Journal of Arts & Humanities

Volume 09, Issue 08, 2020: 18-33
Article Received: 02-07-2020
Accepted: 26-08-2020
Available Online: 29-01-2020
ISSN: 2167-9045 (Print), 2167-9053 (Online)
DOI: http://dx.doi.org/10.18533/journal.v9i8.1948

Assessment of Tomato Farming Systems and Rainfall Variability Related Implications in Semi-Arid Regions of Central Kenya

Joseph M. Karienye[1*], Tom Ouna[1], Hellen Kamiri[2]

ABSTRACT

The future of African agriculture depends on the outcome of climate and specifically on rainfall variability. In arid and semi-arid areas, the impacts of rainfall variability can be adverse especially where the main farming system is horticultural oriented. This study aimed at assessing tomato farming systems and how they were influenced by rainfall variability. The study focused mainly on examining the aspects of tomato farming practices and rainfall variability over a period of thirty four years (1980-2014). Data was collected from tomato farmers in four wards namely Kabaru, Thegu River, Narumoru/ Kiamathaga and Gakawa in Kieni East Sub-County, using face-to-face interviews and semi structured questionnaires. Rainfall data was obtained from Kenya Meteorological Department in Nairobi. Historical climatic data was analyzed to establish patterns and trends which were then correlated to production data. The study revealed that tomato farming system is determined by climate (rainfall), economic and social wellbeing of the farmers. The study further established the rainfall characteristics over the thirty four years under study varied both annually and seasonally. Farming practices applied by farmers in tomato production, included irrigation, crop rotation, and use of certified seeds, mulching, use of manure and use of greenhouse technology. These practices were however influenced by rainfall patterns and social economic status of the farmers. These findings show that there is need to develop policies that will enhance adoption of farming systems suited to the study area and therefore safeguard farmers from adverse effects of rainfall variability, and make tomato production a viable venture.

Keywords: Farming systems, tomato, rainfall variability, social factors.

1. Introduction

Farming systems are dynamic and the components are site specific (Shaner, 2019). Thus a logical approach in evaluating a farming system is to identify integral components that can be

* corresponding author.Email: j.macaria.mj@gmail.com, j.macaria@yahoo.co.uk
1Department of Humanities and Languages, Karatina University, Kenya.
2 Department of Agricultural Sciences, Karatina University, Kenya.

combined into site-specific farming systems to meet specific needs. A more ecologically sustainable system would increase agricultural productivity using less farmland and fewer inputs but adopting new technologies; while yielding to less environmental impacts (Kremen et al., 2012; Francis, 2008). In the rural communities of highly populated regions, farmers produce and consume vegetables and fruits that are mostly produced at local scales. Evaluation of such systems enables farmers to produce high-yielding fresh vegetables year round and to secure off-season supplies and consequently stable incomes. For instance, in regions that are prone to short-term droughts during the growing season soil moisture conservation is always considered as a key factor in sustained production. In addition to losses by runoff, those by soil evaporation must be minimized through mulching, addition of manure and rainfall supplemented through irrigation (Lal, 2015). Excess runoff during the rainy season can be stored in small farm ponds and dams and used for supplemental irrigation to prolong the growing season and alleviate drought. Soil fertility can be improved through application of manures and fertilizers at small scale to enhance production. However, effectiveness of farming systems is seen to revolve around climatic variables mainly rainfall (Kremen et al., 2012).

Variability in rainfall amounts and patterns on a global scale has greatly impacted on agricultural production (Kumar et al., 2012). Projections of changing rainfall patterns suggest that East Africa will experience warmer temperatures and a 5 to 20 percent increase in rainfall from December through to February; and 5 to10 percent decreased rainfall from June through to August by 2050 (IPCC, 2012). In Kenya, rainfall amounts have been declining since 1960 and projections into the year 2029 suggest that parts of the country will experience more than 100 mm of rainfall decline (Coe and Stern, 2011). Consequently, these changes in rainfall patterns permit cultivation of horticultural crops in a pattern or sequence in response to local climatic and social conditions (Ziervogel et al., 2008 and Onyekwelu et al., 2006).

In Kenya, agriculture is an important sector in the economy, contributing approximately 25 percent of the GDP, and employing over 75 percent of the national labour force (HCDA, 2011). Farmers have continued applying inappropriate technology in production thus reducing ability to create jobs, alleviate perennial economic and social problems. Horticulture as a subsector of agriculture is mainly practiced through rain fed or irrigation systems. Farm sizes range from large-scale commercial estates with substantial investments in irrigation and high level use of inputs, hired labour and skilled management (HCDA, 2011) to small scale farm households. Greenhouse cultivation as well as other modes of controlled environmental cultivation have evolved to create more favourable micro-climates, which favour horticultural production throughout the year.

Studies across Africa have shown the contribution of horticultural production to the continents economic and social development. For instance, Tusiime (2014) evaluated horticultural practices for sustainable tomato production in Kamuli, Uganda. He noted that tomato farming created direct jobs for thousands of small-landholders and was a source of steady income for farmers across Uganda. In Ethiopia, tomato is among the most important vegetable crop produced in private horticultural enterprises, commercial farms and small holder farmers scattered in various parts of the country (Jiregna et al., 2012). In the semi-arid areas of Kenya, farmers have adapted to rainfall variability by embracing diverse tomato production systems that increase productivity and lengthen production period, for example use of irrigation from water harvested in ponds, cultivation along river systems, greenhouse farming and agricultural practices such as mulching and addition of manures to protect soil moisture (Speranza et al., 2010). However, there is limited documentation of tomato farming systems that enhance adaptation to variability in rainfall patterns in semi-arid parts of Kenya. In this study, components of farming systems for tomato production were assessed aimed at increasing tomato production and improved livelihoods in semi-arid regions of central Kenya. The aim of the study was to determine tomato farming systems in a semi-arid region and to assess the influence of rainfall patterns and variability on the systems.

1.1 Literature review

Rainfall has a direct relationship with agricultural crops with an increase or decrease in precipitation having variable impact on yields and quality of the crop (Masahumi et al., 2011). Data from the Kenya Meteorological Department (KMD) shows evidence and impacts of changing rainfall variability trends in Kenya over the last 50 years (GoK, 2010). In regards to rainfall patterns, there has been a notable general decline of precipitation with time, in the main rainfall seasons of March-May (the 'Long Rains') and a tendency for the October-December (the 'Short Rains') to extend into the normally hot and dry period of January and February. Precipitation is highly variable spatially and temporally, and data are limited in some regions (IPCC, 2007). The global climate model predicts that variability of rainfall may range 5 to 20 percent in Kenya by the year 2030 (World Wide Fund, 2006). In the last two decades agricultural sector in Kenya has been faced by frequent droughts and occasional flash floods, leading to a decline of reliability of rainfall, particularly in the aid and semi-arid areas (ASALs). These changes in rainfall amounts received, timing and distribution patterns, has lowered agricultural production (Huho and Kosonei, 2013).

Rain fed farming is very susceptible to weather fluctuations and over the last three decades East Africa has recorded high frequency of droughts and floods that resulted to increased crop failures, water shortage and loss of livestock (Salami, Kamara, and Brixiova, 2010). Notably, more varying rainfall patterns and unpredictable high temperature spells reduced tomato production. Therefore stringent measures need to be undertaken to mitigate the effects of rainfall variability on food security in developing (Kumar et al., 2012). Improved adaptations strategies in the agricultural sector to the adverse effects of climate change will be imperative to protect and raise the livelihoods of the rural poor and to ensure food security (FAO, 2012).

