actual crop yields per hectare in Turkana County is half the expected yields mainly due to: inadequate means to maintain crop soil moisture requirements, inadequate soil fertility management, poor means to control soil salinity in some cultivated fields, limited agricultural extension services and lack of commercialization (Diocese of Lodwar *et al,* 2012; Turkana County Government, 2015).

Table 4.10 Level of crop production and food security status in the County

Questions	Responses	Turkana Central Sub-county Agric Officer	Turkana Loima Sub-county Agric Officer	County Director of Agriculture Turkana County	Respondents	
					n	%
What size of land is mostly cultivated per household in the County?	< ¼ acre		1		1	33
	¼ acre	1		1	2	67
What range of cereal crop yields is experienced in 90 kg-bags per acre?	3-5 bags - (maize & sorghum)		1		1	33
	6-10 bags - (maize & sorghum)	1		1	2	67
Give reasons for obtaining the yield mentioned above	Inadequate use of certified seeds	1		1	2	67
	Inadequate water for irrigation		1	1	2	67
	Poor agronomic practices	1			1	33
	Inadequate use of inorganic fertilizer		1		1	33
	Insect pest attacks		1		1	33
	Soil salinity			1	1	33
Which varieties are of high performing crops in the area?	PH4 seed maize	1	1	1	3	100
	DH04 seed maize	1	1	1	3	100
	Gadam seed sorghum	1	1	1	3	100
	Seredo seed sorghum			1	1	33
	Serena seed sorghum			1	1	33
	Local seed sorghum			1	1	33
State other improved crop types that could be recommended for growing in the County	Green gram	1		1	2	67
	Cowpeas	1		1	2	67
	Spinach	1		1	2	67
	Tomatoes	1	1		2	67
	Onions		1		1	33
	Watermelon			1	1	33
	Spider plant	1			1	33
	Sweet potatoes		1		1	33
	Cassava		1	1	2	67
	Mangoes	1	1		2	67
	Pawpaw	1			1	33

Moreover, all the 3 (100%) key informants reported the varieties of high performing crops in Turkana County as DH04, PH4 and Gadam Sorghum; while 67% of them reported green grams, cowpeas, spinach, tomatoes, cassava and mangoes as other improved crop types that could be recommended for growing in the County; and other crop types reported by 33% of the Key Informants were: onions, watermelons, spider plants, sweet potatoes and pawpaw (Table 4.10); similar to what was reported in Table 4.2 by the farm household heads.

This may imply that farmers have planted these varieties and found their performance more superior than the local varieties. The three main varieties of cereal crops grown in Turkana County are DH04 and PH4 seed maize and Gadam seed sorghum; and other recommended crops include: green grams, cowpeas, spinach, tomatoes, cassava and mangoes (Diocese of Lodwar *et al*, 2012). This echoed the findings that one of the strategies for poverty reduction through increased agricultural productivity is to promote the production of the high yielding varieties (Nkonya *et al*., 2004).

4.5 Measures towards Increased Adoption of Viable Crop Production Systems in the County

4.5.1 Soil Moisture Conservation Methods used in Crop Farming in Turkana County:

Table 4.11 indicated the majority 14 (47%) respondents who agreed that adequate crop rotation and intercropping the crop with soil crop cover as well as minimum tillage are practiced by Turkana Agro-pastoralists, while 13 (43%) respondents agreed that majority of Turkana people adopted using flood irrigation for crop production in the vast arable land with inherent soil fertility along rivers Turkwel and Kerio that produces medium to high crop yields. This may imply that such practices as flood irrigation are used by the agro-pastoralists for conserving crop soil moisture in the County. However with this small percentage of the respondents, these practices may have not been effective due to the little water supply to the crops; as was echoed by the findings of the Diocese of

Lodwar *et al* (2012) which explained that low productivity as a result of inadequate soil moisture is due to unreliable rainfall throughout the year and high rates of evapotranspiration in the County.

Table 4.11: Appropriateness of crop soil moisture conservation method used in Turkana

No.	Statement	Agreed (A)		Not Agreed (NA)		Undecided (UD)	
		n	%	n	%	n	%
1	Potential crop farming areas in Turkana County under irrigation produce reasonably high crop yields to the satisfaction of the households	**11**	37	**7**	23	**12**	40
2	The performance of drought tolerant cereal crops such as green-grams, cowpeas, sorghum, and PH4 or DH04 series of maize in Turkana County has been good	**13**	43	**8**	27	**9**	30
3	Cultivation of high value vegetables such as improved varieties of tomatoes, capsicum, kales, spinach and onions has been doing well in greenhouses under drip irrigation	**4**	13	**18**	60	**8**	27
4	Cultivation of high value vegetables such as improved varieties of tomatoes, capsicum, kales, spinach and onions also give good yields in Turkana County under drip irrigation outside greenhouses	**11**	37	**15**	50	**4**	13
5	Turkana people have adopted using flood irrigation for crop production in the vast arable land with inherent soil fertility along rivers Turkwel and Kerio	**13**	43	**12**	40	**5**	17
6	Sustainable land management practices such as Organic farming practices and Conservation Agriculture are also widely used to conserve soil moisture for the growing crops	**10**	33	**17**	57	**3**	10
7	Appropriate techniques to manage soil and water salinity in most parts of Turkana County including mulching are used.	**11**	37	**12**	40	**7**	23
8	Adequate crop rotation and intercropping the crop with soil crop cover as well as minimum tillage are practiced by Turkana Agro-pastoralists	**14**	47	**13**	43	**3**	10

In addition, 11 (37%) respondents agreed that potential crop farming areas in Turkana County under irrigation produce reasonably high crop yields to the satisfaction of the households; and cultivation

of high value vegetables such as improved varieties of tomatoes, capsicum, kales, spinach and onions give good yields in the County under drip irrigation outside greenhouses. This may imply that unlike rain-fed farming, irrigation system produces reasonably high crop yields in the County, particularly drip irrigation for horticultural vegetables growing outside greenhouses (Table 4.11). This was echoed by the findings of the Diocese of Lodwar et al. (2012) which explained that, as a result of unreliable rainfall throughout the year, drought and resultant famine is recurrent in Turkana County due to poor harvests from rain fed farming sites; and that existing irrigation projects have contributed to food security and incomes.