Tomato production is an important source of income to most smallholder farmers in the semi-arid areas. Changing rainfall trends have led to variations in tomato yields and consequently to tomato income, thus influencing the tomato farmers' livelihood. Tomato production is also constrained by market imperfection, inappropriate technologies, and inability to access credit by tomato farmers, attack from pests and diseases and its perishability.

2. Materials and methods

2.1 Study area descriptions

The study areas comprised of Kieni East Sub County which is part of the semi-arid zones of Nyeri County in Central Kenya. The area lies between 00 00' and 00 24' South and 370 00' to 370 12' East and borders Meru Central Sub County to the North, Mathira Sub County and Nyeri Municipality to the South, Mount Kenya to the East and Kieni West Sub County to the West (Figure 1). The region falls within agro ecological zone- IV (Jaetzold et al., 2006). The area is located on the lee ward side of Mt Kenya which makes it vulnerable to extreme weather events which are sensitive to the agricultural economy of the area. Soils in the study area are characterized by vertisols, (black cotton soils) which are dark, with about 30 percent of clay content, poorly drained and usually crack during dry seasons.

The region experiences two distinct rain seasons occurring from March to May (MAM) and October to December (OND). The annual rainfall received in the region ranges between 550 mm in the lowlands parts of Kiganjo area and 1500 mm in the areas, neighboring Mt Kenya (Jaetzold et al., 2006). The areas adjacent to Mt. Kenya are wetter and therefore densely populated and population density decreases as you move away from the mountain towards western side which is relatively dry. Temperature ranges between 12°C during the cold months and 27°C in the hottest months. Kieni East Sub County has a population of 94,737 in 28,692 households (KNBS, 2019). The land size per household varies across the Sub County but with an average of 2 hectares per household (Jaetzold et al., 2006), and land ownership is predominantly freehold.

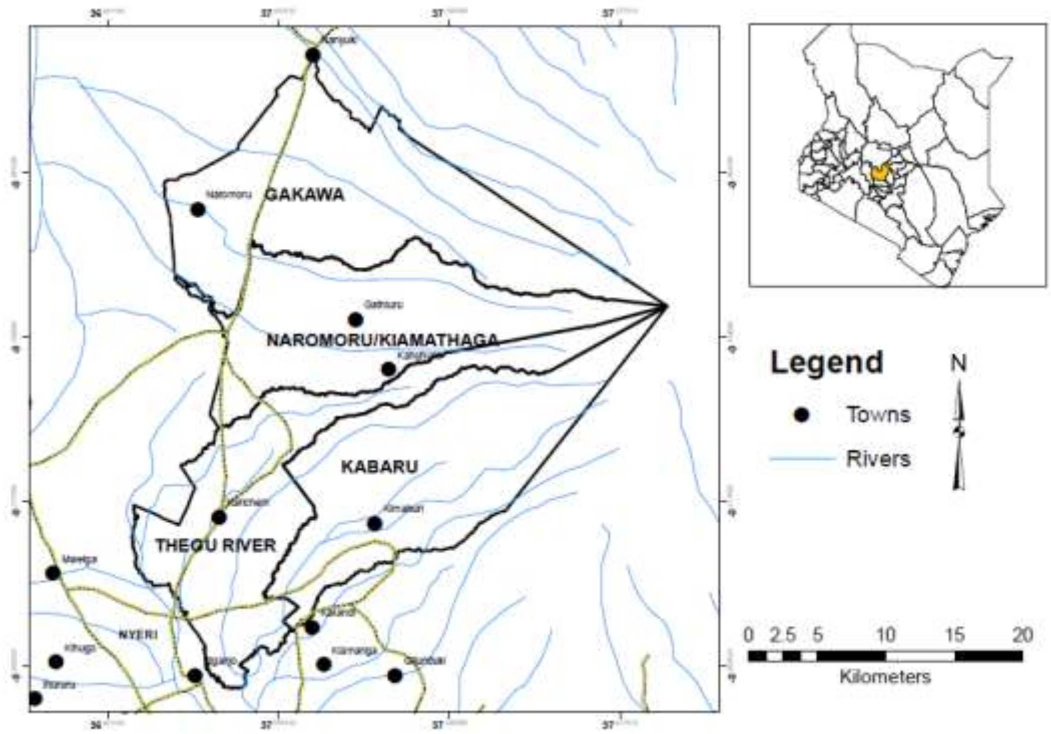

Figure 1. Map of Kenya showing Kieni Easy Sub County and wards selected for this study. (Map credit G. Wambugu)

2.2 Methodological design

Data collection was carried out in the wet and dry seasons of 2016. The target population included tomato farmers in four wards namely Thegu River, Kabaru, Narumoru/ Kiamathaga and Gakawa with estimated 142 tomato farmers. A sample size of 45 farmers was included in this study. A combination of methods was used to collect data. First the research methodology involved qualitative characterization of socio- economic, demographic, climatic and agricultural aspects of tomato growing in the study area. Data was collected using open semi-structured questionnaires, document analysis and field observations of selected tomato farmers and agricultural officers. Secondly, historical climatic data from Naromoru weather station was assembled from the Kenya Meteorological Department and analyzed for trend and patterns. Thirdly, a statistical description of the farming system components was conducted and analysis done to establish trends and patterns in rainfall and production. Data gathered from the semi-structured questionnaires were analyzed using Statistical Package for the Social Sciences (SPSS).

3. Results and discussions

3.1 Qualitative characterization of tomato farming systems

The characterization aspects involved analysis of social demographic, agricultural, economic and environmental aspects of the tomato farming systems in the study regions. Level of education ranged from basic to university level, land ownership is predominantly freehold and the majority of the farms in the area are small scale. The characterization variables are presented in Table 1.

Table 1.

Variables used in characterization of tomato farming systems.

Variables	Assessment ranges
Social demographic aspect	
Tomato farmers per ward	Kabaru (11), Thegu (16), Gakwa (6) and Narumoru/ Kiamathaga (12)
Level of education	Basic; Secondary; College level.
Gender of house hold head	Male: 83.3%, Female: 16.7%

Age	15 - 24; 25 - 34; 35 - 44; 45 - 54; > 54 years.
Occupation	Farming; Business; Professional employment; Informal sector.
Agricultural aspects	
Land size for growing tomato	< 2 acres; 2 to 4 acres; > 4 acres
Duration of tomato growing	0 – 3; 4 – 7; 8 – 11; > 11 years
Production level	Open field; Green house; Irrigation; Rain fed; Crop rotation.
Use of inputs (organic, inorganic)	Manure; Mulching; Fertilizers.
Access to Extension services	Availability, literacy level.
Environmental aspects	
Rainfall	Distribution and patterns (total and average amounts).
Temperature	Monthly averages.
Economic aspects	
Credit accessibility	Commercial banks; savings and credit cooperative. organizations (Sacco); Other source.

3.2 Social-demographic characteristics of the respondents

3.2.1 Gender

The studies revealed that majority of the respondents were male, representing 83.3% of farmers growing tomato in the region while 16.7% were female (Table 2). Gender distribution gives credence to the fact that tomato production in the study region is mainly dominated by males. This was attributed to labour demand, such as in preparing of seedbeds (nurseries), clearing and digging of farm lands not earlier planted, pumping irrigation water from rivers and water reservoirs and spraying the tomato against pests and diseases. Tomato production demands more skills during transplanting, staking, pruning, application of fertilizers, loading of crates and transporting to the markets which are usually done by men while the females carried out lighter domestic duties like weeding tomato farm, harvesting, sorting, grading and packing.

Table 2.

Social and demographic characteristics of the respondents.

Variable		Frequency N = 45	Percentage
Gender	Male	37	83.3%
	Female	8	16.7%
Level of education	Primary level	20	45.2%
	Secondary level	20	45.3%
	University/college	5	9.5%
Age group			
	15 – 24 years	3	6.7%
	25 – 34 years	6	13.3%
	35 – 44 years	15	33.3%
	45 – 54 years	16	35.6%
	above 54 years	5	11.1%

Respondents had varying levels of education. About 45.3% had acquired secondary level of education; 45.2 percent had attained primary level of education while 9.5 percent were university or college graduates (Table 2). This implies that the tomato farmers had acquired some basic knowledge and information relating to tomato farming, which enabled them interpret and adopt various modern methods of tomato production. These results imply that the educational level of the respondents has a greater potential of influencing their adoption and implementation of sound adaptive strategies to improve the yields of tomato production among the farmers in the Sub County. The farmers in the study area who were literate understood a number of tomato management practices, diseases and pests that affect tomatoes and control measures. As noted by (Awan et al., 2012), literacy is an important aspect in farming that influence crop production.

3.2.2 Age and occupation of respondents

The variation of the respondents' age was analyzed to ascertain the age differentials of the farmers engaged in tomato production in Kieni East Sub County. The findings are presented in the Table 2. Only 6.7 percent of the respondents were in the age group of 15 to 24 years. This was attributed to the fact that majority of the respondents within this age group are in learning institutions; primary, secondary schools, colleges and universities, leaving only a few in the sector of tomato production. The respondents in the age group between 35 and 44 years accounted for 33.3 percent. This comprises of young families venturing in tomato production to earn income and uplift their standard of living.

The age group with highest number of respondents was 45 to 54 years which accounted for 35.6 percent (Table 2). These are respondents who have been in tomato production for a longer period and might have adapted it as a means of livelihood. The majority of the tomatoes farmers in the Sub County were of over 35 years old which constituted of about 80 percent. They had acquired adequate information, knowledge, skills and experience over years about tomato production and hence practiced it as a source of livelihood. The respondents who were over 54 years old constituted 11.1 percent. The study established the labour demand of tomato production made the elderly people shy off, they were aging, becoming weak and could not carry on with the practice opted to leave tomato production for lighter tasks.

The study further revealed that respondents who had practiced tomato production for a longer period had adequate experiences that enhanced adaptation strategies to the changing rainfall variability and therefore they were able to increase tomato production in the Sub County. About 82% of the respondents grew other crops like cabbages, peas, beans, French beans, maize and kept cows, goats, sheep and poultry. The professional employment category comprised of the 10.3% of the total respondents. Only 5.1% of the total respondents were in business and 2.6 percent were involved in informal sector respectively for extra income (Figure 2).

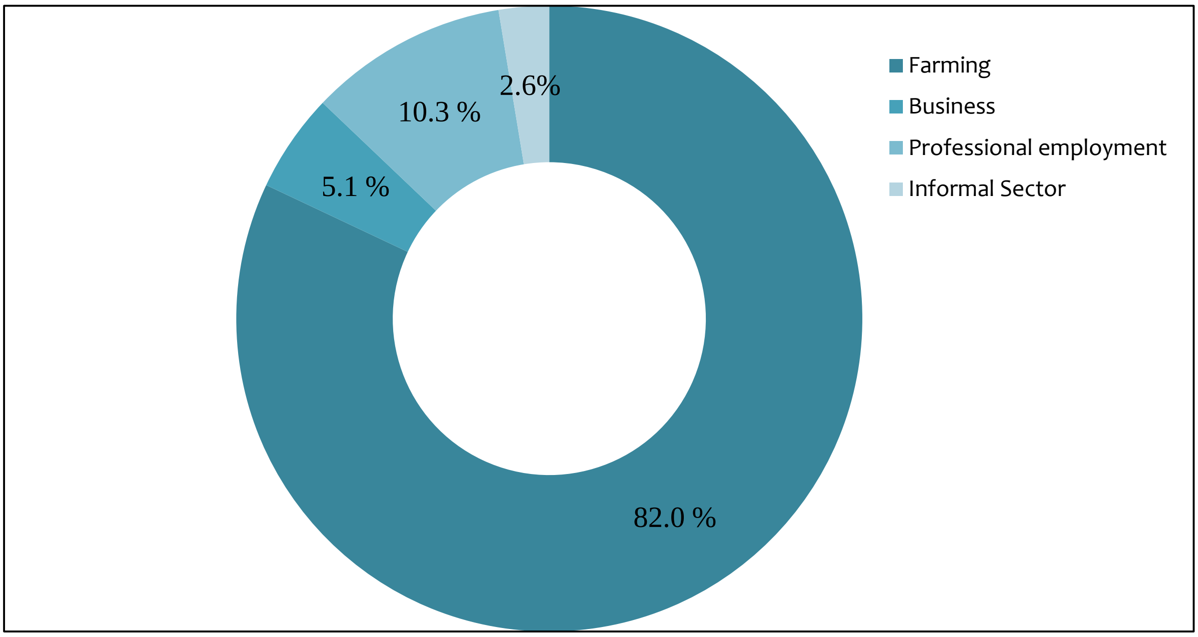

Figure 2. Categorization of Occupations of the Respondents

The respondents argued that they undertook extra occupations to supplement income from tomato production and for food security in case of tomato production failed, decreased or fetched low income. Those in professional employment, informal sector as well as in other businesses supported tomato production through purchase tomato seeds, pesticides, herbicides, fertilizers, putting up water reservoirs, purchasing of water pumps, leasing of land, paying the labourers and putting up of greenhouses to increase production hence increased income. It was observed that tomato farms where owners had extra and alternative source of income were better managed, employed several labourers and therefore generated more yields and so is the income.

3.3 Agricultural aspects of tomato farming systems

The study established that tomato farming was practiced by small scale farmers (41.8%) who owned less than 2 acres of land. About 32.6 % grew tomato on four (04) or more acres while 25.6% had 2- 4 acres of land (Figure 3).

Small land sizes were attributed to land fragmentation due to increasing population (currently at 2.3%, KNBS, 2019) and selling off the land to new immigrants to the area. These findings agree to studies by Ogola et al., (2011) who reported that small land sizes were an indication that intensive farming is the only option to enhance a profitable tomato production. Further findings by Starke Ayres, (2014) and Mango et al., (2015) reveal that tomato farming is time demanding, labour intensive and expensive in terms of inputs, therefore farmers grew tomato in small parcels of land which were manageable throughout the entire production period.