Moreover, 11 (37%) respondents agreed that appropriate techniques such as mulching are used to manage soil and water salinity in most parts of Turkana County; while 10 (33%) respondents agreed that Sustainable Land Management practices such as Organic farming and Conservation Agriculture (CA) are widely used to conserve soil moisture for the growing crops in Turkana. This small percentage of respondents in agreement implies that majority of the respondents have not been exposed to these practices which would provide useful means to conserving crop soil moisture in the County. According to FAO (2010), conservation agriculture (CA) is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment; it is characterized by three principles which are linked to each other, namely: continuous minimum mechanical soil disturbance, permanent organic soil cover, and diversified crop rotations in the case of annual crops or plant associations in case of perennial crops.

4.5.2 Farm household-heads' responses on appropriate methods of conserving soil moisture

Table 4.12 indicates that 19 (63%) respondents reported soil cover crop growing, contour ploughing and crop rotation; as well as mulch application reported by 47% of the respondents as some of the soil moisture conservation practices used for adequate crop soil moisture management in Turkana. This may imply that such practices are the main methods they use in conserving soil moisture for their cultivated crops. Further, 40% of the respondents reported organic manure application, and other 37% of the respondents reported mulching & adequate water supply as appropriate techniques that are used to manage soil and water salinity in most parts of the County. This may imply that organic farming practices as well as adequate water supply could be preferred practices for use in Turkana County to conserve crop soil moisture and manage soil salinity in cultivated fields.

In addition, the majority 11 (40%) respondents reported afforestation and agro-forestry as some of the appropriate techniques that can be used to manage soil and water salinity in most parts of Turkana County. This implies that the farmers must have used these techniques in managing soil salinity since most schemes in the County are basin irrigated which lack a drainage network (Table 4.6), thus allowing salts accumulation in the irrigation fields. This echoed the findings by the Ocra Company Ltd Technical Team (2013) which established that the Turkana farmers in most irrigation schemes address soil salinity by burning vegetation trash on the affected areas to moderate the effect of salts. Thus afforestation and agro-forestry practices reported by the farmers could mean production of vegetation trash for burning to control such soil salinity. Hence, in absence of other locally tested salt control measures, the tacit knowledge of the burning of trash to address soil salinity should be encouraged in Turkana (Ocra Company Ltd Technical Team, 2013).

97% of the respondents (Table 4.12) reported that integration of crop farming and livestock keeping improve household food security in Turkana County. This implies that livestock keeping alone cannot sustain food security in the County and that integrating crop agriculture with livestock keeping helps in diversifying livelihoods. This was echoed by Akall's findings (2014) which explained that vulnerability of the pastoralists in Turkana County could be alleviated by integrating crop farming with pastoralism in order to diversify their livelihoods.

Table 4.12: Responses on the appropriate methods used to conserve soil moisture

Questions	**Responses**	**Respondents**	
		n	%
Other soil conservation methods used for adequate crop soil moisture management	Crop cover growing, contour cultivation & crop rotation	19	63
	Mulching application	14	47
Appropriate techniques that can be used to manage soil and water salinity in most parts of Turkana County	Mulching application & adequate water supply	11	37
	Organic manure application	12	40
	Afforestation & Agro-forestation	12	40
Other comments regarding integration of crop farming & livestock keeping in Turkana County	Integrating crop and livestock farming improve food security	29	97
	Farmers training on modern farming technologies and control of livestock pests and diseases	11	37

VSF Belgium (2013) identified diversification of alternative livelihood activities by the Turkana Pastoralists to be one of the options in minimizing effects of drought. Furthermore, 11 (37%) respondents commended farmers training on modern farming technologies and on control of

livestock pests and diseases for better crop and livestock farming integration. This implies that improved agro-pastoralism can contribute towards sustenance of food security in Turkana County. Watete et al. (2016) established that agro-pastoral households in Turkana and Mandera are able to survive drought events better than the pastoral and off-farm households as they utilize their own produced food during the initial stages of a drought, thus reducing the negative impact of drought; and are able to use crop residues to supplement their animals during drought periods.

4.5.3 Key informants' responses on the appropriate methods used to conserve soil moisture:

Table 4.13 indicates that all the 3 (100%) key informants reported application of organic manure as the most preferred method of soil moisture conservation, and flood irrigation as an appropriate technique which could be used to manage soil and water salinity; as was reported by the farm household heads (Table 4.12). This implies that application of organic manure improves soil water retention capacity; and flood irrigation flushes away salt from accumulating on soil surface. However, combinations of other means could be employed as well; as reported by 33% of the Key Informants that soil moisture conservation methods used include: planting cover crops & mulching in Central Turkana; chisel ploughing, conservation agriculture & zero tillage in Loima; and trapezoidal bunds in other parts of the County (Table 4.13). This echoed IAASTD's findings (2009) which explained that, many of the challenges facing agriculture currently and in the future will require more innovative and integrated applications of existing knowledge, science and technology, as well as new approaches for agricultural and natural resource management. In addition, 67% of the Key informants reported growing of Sudan Sorghum, and 33% of them reported planting crops that do well in saline soils such as pawpaw in Central Turkana and flushing in Loima as appropriate techniques which could be used to manage soil and water salinity (Table 4.13). This may imply that the Key Informants have working experience of such techniques in their areas of jurisdiction. This

echoed the findings by Sherr (1999) which stated that farmers who have been resident in a particular natural region will be aware of soil management problems like soil physical and chemical deterioration through effects such as low yields, soil salinity or sodicity.

Table 4.13: Appropriateness of soil moisture conservation methods in Turkana crop farming

Questions	**Responses**	Turkana Central Sub-county Agric Officer	Turkana Loima Sub-county Agric Officer	County Director of Agriculture Turkana County	Respondents	
					n	%
Which soil moisture conservation methods are used in Turkana County?	Planting of cover crops	1			1	33
	Mulching	1			1	33
	Chisel ploughing		1		1	33
	Conservation Agriculture		1		1	33
	Zero tillage		1		1	33
	Trapezoidal bunds			1	1	33
	Manure application	1	1	1	3	100
Which appropriate techniques do you think could be used to manage soil & water salinity in the County?	Plant crops that do well in saline soils	1			1	33
	Flushing		1		1	33
	Flooding	1	1	1	3	100
	Growing of Sudan sorghum	1		1	2	67
	Growing of pawpaw	1			1	33
Any other comments with regard to integrating crop farming & livestock keeping in the County?	Crop production in the irrigation schemes, should be integrated with pasture production, hayshed construction for better integration	1			1	33
	More funding towards extension will help to improve output both in crops and livestock production		1		1	33
	Practicing Agro-forestry together with crops and livestock			1	1	33

Finally, 1 (33%) Key Informant reported that integrating crops in the irrigation schemes with pasture production would ensure better integration of crop farming with livestock rearing in Turkana County, and another 1 (33%) Key Informant said more funding towards extension would help to improve output both in crops and livestock production; while 1 (33%) Key Informant stated that practicing agro-forestry together with crops and livestock is another means of integrating crops with livestock to improve food security in the County (Table 4.13). This implies that agro-forestry would increase organic matter in the farms that would improve soil structure and fertility as well as providing forage to feed livestock which are always around the irrigation schemes.