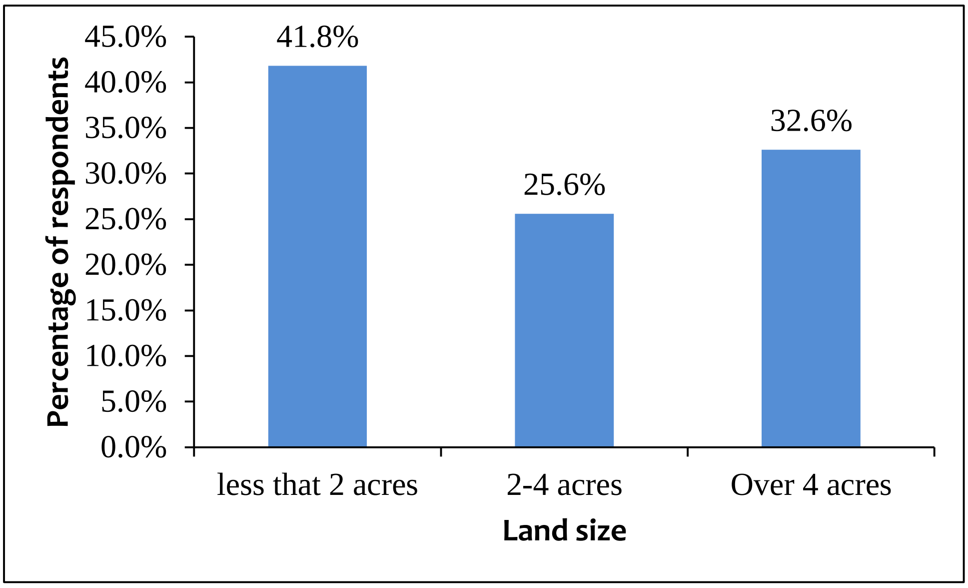

Figure 3. Land sizes attributed to Tomato farming in the study areas

Duration of tomato farming varied across the respondents. About 35.6 % of the respondents had practiced tomato farming for a period of 4-7 years, 26.7 % for a period of less than 3 years while 20% percent had tomato crop for a period exceeding 11 years. Only 17.7% had grown tomato for a period of between 8 to 11 years in the study sub county Table 3.

Table 3.

Duration in years of Tomato Production by the respondents

Tomato Growing Period by Farmer	No. of respondents	Percentage (%)
0 – 3 years	12	26.7
4 – 7 years	16	35.6
8 – 11 years	8	17.7
Over 11 years	9	20.0
Total	45	100.0

3.4 Farmers adoption of improved tomato farming systems

The study revealed that farmers applied diverse range of tomato production practices as a shown in Figure 4. Among these was the adoption of certified seeds, greenhouse technology, use of manure and certified seeds.

3.4.1 Use of certified seeds

The choice of seed variety is based on fruit quality, adaptability and reliability, susceptibility to diseases and pests, plant growth habit, the specific market and the planting time. It was noted that about 82% of the respondents across the study area used certified seeds which were obtained from licensed research institutions like East Africa Seed Company, Simlaw Seed, and Syngenta. It was noted that improved seeds are associated with high productivity level, reliability in germination, early maturity, and better capacity to resist pests and diseases such as tomato leaf curl virus and bacterial wilt (Abay, 2007). Studies by Tshiala and Olwoch (2010) revealed that the use of certified seeds is a good adaptation strategy that improves tomato yields.

3.4.2 Use of manure and mulching

Mulching is as a process of covering and spreading a layer of materials about 30 percent of the soil surface (Erenstein, 2003). Majority of farmers in the study area practiced dairy farming hence manure was cheaply available to all households. Use of manure was adopted by 91% of the respondents (Figure 4). Mulching was commonly applied in Narumoru/Kiamathaga wards where partly 11.1% of the respondents adopted the practice. Use of farmyard manure was preferred due to added benefits of soil nutrients and conservation of soil moisture. Mulch can be of organic origin, such as straw, grass, leaves and composted yard waste. This practice has been used in moisture conservation in dry land farming to improve crop yields through water retention, soil ecology improvement, and general environmental maintenance (Creswell & Martin, 1998; Erenstein, 2003).

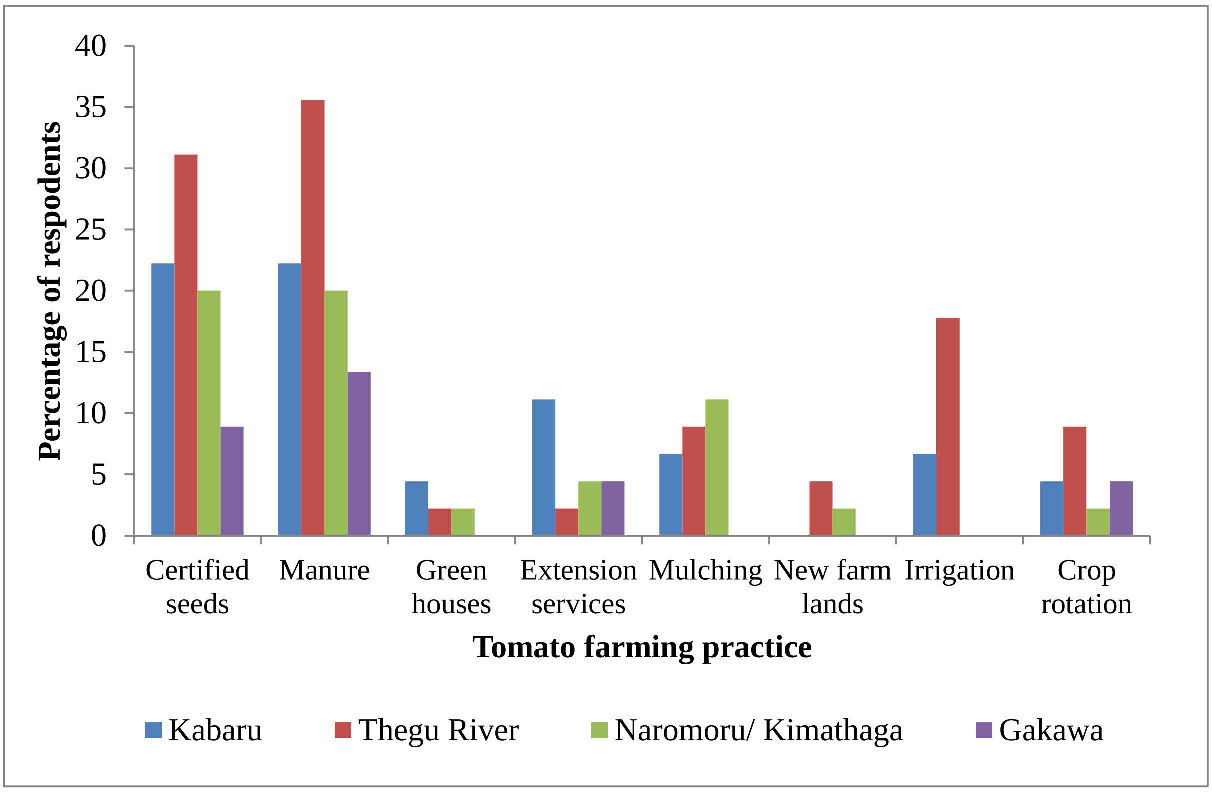

Figure 4. Type of tomato production practice per ward in Kieni East Sub County

3.4.3 Use of greenhouses technology

About 9% of the respondents grew tomato in greenhouses (Figure 4). The use of greenhouse technology was adopted in Kenya, mainly for the purpose of increasing yields and production of high quality tomato (Osure, 2010). Use of greenhouse provides opportunities for year- round production of tomato. Tomato pests and diseases are easily controlled in greenhouses; a smaller portion of land is required while water consumption for irrigation is less as compared to drip and overhead irrigation hence the farming practice is economically viable. The limited use of greenhouse technology in the study area is due to high cost involved in installation. For instance installation of a 120 square meter greenhouse would cost Kshs 150,000 (Osure, 2010) taking into this consideration only about 24.5 percent (Table 4) are able to access finances from Banks and SACCOs.

3.4.4 Access to agricultural extension services

The study revealed that 22% of the farmers in the study area had access to agriculture extension workers who provided advice on how to grow tomato. Such farmers obtained high and reliable tomato production despite shortage or unreliable annual rainfall. Agricultural officers guide farmers on seed selection, weed and pest management and application of manures and fertilizer throughout the entire production period. The Sub County offices have inadequate Agricultural Officers and few vehicles facilities to facilitate visits to farmers over expansive areas.

3.4.5 Opening of new or fallow farm Lands

New (virgin) lands were a great potential to tomatoes farmers. New farm lands have fertile soils, high moisture retention and have minimal cases of pests and diseases. About 7% of the respondents extended their tomato farming in new farm lands (Figure 4). New lands for cultivation were available along the rivers and stream in Thegu and Narumoru/ Kiamathaga wards. However, new farm lands were not readily available because of the increasing population pressure and demands for lands. Cultivation of tomato in new farm lands was said to be cumbersome and expensive. It involved process of leasing, clearing bushes and burning, digging, putting a farm house to guard tomatoes from destruction by wild animals and fencing of such lands. New farmlands were ideal for tomato farming because soils were very fertile free of tomato soil related diseases and pests that would attack tomato crop. The soils had high water retention capacity and required less farm inputs (fertilizers, herbicides, manures and pesticides) thus increasing the profitability.

3.4.6 Use of irrigation

Irrigation is critical in tomato production. It is important to supply sufficient water at critical times, such as immediately after sowing or transplanting. Use of man-made water reservoir to irrigate tomato was not applied in Kiamathaga/ Narumoru and Gakwa wards. Most of the tomato farms were along rivers while other farmers used greenhouses to grow tomato. In Thegu River and Kabaru wards 18% and 7.3% of the respondents respectively adopted use of irrigation either from rivers and man-made earth water reservoir (Figure 4). The study further established that water was readily available due to presence of seasonal streams such as Kandune, Lusoi, Nyange and rivers Nairobi, Thegu, Tigithi in the study but the water volumes decreased considerably during drought periods. Thus farmers constructed water reservoir and harvested water during the rainy months for use in tomato farming uring the drought periods. Irrigation being an adaptive mechanism is seen as relevant particularly in the dry season as it could improve yield of tomato in the era of rainfall variability (Tshiala and Olwoch, 2010).

3.4.7 Crop rotation practices

Crop rotation was adapted in total by about 20% of the respondents in the study areas (Figure 4). Thegu Ward recorded the highest number of respondents about 9% practicing crop rotation. Crop rotation meant farmers planted different crops on the field each season and only returning the same crop after at least three growing seasons, and this interrupted the life cycle of pathogens and reduces the chance of damage by diseases and pests in (Naika et al., 2005) increasing tomato production. Crop rotation cautioned farmers against continuous tomato attack by pests and diseases.

3.5 Economic aspects of tomato farming systems

On tomato farmers' accessibility of finances to improve tomato production, the study established that 17.8% of the respondents accessed loans from the local commercial banks (Table 4). About 6.7 percent received loans from savings and credit cooperative organizations (Sacco), while 2.2 percent got finances from other sources like borrowing from fellow farmers. Majority of the respondents (73.3%) did not access loans or finances from financial institutions as shown Table 4.

Table 4.

Accessibility of Finances by the Respondents

Financial Institutions	Frequency	Percentage (%)
Banks	8	17.8
SACCO	3	6.7
Any Other Source	1	2.2

None	33	73.3
Total	45	100.0

The study established that accessibility to quick loans from reputable financial institutions helped tomato farmers to improve tomato production. This was through leasing farm land, purchase of quality and clean seeds, farm chemicals and manure, hiring of labour, construction of small dams and greenhouses which enhanced tomato production.

3.6 Environmental aspects of tomato farming systems

3.6.1 Rainfall distribution in the study area

Data on mean, monthly and total annual rainfall for the period 1981 to 2014 in Kieni East Sub County was obtained from the Kenya Meteorological Department (KMD) in Nairobi. The study area received a mean annual rainfall of 637 mm between 1981 and 2014 (Figure 5), a characteristic of Semi-Arid climates which receive normally less than 850 mm of rainfall annually (Jaetzold et al., 2006; UNDP, 2013).

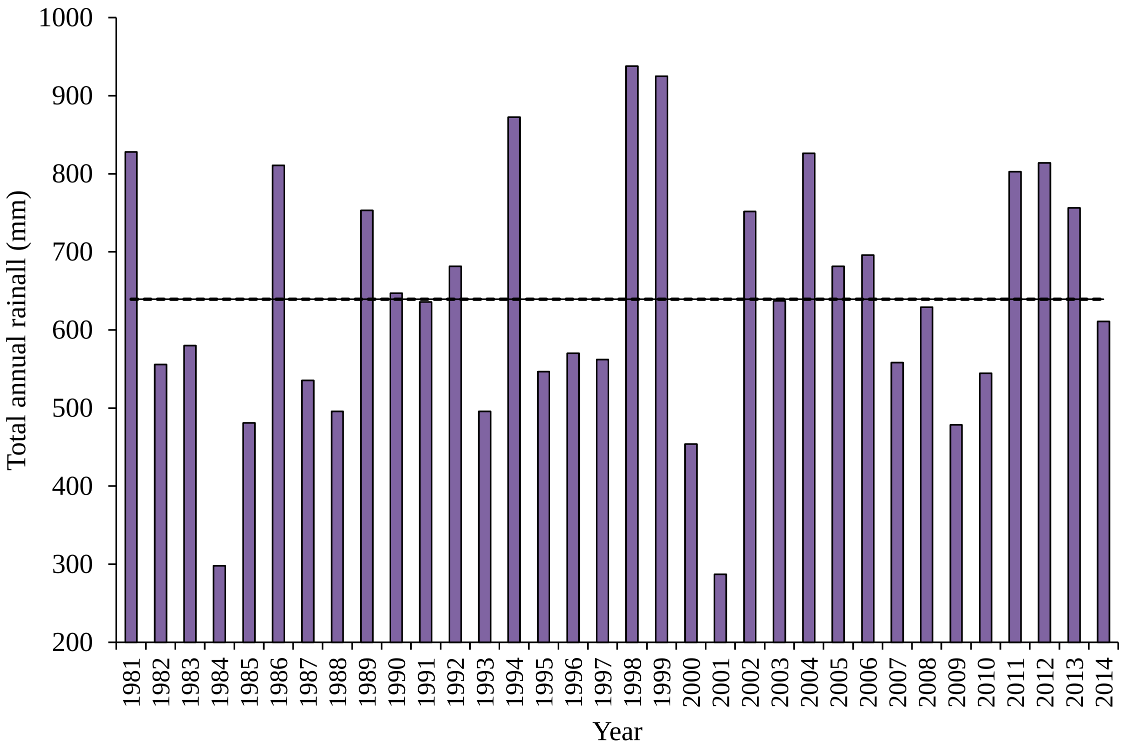

Figure 5. Total annual and mean rainfall for the period between 1981 and 2014 in Kieni East Sub County. Source: Kenya Meteorological Department, Nairobi

Based on the rainfall amounts and patterns, the study region favours mixed rain-fed irrigation and agro pastoral agriculture in smallholdings (Jetzold et al., 2006). In addition to the low annual rainfall, as recorded in the years 1984 (298mm), 1993 (495 mm), 2001 (297 mm) and 2010 when the study area received 480 mm, there was a wide range of year-to-year variability in rainfall which made drought a common occurrence in Kieni East Sub County (Republic of Kenya, 2012). The Sub County received total annual rainfall amount above the mean in the years 1981, 1986, 1989, 1992, 1998, 1999, 2002, 2004, 2005, 2006, 2007, 2008, 2011, 2012, 2013 and 2014. The year with the highest rainfall amount was 1998 when 980 mm rainfall was recorded and coincided with the period Kenya experienced the El Nino phenomena (IPCC, 2007). In the years 1991/92, 1995/96, and 1999/2000, the region experienced drought period (Orindi, 2005; Fund, 2012).