However, it has not been explained how the farmers could use this technology since there seem to be inadequate water supply for food crop irrigation in the County; hence further research is needed to investigate appropriate means for reliable water source of getting adequate water supply for food crop and agro-forestry irrigation.

4.5.4 The On-Farm Experimentation Results:

4.5.4.1 Amount of Water and Labour required for Drip and Bucket Irrigation methods:

Table 4.14 indicates data collected for the amount of water used in 2 experimental units of spinach production: one using drip method of irrigation and the other using bucket method. The experiment was carried out by ten randomly selected farmers to assess cost effectiveness of gravity drip-irrigation technology as compared with the commonly used bucket irrigation in the target five locations (blocks) of Turkana County; 2 farmers randomly selected in each block.

Table 4.14: Data Collection on water amount from On-Farm Experiment of Spinach Vegetable Production

Amount of water used in drip and bucket method application in the months of Jan to Jun 2018																		
Block	**Drip Volume of water applied (m^3 per1/8acre)**									**Bucket Volume of water applied (m^3 per1/8acre)**								
	Farmer	Jan (ltrs)	Feb (ltrs)	Mar (ltrs)	Apr (ltrs)	May (ltrs)	Jun (ltrs)	Total (m^3)	**Av (m^3 per acre)**	Jan (ltrs)	Feb (ltrs)	Mar (ltrs)	Apr (ltrs)	May (ltrs)	Jun (ltrs)	Total (m^3)	**Av (m^3 per acre)**
Monti	1	2700	2500	2200	2000	3500	3800	16.70	**135.20**	3500	3400	3200	3200	4200	4500	22.00	**175.96**
	2	2850	2400	2300	2250	3600	3700	17.10		3600	3450	3200	3100	4140	4500	21.99	
Kakwanyang	3	2800	2400	2400	2260	3560	3800	17.22	**137.88**	3600	3500	3450	3300	4140	4600	22.59	**181.20**
	4	2850	2500	2400	2200	3500	3800	17.25		3700	3550	3400	3200	4260	4600	22.71	
Kang'atosa	5	2880	2500	2450	2400	3400	3700	17.33	**137.96**	3790	3700	3550	3200	4000	4500	22.74	**181.68**
	6	2800	2600	2460	2400	3400	3500	17.16		3780	3700	3500	3100	4100	4500	22.68	
Kangalita	7	2800	2750	2440	2400	2900	3600	16.89	**135.48**	3740	3700	3500	3400	3900	4200	22.44	**179.40**
	8	2830	2700	2500	2300	3150	3500	16.98		3760	3650	3500	3400	4000	4100	22.41	
Koono	9	2850	2800	2600	2450	2900	3500	17.10	**136.08**	3800	3750	3640	3500	3800	4400	22.89	**182.88**
	10	2820	2750	2450	2400	3000	3500	16.92		3880	3750	3600	3500	3900	4200	22.83	
Average (Mean)		2818	2590	2420	2306	3291	3640	17.07	**136.52**	3715	3615	3454	3290	4044	4410	22.53	**180.22**

Comparing the total average amount of water applied (Table 4.14) for spinach production in each block, it shows that more volume of water was used in bucket irrigation than drip method of irrigation by average (Mean) 43.7 m^3 per acre. This could imply that using drip method of irrigation is more efficient than the bucket method; which agreed with the findings by Nicol A. *et al* (2015) which said that using gravity drip irrigation significantly reduced the total amount of water required. The total average volume of water applied in each block for each experimental unit in Table 4.14 was used in Table 4.15 for RCBD computation on volume of water applied in m^3/acre. This was used to help in determining the F-values that would make conclusion on the water use efficiency with drip method of irrigation compared with the commonly used bucket method application in the target five locations of Turkana County.

Table 4.15: Amount of water used in drip and bucket method application (m^3/acre)

Water applied (m^3/acre)	**Blocks**					
Treatments	Monti	Kakwanyang	Kang'atosa	Kangalita	Koono	**Y_j**
Drip method (D)	135.20	137.88	137.96	135.48	136.08	**682.60**
Bucket Method (B)	175.96	181.20	181.68	179.40	182.88	**901.12**
Y_i	311.16	319.08	319.64	314.88	318.96	**1583.72**
ΣYij^2	49240.96	51844.33	52040.58	50539.19	51962.86	255627.93

The hypotheses to be tested in checking for water use efficiency with drip irrigation method are thus: H_o: $\mu_1 = \mu_2$; H_a: $\mu_1 \neq \mu_2$.

Table 4.16 indicates the F-calculated values compared with the F-table values for concluding the water use efficiency with the drip and bucket method of irrigation; using the total volume of water applied (Table 4.15). Thus the correction factor (CF) is $(1583.72)^2/10$ and sum of squares total (SS_T) is 255,627.93 – CF, that is 4,811.03; sum of squares treatment (SS_{Trt}) is $(311.16^2 + 319.08^2 + 319.64^2 + 314.88^2 + 318.96^2)/2$ – CF, that is 26.70; sum of squares block (SS_{Blk}) is $(682.60^2 + 901.12^2)/5$ – CF, that is 4775.10; and sum of squares error is $SS_T - SS_{Trt} - SS_{Blk}$, that is 9.22.

Hence, comparing the F-calculated and the F-table values on treatments source of variation in Table 4.16, the H_o hypothesis is rejected at 95% and could not be rejected at 99% level of confidence. This implies that more amount of water is saved for irrigating more farms at 95% level of confidence when drip irrigation is used than when bucket method of irrigation is used. Hence, using drip irrigation for crop production in Turkana County could be of benefit to the farmers. All treatment means may be equal at 99% level of confidence.

Table 4.16: Completion of ANOVA on volume of water applied (m^3/acre)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F_{calc}	F_{table}
Treatment	1	26.70	26.70	11.56	7.71 at 0.05 s. l 21.20 at 0.01 s. l
Block	4	4775.10	1193.78	516.79	6.39 at 0.05 s. l 15.98 at 0.01 s. l
Error	4	9.22	2.31		
Total	9	4811.03			

Table 4.17 indicates data collected for the amount of labour used in the 2 experimental units of spinach production: one using drip method of irrigation and the other using bucket method.