3.7 Rainfall patterns and their influence on tomato production

Tomato farming activities were overlaid on monthly average rainfall as shown in Figure 6. The main farming activities included seed bed preparation, preparing the land, planting, spraying against pests and diseases, weeding, staking, harvesting, sorting and packing. Seed bed preparation and sowing are done between January to March followed by transplanting in April for MAM and November for OND seasons when rainfall sets in. This is because tomato plants cannot withstand heavy rainfall (Nuruddin, 2001). A moisture content of about 600 mm (evenly distributed throughout the season) is required.

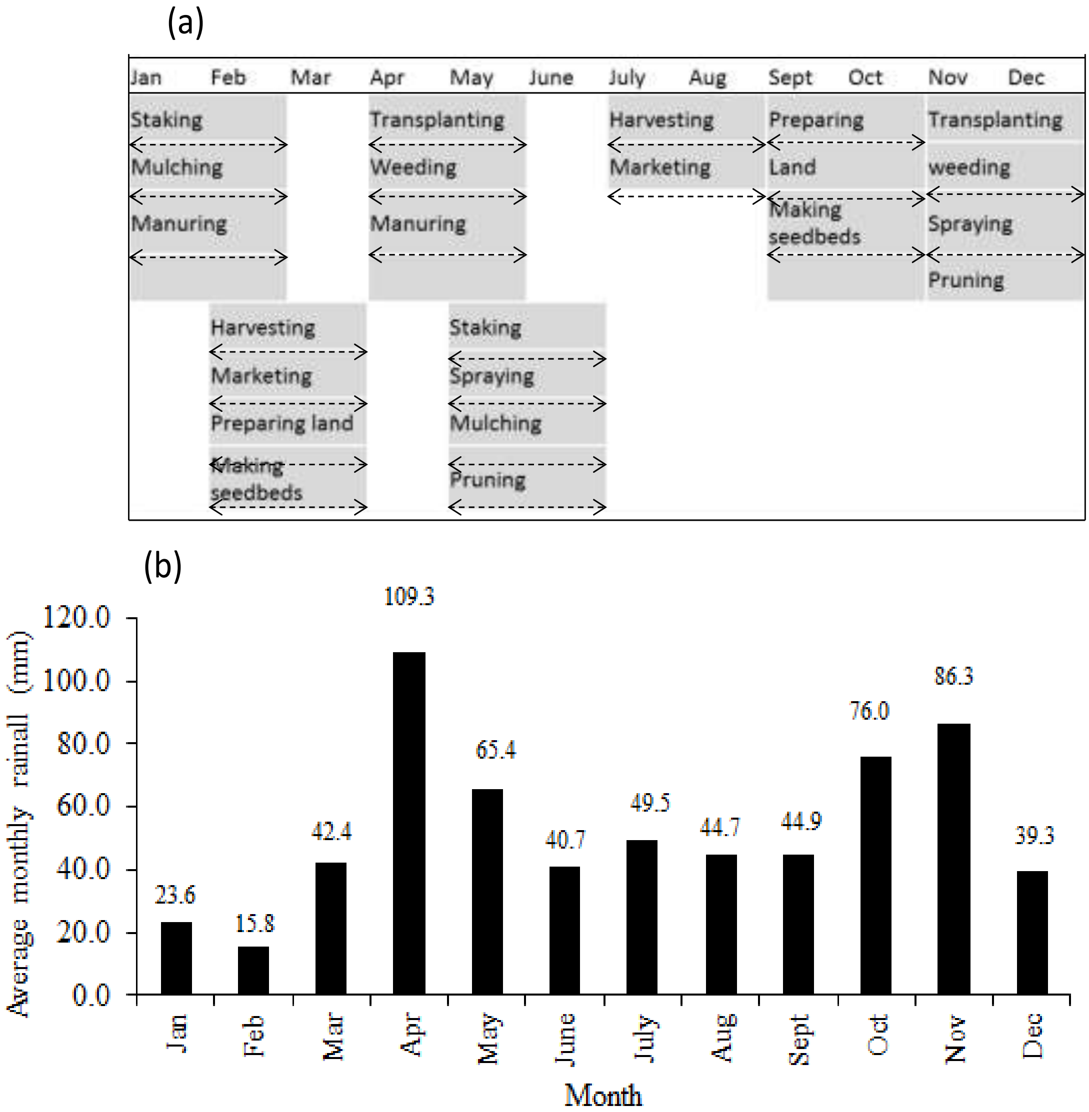

Figure 6. Tomato growing operations (a) and average monthly rainfall between 1981- 2014 (b) in the study areas.

Additionally, an optimum day temperature of 20-25°C and 15-17°C (night) is required. The tomato fruit ripening require relatively warm and sunny period which occurs in the months of January and June respectively for each season.

The study further sought to establish the relationship between rainfall patterns and tomato yields. In this regard, the study focused on rainfall distribution for the period between 2009 and 2014. This is when tomato production data on yields and income were available from Kieni East Sub County Agricultural Office in Narumoru. Figure 7 shows the annual rainfall and tomato yields for the years 2009 to 2014. In the year 2009, the area recorded an annual rainfall of about 534 mm, and produced 1800 MT of tomato. In 2010, the area received annual rainfall of about 480 mm and the same year a yield of 5250 MT- was realized. In 2012 despite the high rainfall of 844 mm, 4520 MT of tomato was produced. It was revealed that in the year 2010, despite the low rainfall, farmers adopted use of irrigation to compensate for reduced soil moisture. This resulted to high tomato yields of 5250MT.