Table 4.17: Data Collection on labour used from On-Farm Experiment of Spinach Vegetable Production

Amount of labour used in drip and bucket method application in the months of Jan to Jun 2018																	
Block	**Drip Amount of labour (man-days per 1/8 acre)**									**Bucket Amount of labour (man-days per 1/8 acre)**							
	Farmer	**Jan (hrs)**	**Feb (hrs)**	**Mar (hrs)**	**Apr (hrs)**	**May (hrs)**	**Jun (hrs)**	**Total (man-days)**	**Av (man-days/acre)**	**Jan (hrs)**	**Feb (hrs)**	**Mar (hrs)**	**Apr (hrs)**	**May (hrs)**	**Jun (hrs)**	**Total (man-days)**	**Av (man-days/acre)**
Monti	No. 5	5.49	5.46	5.48	5.45	5.54	5.54	4.12	**34.56**	6.59	6.57	6.58	6.54	6.65	6.59	4.94	**39.48**
	No. 2	6.03	6.00	6.02	6.01	6.05	6.05	4.52		6.57	6.56	6.57	6.53	6.61	6.60	4.93	
Kakwanyang	No. 11	7.27	7.17	7.25	7.26	7.32	7.33	5.45	**43.72**	12.12	12.02	12.08	12.10	12.20	12.20	9.09	**73.20**
	No. 23	7.31	7.29	7.30	7.31	7.31	7.32	5.48		12.28	12.26	12.27	12.27	12.30	12.30	9.21	
Kang'atosa	No. 71	6.69	6.65	6.67	6.68	6.73	6.74	5.02	**39.48**	16.51	16.50	16.48	16.49	16.53	16.53	12.38	**98.80**
	No. 58	6.47	6.46	6.46	6.47	6.47	6.47	4.85		16.43	16.42	16.40	16.41	16.45	16.45	12.32	
Kangalita	No. 54	6.59	6.57	6.58	6.59	6.59	6.60	4.94	**39.88**	8.99	8.95	8.98	8.99	9.00	9.01	6.74	**53.80**
	No. 38	6.71	6.70	6.69	6.70	6.72	6.72	5.03		8.95	8.91	8.92	8.95	8.97	8.98	6.71	
Koono	No. 64	6.88	6.85	6.89	6.89	6.88	6.89	5.16	**40.56**	14.57	14.55	14.56	14.57	14.59	14.60	10.93	**87.20**
	No.43	6.64	6.62	6.63	6.64	6.65	6.66	4.98		14.49	14.47	14.48	14.49	14.51	14.52	10.87	
Average (Mean)		**6.61**	**6.58**	**6.60**	**6.60**	**6.63**	**6.63**	**4.96**	**39.64**	**11.75**	**11.72**	**11.73**	**11.73**	**11.78**	**11.78**	**8.81**	**70.50**
Labour cost = Ksh 200.00 per man-day																	

Looking at the total average amount of labour used in man-days per acre for spinach production in each block, it shows that more labour was used in bucket irrigation than drip method of irrigation by average (Mean) 30.86 man-days per acre (Table 4.17). This may imply that using drip method of irrigation is more efficient than the bucket method since less amount of labour is used; as it is with the findings by Nicol et al. (2015) which indicated that using gravity drip irrigation significantly reduced the total amount of labour required.

The total average amount of labour used in each block for each experimental unit in Table 4.17 was used in Table 4.18 for RCBD computation on the amount of labour used in man-days/acre. This was used to help in determining the F-values that would make conclusion on the labour use efficiency with drip method of irrigation compared with the commonly used bucket method application in the target five locations of Turkana County.

Table 4.18: Amount of labour used in drip and bucket method application (man-days/acre)

Labour used (man-days/acre)	**Blocks**					
Treatments	Monti	Kakwanyang	Kang'atosa	Kangalita	Koono	$\mathbf{Y_j}$
Drip method (D)	34.56	43.72	39.48	39.88	40.56	**198.20**
Bucket Method (B)	39.48	73.20	98.80	53.80	87.20	**352.48**
$\mathbf{Y_i}$	**74.04**	**116.92**	**138.28**	**93.68**	**127.76**	**550.68**
$\mathbf{\Sigma\ Yij^2}$	2753.06	7269.68	11320.11	4484.85	9248.95	**35076.66**

The hypotheses to be tested in checking for labour use efficiency with drip irrigation method are thus: H_o: $\mu_1 = \mu_2$; H_a: $\mu_1 \neq \mu_2$.

Table 4.19 indicates the F-calculated values compared with the F-table values for concluding the labour use efficiency with the drip and bucket method of irrigation; using the total amount of labour

used (Table 4.18). Thus the correction factor (CF) is $(550.68)^2/10$ and sum of squares total (SS_T) is 35076.66 – CF, that is 4,751.81; sum of squares treatment (SS_{Trt}) is $(74.04^2 + 116.92^2 + 138.28^2 + 93.68^2 + 127.76^2)/2$ – CF, that is 1361.22; sum of squares block (SS_{Blk}) is $(198.20^2 + 352.48^2)/5$ – CF, that is 2380.23; and sum of squares error is $SS_T - SS_{Trt} - SS_{Blk}$, that is 1010.36.

Table 4.19: Completion of ANOVA on amount of labour used (man-days/acre)

Source of Variation	**Degrees of Freedom**	**Sum of Squares**	**Mean Square**	**F_{calc}**	**F_{table}**
Treatment	1	1361.22	1361.22	5.39	7.71 at 0.05 s. l 21.20 at 0.01 s. l
Block	4	2380.23	595.06	2.36	6.39 at 0.05 s. l 15.98 at 0.01 s. l
Error	4	1010.36	252.59		
Total	9	4751.81			

Thus comparing the F-calculated and the F-table values on treatments source of variation in Table 4.19, the H_o hypothesis failed to be rejected at both 95% and 99% levels of confidence since the F-calculated (5.39) is less than the F-table values at these levels of confidence. This implies that all treatment means may be equal. Hence, using drip irrigation for crop production in this case may have very little or no significant at 0.05 and 0.01 with respect to amount of labour used.

However, Table 4.20 indicates that using the drip irrigation system, 30.86 man-days per acre labour on average was saved over the bucket method for spinach production; as in Table 4.17. Since the labour cost is Ksh 200.00 per man-day, the spinach producers would thus reduce labour by Ksh 6,200.00. As a result, the opportunity cost of labour for drip-using households increases.

Table 4.20: Amount of water and labour required for drip and bucket method application

Vegetable	Block	Volume of water applied (m^3/acre)			Labour (man-days/acre)		
		Drip	Bucket	Difference (B-D)	Drip	Bucket	Difference (B-D)
Spinach	Monti	135.20	175.96	40.76	34.56	39.48	4.92
	Kakwanyang	137.88	181.20	43.32	43.72	73.20	29.48
	Kang'atosa	137.96	181.68	43.72	39.48	98.80	59.32
	Kangalita	135.48	179.40	43.92	39.88	53.80	13.92
	Koono	136.08	182.88	46.80	40.56	87.20	46.64
Average (Mean)		**136.52**	**180.22**	**43.70**	**39.64**	**70.50**	**30.86**

Moreover, Table 4.20 indicates that, using low-cost gravity-drip irrigation reduced the total amount of water required by 43.70 m^3 per acre of land for spinach compared with bucket irrigation method; as in Table 4.14. The amount of water saved could have been used to irrigate spinach on an additional area of approximately one-third of an acre using drip system.

4.5.4.2 Yield of Spinach and Water-use Efficiency for Drip and Bucket Irrigation methods

Table 4.21 indicates data collected for the yield of spinach obtained using drip and bucket method of application from the on-farm experiment of the spinach vegetable production; as narrated above in 2 experimental units of spinach production by ten randomly selected farmers to assess cost effectiveness of gravity drip-irrigation technology as compared with the commonly used bucket irrigation in the target five areas of Turkana County.

Looking at the total average yield of spinach in tons per acre of production in each block, it shows more yields obtained from the drip irrigation than the bucket method of irrigation by average (Mean) 2.26 tons per acre (Table 4.21). This may imply that using drip method of irrigation is more efficient and effective than the bucket method. This echoed the findings by Nicol A. *et al* (2015)

which established increase in crop yields when using gravity drip irrigation as compared with the yields from bucket irrigation.

Table 4.21: Data Collection from On-Farm Experiment of Spinach Vegetable Production

Yield of Spinach for both irrigation systems in the months of Jan to Jun 2018																	
Block	**Drip Total yield of Spinach (in Kg per1/8acre)**									**Bucket Total yield of Spinach (in Kg per1/8acre)**							
	Farmer	**Jan (Kg)**	**Feb (Kg)**	**Mar (Kg)**	**Apr (Kg)**	**May (Kg)**	**Jun (Kg)**	**Total (ton)**	**Av (tons per acre)**	**Jan (Kg)**	**Feb (Kg)**	**Mar (Kg)**	**Apr (Kg)**	**May (Kg)**	**Jun (Kg)**	**Total (ton)**	**Av (tons per acre)**
Monti	No. 5			157.14	191.86	299.29	209.86	**0.86**	**8.11**			124.86	176.29	126.71	181.00	**0.61**	**5.88**
	No. 2			192.52	292.57	356.78	328.13	**1.17**				187.83	211.95	225.48	234.74	**0.86**	
Kakwanyang	No. 11			97.89	126.73	215.60	266.60	**0.71**	**6.03**			137.90	142.82	147.50	161.78	**0.59**	**4.44**
	No. 23			156.75	180.96	194.68	267.61	**0.80**				113.25	123.62	130.17	152.96	**0.52**	
Kang'atosa	No. 71			312.50	489.34	584.12	664.04	**2.05**	**14.00**			387.23	398.88	425.73	488.16	**1.70**	**11.04**
	No. 58			297.27	336.77	367.53	448.43	**1.45**				235.42	255.65	265.79	303.14	**1.06**	
Kangalita	No. 54			215.31	219.56	231.15	273.98	**0.94**	**8.04**			152.50	169.51	172.80	195.19	**0.69**	**6.20**
	No. 38			217.31	220.95	287.50	344.24	**1.07**				191.71	205.94	215.74	246.61	**0.86**	
Koono	No. 64			397.50	416.65	422.05	433.80	**1.67**	**11.68**			269.41	291.49	332.75	436.35	**1.33**	**9.00**
	No.43			300.57	308.76	315.08	325.59	**1.25**				226.48	229.86	230.68	232.98	**0.92**	
Average (Mean)				**234.48**	**278.42**	**327.38**	**356.23**	**1.20**	**9.57**			**202.66**	**220.60**	**227.34**	**263.29**	**0.91**	**7.31**
Spinach Price: Ksh 70.00 per Kg																	

The collected data in Table 4.21 was summarized in Table 4.22 for RCBD computation on the yield of spinach obtained in tons/acre. This was to help in determining the F-values that would make conclusion on crop productivity with drip method of irrigation compared with the commonly used bucket method in the target five locations of Turkana County.

Table 4.22: Yield of Spinach for drip and bucket irrigation method (tons/acre)

Yield of Spinach (tons/acre)	**Blocks**					
Treatments	Monti	Kakwanyang	Kang'atosa	Kangalita	Koono	$\mathbf{Y_j}$
Drip method (D)	8.11	6.03	14.00	8.04	11.68	**47.86**
Bucket Method (B)	5.88	4.44	11.04	6.20	9.00	**36.56**
$\mathbf{Y_i}$	**13.99**	**10.47**	**25.04**	**14.24**	**20.68**	**84.42**
$\mathbf{\Sigma\ Yij^2}$	**100.34**	**56.04**	**317.88**	**103.08**	**217.42**	**794.76**

The hypotheses to be tested in checking for the yield of spinach with drip and bucked irrigation methods are thus: H_o: $\mu_1 = \mu_2$; H_a: $\mu_1 \neq \mu_2$.

Table 4.23 indicates the F-calculated values compared with the F-table values for concluding the crop productivity with the drip and bucket method of irrigation; on the yield of spinach obtained (Table 4.22). Thus the correction factor (CF) is $(84.42)^2/10$ and sum of squares total (SS_T) is 794.76 – CF, that is 82.17; sum of squares treatment (SS_{Trt}) is $(13.99^2 + 10.47^2 + 25.04^2 + 14.24^2 + 20.68^2)/2$ – CF, that is 68.74; sum of squares block (SS_{Blk}) is $(47.86^2 + 36.56^2)/5$ – CF, that is 12.78; and sum of squares error is $SS_T - SS_{Trt} - SS_{Blk}$, that is 0.65.

Hence, comparing the F-calculated and the F-table values on treatments source of variation in Table 4.23, the H_o hypothesis is rejected at both 95% and 99% levels of confidence. This implies that more crop yield is obtained at both 95% 99% levels of confidence when drip irrigation is used than when bucket method of irrigation is used. Hence, using drip irrigation for crop production in Turkana County could be of benefit to the farmers.