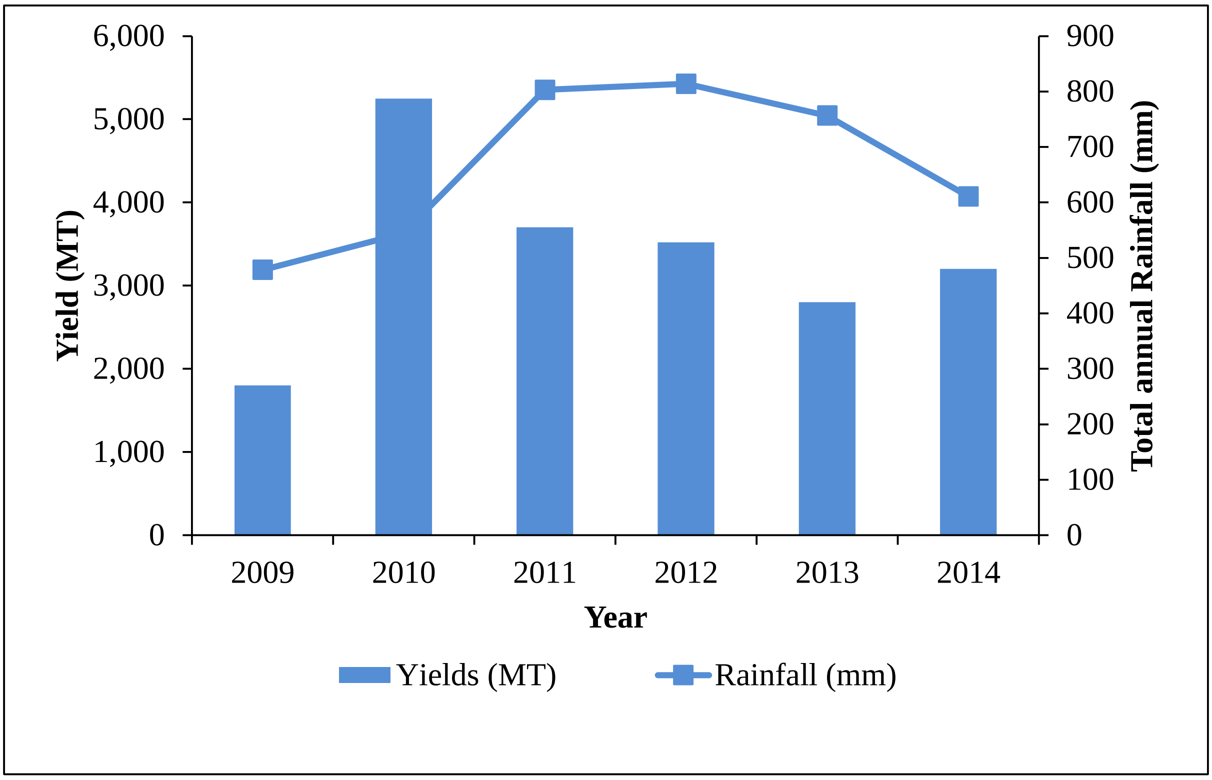

Figure 7. Tomato yield and total annual rainfall in the study area (2009-2014)

3.8 Tomato production constrains associated with rainfall in the study region

The study revealed that rainfall variability was the major constraint to tomato farming and production. The study established that the area experienced reduced rainfall amounts (below the mean of 637 mm of rainfall per annum and which was inconsistence (varying rainfall amounts) over the study reference period as revealed on Figure 6. Rainfall variability in the area was also observed to be on the rise as the farmers reported increasing unpredictability of seasonal rainfall onset. Increase in rainfall amounts was associated with increased occurrence of tomato diseases like wilt, early and late blight, leaf spots and mildews and destroyed the tomato plants thus reducing the yields as indicated by 84.4% of the respondents (Table 5).

Table 5.

Tomato production constraints related to rainfall variability in the study region.

		Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Total
During rainy season transport charges reduce profit margin in tomato sales	Frequency	7	1	5	19	13	45
	%	15.6	2.2	11.1	42.2	28.9	100
Frequent dry periods lowers quantity/ quality of tomato production	Frequency	6	10	10	13	6	45
	%	13.3	22.2	22.2	28.9	13.3	100
Tomato pests increases in drought periods	Frequency	1	3	3	18	18	43
	%	2.3	7	7	41.9	41.9	10
Tomato diseases increases with high rainfall	Frequency	2	4	1	18	20	45
	%	4.4	8.9	2.2	40	44.4	100
Profits from tomatoes are low during rainy seasons	Frequency	5	10	4	13	6	38
	%	13.2	26.3	10.5	34.2	15.8	100

Rainfall shortages reduces tomato production	Frequency	5	10	5	17	8	45
	%	11.1	22.2	11.1	37.8	17.8	100
Too much rainfall lowers tomato productions	Frequency	5	8	3	19	10	45
	%	11.1	17.8	6.7	42.2	22.2	100

In addition, 64.4% of the respondents stated that high rainfall amounts lowered production of tomato. High rainfall amount led to increased transport costs and thus increased prices of tomato as revealed by 15.6 percent of the respondents. Increased rainfall led to water logging in soils, reduced the flowering period of tomato plants and ripening of tomato fruits and consequently resulted to low yields of tomato. The results of the present study are in line with the findings by Nuruddin (2001) who found that tomato productivity and quality was affected by amount of water supplied to the crop during the growing season. The results indicated that about 83.8% of the respondents agreed that tomato pests like aphids, white flies, red spider mites, thrips, American bollworm caterpillars and Tuta absoluta increases in seasons of dry and low rainfall. Seasons of low rainfall offered suitable warm environment for pests to survive and fast breed (Nyabundi & Hsiao, 1989a). Majority of the respondents agreed that diseases such as early and late bright increased with high rainfall.

High rainfall triggered early bright and late tomato diseases which eventually lowered tomato production. About 70.1% of the respondents agreed that during rainy seasons transport cost of tomato produce to the market escalated thus reduced, the profit margin of the farmers (Table 5). Transport of tomato produce was expensive due to the muddy roads which were impassable in accessing tomato farms and markets. The delay in picking the tomato produce reduced its quality and quantity. Results indicated that about 64.4% of the respondents concurred that too much rainfall lowered the tomato production. Too much rainfall is associated with water logging of the soil, fungal diseases, early and late bright (Nyabundi & Hsiao, 1989b). The results of the present study are in line with the findings by Tya and Othman, (2014) which shows that tomato yield increased with increase in soil moisture up to an optimum level after which there was a reduction in yield.

4. Conclusion

The study revealed that tomato farming system is determined by climate (rainfall) and economic and social wellbeing of the farmers. Farmer management practices are related to judicious use of available resources to overcome challenges of climate variability, need for inputs and labour deficits.

The study established that rainfall characteristics over the past thirty four years (1982 – 2014) considered in this study varied both annually and seasonally. Climate conditions in the study area permits production of a wide range of tomato varieties throughout the year and when timely produced can provide a reliable and regular source of income to the farmers. An increase in rainfall causes a significant variation in tomato yields with some confounding variables such as soil type, pests, disease, and application of certified seeds, irrigation, tomato variety and regular weeding held constant. Access to weather information by tomato farmers should enhance adaptive strategies of the farmers. This could reduce the adverse effects of rainfall variability on their activities. Rainfall change impacts to rural farming communities can be reduced by distributing climate data regarding seasonal climate forecasts (based on short-term and long-term forecasts) to small farmers. By so doing they can make more informed farming decision and adapt to the changing climate conditions. Farmers may use this information during dry conditions or by planting drought-tolerant crops (Patt et al., 2005). The study revealed a number of farming strategies employed by the farmers in tomato production, which included irrigation, crop rotation, use of certified seeds, application of mulching, use of manure and use of greenhouse technology.

Production of tomato is well placed to contribute significantly to the paradigm shift aimed at transforming small holder agriculture from subsistence to a modern, innovative business and commercially - oriented sector. Since the study area is vulnerable to rainfall variability and tomato farming is the major economic activity for the local people, it is important to develop tomato varieties which can withstand high rainfall conditions, with a longer harvesting period and enhancing financial mechanisms to the small scale farmers.

4.1 Policy recommendation

Soil and water management practices be enhanced to reduce loss of moisture from the soil and increase soil nutrients and water retention (through mulching, water harvesting etc) capacity during dry seasons. Farmers should be encouraged to enhance crop diversification to caution them from rainfall variability trends. Training of farmers on importance of timely planting to utilize the available rains at different stages of growth such as flowering to maturity, hence the Kenya Meteorological Department should avail relevant data information on weather predictions to the farmers through radio and short message text (SMS). Resistant tomato varieties that can withstand the pressures of the climatic variations be developed by the Kenya Agricultural and Livestock Research Organization (KARLO) and other private entities like Syngenta.

Conflict of interest

The authors have no conflicts of interest to declare regarding the publication of this paper.

Acknowledgement

We gratefully acknowledge the technical assistance of the Agricultural Office in Kieni East Sub county and Kenya Meteorological Department, Nairobi for providing production and climatic data.