Table 4.23: Completion of ANOVA on yield of Spinach (tons/acre)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F_{calc}	F_{table}
Treatment	1	68.74	68.74	429.63	7.71 at 0.05 s. l 21.20 at 0.01 s. l
Block	4	12.78	3.20	20.00	6.39 at 0.05 s. l 15.98 at 0.01 s. l
Error	4	0.65	0.16		
Total	9	82.17			

Table 4.24 indicates spinach yield of 9.57 tons/acre with the gravity-drip irrigation method, applying 136.52 m^3 irrigation water (Table 4.20) during the growing season; while bucket method providing spinach yield of 7.31 tons/acre by applying 180.22 m^3 irrigation water (Table 4.20). In addition to the amount of water saved by the drip system, a considerable yield advantage was obtained using this drip system compared with the bucket method. Furthermore, the mean yield advantage by using drip irrigation was 2.26 tons for the spinach; and average water productivity of spinach was 0.07 kg/L and 0.04 kg/L for drip and bucket applications respectively (Table 4.24).

Table 4.24: Yield of Spinach and water-use efficiency for drip and bucket method application

Vegetable	Replication	Total yield (tons/acre)			Water productivity (Kg/L)	
		Drip	Bucket	Difference (D-B)	Drip	Bucket
Spinach	Monti	8.11	5.88	2.23	0.06	0.03
	Kakwanyang	6.03	4.44	1.59	0.04	0.02
	Kang'atosa	14.00	11.04	2.96	0.10	0.06
	Kangalita	8.04	6.20	1.84	0.06	0.03
	Koono	11.68	9.00	2.68	0.08	0.05
Average (Mean)		**9.57**	**7.31**	**2.26**	**0.07**	**0.04**

4.5.5 Partial Budget Analysis for Drip Irrigation Technology compared with Bucket Method

Table 4.25 indicates the drip marginal rate of return as 353.12%; thus users of the drip technology would obtain a return of Ksh 3.50 from spinach by investing Ksh 1.00. From the partial budget analysis, one can easily realize that spinach can give smallholder farmers a much higher return, in a short period of time, if they apply gravity-drip technology packed with local water storage; which agrees with the findings by Nicol A. *et al* (2015). The local water storage should have siltation filters connected to it and the piping system to allow clean water to through without no silt blocking drip-line emitters; and further research should be done to investigate the effectiveness of applying fertigation with weak Phosphoric acid or Supper-link cleaner product from Amiran (K) that solve the problem of drip-lines clogging (Herman Vertlodt and Jan Van den Abeele, 2005).

Table 4.25: Partial budget analysis for drip irrigation technology compared with the bucket method

Variable	**Spinach**	
	Drip	**Bucket**
Labour cost (Ksh/acre)	7,928.00	14,100.00
Drip material cost (Ksh)	76,000.00	-
Total cost (Ksh/ha)	**83,928.00**	**14,100.00**
Benefit, yield (Ksh/acre)	669,900.00	511,700.00
Benefit, water (Ksh/acre)	158,200.00	-
Total benefit (Ksh/acre)	**828,100.00**	**511,700.00**
Net benefit (Ksh/acre) (Total benefit-Total cost)	744,174.00	497,600.00
Marginal rate of return (%) (Net benefits difference ÷Total costs difference) x 100	353.12	-

The lesson learnt is that, drip irrigation is a very simple technology to use, the labour required for cultivating vegetables was less and its drip investment cost was affordable to the average farmers.

CHAPTER 5: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of the Study Findings

The overall objective of this study was to assess the status of crop agriculture in the semi-arid pastoral ecosystem of Turkana County in order to suggest options for its adoption towards enhanced survivability during difficult times occasioned by drought events.

Research responses showed that livestock keeping alone cannot guarantee sustainable food security in the area, and it was found that integrating crop agriculture with livestock keeping would change the situation for the better. Households practicing crop farming are more food secure than those dependent on pastoralism. Attitude among land users is more critical for increased adoption of crop farming than technical acumen.

Crop farming was done mostly on subsistence basis in the County and there was inadequate commercialization. Market access could encourage smallholders to invest in enhanced productivity. Both irrigated and rain-fed agriculture are the main crop production systems used in Turkana County; with basin and furrow irrigation types being the main irrigation methods used. The Drip (conservational) type of irrigation begins to be used in the new irrigation schemes to scale up yields. Furrow irrigation provides adequate soil moisture for use by the crops and compensate for the water loss through high rates of evapotranspiration, but water supply for it needs to be improved.

Farmers in Turkana County use farmyard manure to maintain soil fertility and improve soil water retention capacity. However, crop farming in the County does not involve adequate use of inorganic fertilizers; which is a sign of low adoption of new crop farming methods by the Turkana Agro-

pastoralists. Cultural and biological methods are more accessible for use by the farmers to control crop pests and diseases than using chemicals and Integrated Pest Management (IPM).

Annual average yield of maize in Turkana County was found to be 12 90kg-bags per acre, and sold at farm gate price of Ksh 2,700.00 per 90kg-bag; thus annual revenue from maize is Ksh 32,400/acre. Its annual cost of production was Ksh 12,600/acre; thus annual gross farm profit is Ksh 19,800/acre. Similarly, annual average yield of sorghum in Turkana County was found to be 12 90kg-bags per acre, and could be sold at farm gate price of Ksh 3,600.00 per 90kg-bag; thus annual revenue from sorghum is Ksh 43,200/acre. Its annual cost of production was Ksh 6,800/acre; thus giving annual gross farm profit of Ksh 36,400/acre.

Currently crop farming generates income through sale of crop produce and provides alternative livelihoods to Turkana people. Turkana households get more benefits in terms of food security from crop agriculture than livestock keeping which is traditionally a symbol of prestige to the society. Hence, the Turkana people are now changing their lifestyle at high rate (73%) from pure pastoralism to agro-pastoralism.

Irrigation system produces reasonably high crop yields in the County, particularly drip irrigation for horticultural crops growing even outside greenhouses. The reason for obtaining low crop yields in Turkana has been inadequate water for irrigation, and the farmers use inadequate certified dry-land seeds as they have limited access to most of the crop farm inputs in the County. There is need to promote Sustainable Land Management practices such as Organic farming and Conservation Agriculture (CA) which conserves soil moisture for the growing crops in the County.

Vulnerability of the pastoralists in Turkana County could be alleviated by integrating crop farming with pastoralism. Integrating crops in the irrigation schemes with pasture production ensures better integration of crop farming with livestock rearing; and practicing agro-forestry also increases organic matter in the farms that improves soil structure and fertility as well as providing forage to feed livestock which are always around the irrigation schemes.

5.2 Conclusions

An increasing number of pastoralists are now venturing in crop farming for subsistence purposes. Seventy three percent (73%) of the respondents were agro-pastoralists. With a change in attitude away from cultural pastoralism, this percentage can increase. With more deliberate extension service at the County level, subsistence farming can gradually move to commercial farming in order to somehow enhance households' financial security for other needs.

Annual average yield of maize in Turkana County was found to be 12 90kg-bags per acre, and its annual cost of production was Ksh 12,600/acre with annual revenue of Ksh 32,400/acre. The annual average yield of sorghum in the County was relatively same as maize, 12 90kg-bags per acre, and its annual cost of production was Ksh 6,800/acre with annual revenue of Ksh 43,200/acre. These figures suggest positive potential in crop farming under proper land and crop husbandry practices including water use efficiency.

The challenge of water scarcity is now real and Turkana people are slowly shifting from rain-fed agriculture to small-scale irrigation farming, with basin and furrow irrigation methods being dominant. A shift to drip irrigation is constrained by financial poverty.

Where irrigation is being used, increasing salinity problem was noted. On farm trials with spinach crop as the test crop demonstrated more superiority of water use efficiency under drip irrigation than under bucket method of irrigation.

The use of inorganic fertilizers is also not common in Turkana County because of the combined reasons of costs and knowledge on fertilizer use. Most farmers use farmyard manure, whose availability is guaranteed by the hundreds of goats that typify their cultural pastoralism. In general crop yields are poor.

There is an increasing realization that relying on livestock alone cannot guarantee sustainable food security in the area. This provides the opportunity to integrate crop production within households through targeted extension services.

5.3 Recommendations

Based on the study findings, the following recommendations were made:

- The County Government to prioritise extension service and education at household level to gradually shift from culture-centred pastoralism to diversified livelihoods that begin from integrating crop production within the community.
- The County government and its development partners however prioritize investment in water resources development and resource use efficiency around drip irrigation to enhance adoption of crop farming in Turkana County. .
- Diversifying in to crop farming should not result into the demise of their livestock industry. The County government should invest into a meat industry that ensures that livestock deaths

do not lead to farmer impoverishment during the drought conditions. Livestock can be replaced with cash to be used for re-stocking when the rainy season resumes.

From this study, the following further research could address the gaps identified:

- Evaluate the effect of manure and fertilizer in improving farming in Turkana County
- Scaling up the results to more farmers and commercialising Crop farming
- Prospecting for underground water and its abstraction for irrigation is worthy investment to be ingrained in County policy.

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7. APPENDICES

Appendix 7.1: Semi-structured Questionnaire for the Study

SECTION A: Background Information:

Your age: Below 20 years ( ) 20-25 years ( ) 26-30 ( ) 31-36 ( ) Above 36 ( )

Your sex: Male ( ) Female ( )

Your education level: None ( ) primary ( ) secondary ( ) University ( ) other: _____

Your family size: Alone ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( ) 6 ( ) More than 6: _____

What do you do for a living? (Source of Income): Employed ( ) Entrepreneur ( ) Farmer ( ) Pastoralist ( ) Agro-pastoralist ( ) other: _____

What is the acreage of the land that you own? Less than a ¼ of an acre ( ) A ¼ acre ( ) Less than 1 acre ( ) 1 acre ( ) More than 1 acre ( ) How is this land being used? Crop Farming ( ) Livestock Keeping ( ) Housing ( ) Bare Land ( ) No. of livestock kept: _____. If crop farming is practiced, state how _____

What farming skills/technical knowhow, if any, have you learnt from crop agriculture projects in your location? _____. Would you apply them on your land? Yes ( ) No ( ). If no, give reasons why not: _____

What types of crops do you grow? _____

SECTION B: The crop production systems and technologies used in Turkana County:

The following tabulated statements refer to the crop production systems and technologies used in Turkana County. How satisfied are you with each of the statement? Please tick (√) where appropriate to you.

Key: 1 = extremely dissatisfied; 2 = Dissatisfied; 3 = Neutral; 4 = Satisfied; 5 = extremely satisfied

No.	Statement	1	2	3	4	5
1	Mostly irrigation and some rain-fed farming systems are used in Turkana					
2	Mostly rain-fed and some irrigation farming systems are used in Turkana					
3	Rain-fed farming system only is used in Turkana					
4	Mostly subsistence and small commercial farming systems are used					
5	Mostly commercial and small subsistence farming systems are used					
6	Subsistence farming system only is used					
7	Sustainable land management practices that can improve soil fertility, such as Organic farming practices, Integrated Soil Fertility Management practices and Conservation Agriculture are used					
8	Appropriate techniques to manage soil and water salinity in most parts of Turkana County are used					
9	Appropriate measures are taken in the county to mitigate Climate Change so as to impact positively on crop production					
10	Adequate access to high value and drought tolerant crops, and integrated pests & diseases control					

Mention the prevailing gender roles with respect to crop agriculture in Turkana County: _____

_____

Do farmers apply organic or inorganic manure/fertilizers in their farms? Organic ( ): types _____ Inorganic ( ): types _____

Which methods do farmers use to control crop pests and diseases? _____

Which types of tools and equipment do farmers use to cultivate and weed their farms? _____

Which types of irrigation methods are used in Turkana County? Basin ( ) Drip ( ) Flood ( ) Furrow ( ) Sprinkler ( ) Others: _____

SECTION C: How the level of crop production in the County influences food security status:

The following tabulated statements explain how the level of crop production influences food security. How satisfied are you with each of the statement as is applied in the case of Turkana County? Please tick (√) where appropriate to you.

Key: SA-Strongly Agree; A-agree; NA-Not agree; SNA-Strongly Not Agree; UD-Undecided.