References

Abay, A. (2007). Vegetable Market Chain Analysis: The Case of FogeraWoreda in ANRS of Ethiopia. Haramaya University)

Awan, S. M., Hussain,Azhar, Abbas, T. & Karamu, R. (2012). Assessment of production practices of small scale farm holders of tomato in Bagrote Valley, CKNP region of Gilgit-Baltistan, Pakistan. Acta Agriculture Slovenica.

Coe, R. and Stern, R. D. (2011) Assessing and addressing climate-induced risk in Sub-Saharan rainfed agriculture: Lessons learned. Experimental Agriculture

Creswell, R., & Martin, F. W. (1998). Dry land farming: Crops & Techniques for arid regions. ECHO technical note, Fort Myers, Fl, USA.

Erenstein, O. (2003). Smallholder conservation farming in the tropics and sub-tropics: a guide to the development and dissemination of mulching with crop residues and cover crops. J.Agri. Ecosystems and Environs.

FAO (2012). Economics of plant genetic resource management for adaptation to climate change. A review of selected literature. S. Asfaw and L. Lipper (available at: http://www.fao.org/docrep/015/an649e/an649e00.pdf).

Francis, C. (2008). Agricultural Systems: Agroecology and Rural Innovations for Development. Edited by Sieglinde Snapp and Barry Pound. 2008. Elsevier, Amsterdam, The Netherlands. 3

Fund, C. (2012). UNDP Project Document Government of Kenya United Nations Development Programme World Bank PIMS 3792, Kenya : Adapting to Climate variability in Arid and Semi-Arid Lands (KACCAL) Period covered : 2008-2012.

GoK (2010). National Climate Change Response Strategy, Government Press Nairobi, Kenya.

HCDA (2011). National Horticulture Report 2011. Republic of Kenya Ministry of Agriculture.

Huho, J. M, and Kosonei. R. C. (2013). The opportunities and challenges for mitigating climate change through drought adaptive strategies: the case of laikipia county,kenya, SAVAP International.

IPCC (2007). Climate Change: Impact adaptation and vulnerability, contribution of working Group II to Fourth Assessment Report on IPCC. United Kingdom, Cambridge University Press.

IPCC, (2012). Managing the risks of extreme events and disasters to advance climate change adaptation, A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

Jaetzold, R., Schmidt. H & Shisanya. C (2006). Farm Management Handbook of Kenya, Central Kenya– Natural Conditions and Farm Management Information, Ministry of Agriculture, Nairobi.

Jiregna Tasisa, Derbew Belew & Kassahin Bantte, (2012). Genetic associations' analysis among some traits of tomato (Lycopersicon esculentum Mill.) Genotypes. International Journal of Plant Breeding and Genetics.

Kenya Emerging Lessons from Empowering Local Communities, Kenya, Nairobi.

Kenya National Bureau of Statistics (KNBS). (2019). 2019 Kenya Population and Housing Census Volume I: Population by County and Sub-County.

Kremen, C., Iles, A., & Bacon, C. (2012). Diversified farming systems: an agroecological, systems-based alternative to modern industrial agriculture. Ecology and society, 17(4).

Kumar, R., Sharmar, D. H., Kansal, S., & Thakur, K. (2012). Vegetable production under Changing Climate Scenario, Nauni, India.

Lal, R. (2015). Shifting cultivation versus sustainable intensification.. Reference Module in Earth Systems and Environmental Sciences, Elsevier.

Mango, N., Mapemba, L., Tchale, H., Makate, C., Dunjana, N., & Lundy, M. (2015). Comparative analysis of tomato value chain competitiveness in selected areas of Malawi and Mozambique. Cogent Economics & Finance.

Masahumi, J., Oda, T. and Shinohara, Y. (2011). Crop production and Global Warming,

Gloal Warming Impacts – Case studies on Economy, Human Health and Natural Environment, In Tech, China.

Naika, S, Jeude, J., Goffau, M., Hilmi, M., & Dam, B. (2005). Cultivation of tomato:Production, Processing and Marketing Wagenigen, Netherlands.

Nuruddin, M. M. (2001). Effects of water stress on tomato at different growth stages (Doctoral dissertation, McGill University).

Nyabundi, J. O., & Hsiao, T. C. (1989a). Effects of water stress on growth and yield of field-grown tomatoes. Pt. 1, Canopy development and biomass accumulation. East African Agricultural and Forestry Journal, 55(1-2)

Ogola, O., Milton, W., Ayieko, A., Orawa, O., & Kimani, W. (2011). Analysis of fertiliser use in potato production in Nakuru district, Kenya.Africa journal of Agriculture vol.6 (16):3672-3677.

Onyekwelu, J. C., Mosandl, R., & Stimm, B. (2006). Productivity, site evaluation and state of nutrition of Gmelina arborea plantations in Oluwa and Omo forest reserves, Nigeria. Forest ecology and management, 229(1-3), 214-227.

Orindi, A. (2005) Kenya seed fairs as a drought recovery strategy in Kenya, IDS Bull. 36 (4): 87–102, http://dx.doi.org/10.1111/j.1759-5436.2005.tb00236.x

Osure G., (Syngenta Foundation Kenya) (2010). Agribusiness Forum – Uganda Inclusion of Small Scale Producers in Value Chains (Best Practices). Syngenta Foundation for Sustainable Agriculture, Nairobi, Kenya.

Patt A., P. Suarez & C. Gwata. (2005). Effects of seasonal climate forecasts and participatory workshops among subsistence farmers in Zimbabwe. Proceedings of the National Academy of Sciences of the United States of America.

Republic of Kenya, 2012. Releasing our full potential. Sessional paper no. 8 of 2012 on national policy for the sustainable development of northern Kenya and other arid lands, Ministry of State for Development of Northern Kenya and other Arid Lands. Nairobi, Kenya.

Salami, A., Kamara, A. B. and Brixiova, Z. (2010). Smallholder agriculture in East Africa:Trends, Constraints and Opportunities Development Bank. African Development Bank Group: Ghana.

Shaner, W. W. (2019). Farming systems research and development: guidelines for developing countries. Routledge.

Speranza, C. I., Kiteme, B., Ambenje, P., Wiesmann, U., & Makali, S. (2010). Indigenous knowledge related to climate variability and change: insights from droughts in semi-arid areas of former Makueni District, Kenya. Climatic change,

Starke Ayres (2014), Tomato Production Guideline, Member of the Plennegy Group, www.starkeayres.co.za.

Tshiala, M. F. & Olwoch, J. M. (2010), "Impact of climate variability on tomato production in Limpopo Province, South Africa", African Journal of Agricultural Research.

Tusiime, S. M. (2014). Evaluating Horticultural Practices for Sustainable Tomato Production in Kamuli, Uganda, Iowa State University.

Tya, T. S. K., & Othman, M. K. (2014). Effect of irrigation water depth on tomato yield, water charge and net returns at Geriyo Irrigation Project, Yola, Nigeria. Int. J. Agric. Pol. Res, 2(4), 178-184.

UNDP. (2013). Combating Desertification in Kenya: Emerging Lessons from Empowering Local Communities.

World Wide Fund for Nature (2006). Climate Change Impacts on East Africa. A review of Scientific Literature. Gland, Switzerland.

Ziervogel, G., Cartwright, A., Tas, A., Adejuwon, J., Zermoglio, F., Shale, M., & Smith, B. (2008). Climate change and adaptation in African agriculture. Stockholm environment institute, 17-19.