NO	STATEMENT	SA	A	NA	SNA	UD
1	Crop agriculture has more benefits in terms of food security to the Turkana households than livestock keeping					
2	Crop agriculture acts as a source of income and provides alternative livelihoods to Turkana people					
3	The cost of crop production in Turkana County is much lower than the income generated from sale of crop produce					
4	The cost of crop production in Turkana County is much higher than the income generated from sale of crop produce					
5	The possibility of growing more than two crops in a year enables the agro-pastoralists to keep a few animals within the vicinity of the irrigation scheme, which are fed with weeds as well as crop residues					
6	Some households drop out of pastoralism to settle as farmers along the rivers or around underground water points since crop irrigation brings more benefits than pastoralism in Turkana County					
7	Currently there is higher crop adoption rate by the people living in Turkana County than it was in the last five years.					
8	There is improved road linkage of interior areas of the county to the expanding fruit and vegetable markets in Lodwar and neighbouring growing towns					

To the best of your knowledge, give the range of cereal crop yields experienced in 90 kg-bags per acre in Turkana County: Less than a bag ( ) 1-2 bags ( ) 3-5 bags ( ) 6-10 ( ) More than 10 bags ( )

Does crop farming have any significant impact to the life of Turkana people? Yes ( ) No ( )

Name and state the quantities of crop variable inputs used per each crop grown per acre: _____

_____

State the amount of labour used in terms of man-days per crop grown per acre: _____

State the prices of the variable inputs used, labour and outputs of each of the crops grown: Crop Variable Inputs Prices: - _____

Labour Price per man-day: - _____

Crop outputs Prices: - _____

SECTION D: The appropriateness of soil moisture conservation methods used in crop farming in the County:

The following tabulated statements refer to the appropriate soil moisture conservation methods used in crop farming. To what extend do you agree to each of the statements as being used in Turkana County? Please tick (√) where applicable to you.

Key: 1 = extremely disagree; 2 = Disagree; 3 = Undecided; 4 = Agree; 5 = extremely agree

No.	Statement	1	2	3	4	5
1	Potential crop farming areas in Turkana County under irrigation produce reasonably high crop yields to the satisfaction of the households					
2	The performance of drought tolerant cereal crop crops such as green-grams, cowpeas, sorghum, and PH4 or DH04 series of maize in Turkana County has been good					
3	Cultivation of high value vegetables such as improved varieties of tomatoes, capsicum, kales, spinach and onions has been doing well in greenhouses under drip irrigation					

4	Cultivation of high value vegetables such as improved varieties of tomatoes, capsicum, kales, spinach and onions also give good yields in Turkana County under irrigation outside greenhouses					
5	Majority of Turkana people have adopted using flood irrigation for crop production in the vast arable land with inherent soil fertility along rivers Turkwel and Kerio that produces medium to high crop yields					
6	Sustainable land management practices such as Organic farming practices and Conservation Agriculture are also widely used to conserve soil moisture for the growing crops					
7	Appropriate techniques to manage soil and water salinity in most parts of Turkana County such as mulching are used to conserve soil moisture					
8	Adequate crop rotation and intercropping the crop with soil crop cover as well as minimum tillage are practiced by Turkana Agro-pastoralists					

To the best of your knowledge state other soil conservation methods that are used in Turkana County for adequate crop soil moisture management:

_____

_____

Which are the appropriate techniques do you think could be used to manage soil and water salinity in most parts of Turkana County?

_____

_____

Any other comment with regard to integrating crop farming and livestock keeping in Turkana County:

_____

_____

_____

Thank you for your assistance and co-operation.

Appendix 7.2: Key Informants' Structured Interview Schedule for the Study

SECTION A: Background Information:

Name of the station: _____

No of years in the station: Below 1 year ( ) 1-3 years ( ) 4-6 years ( ) above 6 years ( )

Your sex: Male ( ) Female ( )

Your designation: _____

SECTION B: The crop production systems and technologies used in Turkana County:

To the best of your understanding give all the main crop production techniques that are used in Turkana County:

_____

_____

Do you feel that better crop production techniques should be introduced in the County? Yes ( ) No ( ). If yes suggest the crop production techniques:

_____

_____

Do farmers apply organic or inorganic manure/fertilizers in their farms? Organic ( ): types _____ Inorganic ( ): types _____ both organic & inorganic ( ): types _____

Which methods, if any, do the farmers use to control crop pests and diseases in your area?

_____

_____

Which types of irrigation methods are used in Turkana County? Basin ( ) Drip ( ) Flood Furrow ( ) Sprinkler ( ) Others: _____

Which one among the irrigation methods above do you think should be promoted?

_____

_____

SECTION C: How the level of crop production in the County influences food security status:

What acreage of land is mostly cultivated per household in Turkana County? Less than ¼ acre ( ) ¼ acre ( ) Less than 1 acre ( ) 1 acre ( ) More than 1 acre ( )

To the best of your knowledge, give the range of crop yields experienced in 90 kg-bags per acre in Turkana County: Less than a bag ( ) 1-2 bags ( ) 3-5 bags ( ) 6-10 ( ) 11-15 bags ( ) More than 15 bags ( )

What could be the reason for obtaining the yield mentioned above?

_____

_____

Which types of high performing crops are grown in Turkana County?

_____

_____

Which other improved crop types would you recommend for growing in Turkana County?

_____

_____

SECTION D: The appropriateness of soil moisture conservation methods used in crop farming in the County:

To the best of your knowledge state soil moisture conservation methods that are used in Turkana County for adequate crop soil moisture management:

_____

_____

Which are the appropriate techniques do you think could be used to manage soil and water salinity in most parts of Turkana County?

_____

_____

Any other comment with regard to integrating crop farming and livestock keeping in Turkana County:

Thank you for your assistance and co-operation

Appendix 7.3: Record of Results from the On-Farm Experiment

Amount of water and labour required for drip and bucket methods of irrigation							
Vegetable	**Block**	**Volume of water applied (m^3/ha)**			**Labour (man-days/ha)**		
		Drip	Bucket	Difference (Bucket-Drip)	Drip	Bucket	Difference (Bucket-Drip)
Spinach	1. Monti						
	2. Kakwanyang						
	3. Kang'atosa						
	4. Kangalita						
	5. Koono						
Average (mean)							
Yield of spinach and water-use efficiency for both irrigation systems							
Vegetable	**Replication**	**Total yield (tons/ha)**			**Water productivity (Kg/L)**		
		Drip	Bucket	Difference (Drip-Bucket)	Drip	Bucket	Difference (Drip-Bucket)
Spinach	1. Monti						
	2. Kakwanyang						
	3. Kang'atosa						
	4. Kangalita						
	5. Koono						
Average (mean)							

Partial budget analysis for drip irrigation technology compared with the bucket method		
Variables	**Spinach**	
	Drip	Bucket
Labour cost (in Ksh)		
Drip material cost (in Ksh)		
Total cost (in Ksh)		
Benefit, yield (in Ksh/ha)		
Benefit, water (in Ksh/ha)		
Total benefit (in Ksh/ha)		
Net benefit (in Ksh/ha), (Total benefit-Total cost)		
Marginal rate of return (%), (Net benefits difference ÷Total costs difference) x 100		