Farmers' Perceptions of Climate Change and Its Effects on Tree Cover in the Drylands of South Eastern Kenya: The Case of Matungulu Sub-County, Machakos County

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ABSTRACT

Matungulu Sub-County is a semi-arid region in Kenya that is prone to frequent droughts, water shortages and food insecurity. Rapid population growth, coupled with climate change, has led to not only an increasing demand for more land, but also to over-exploitation and degradation of local natural resources, leading to a myriad of socio-economic and environmental challenges in the area. The objective of this study was to assess farmers' perceptions of climate change and its effects on tree cover in Matungulu Sub-County. A structured questionnaire, FDGs, key informants and direct observations were used to collect household socio-economic data from 412 randomly selected households in two locations, namely, Sengani and Koma. Temperature and rainfall data from the Kenya Metrological Department was used to study changes in climatic trends over the three-decade period between 1987 and 2017 in the study area for comparison. Descriptive and inferential statistics were used in the data analysis. Farmer-perceived climatic patterns were collaborated by data from the Kenya Meteorological Department. 84% of respondent farmers perceived climate change to have affected species composition, density and distribution of tree cover. The farmers unanimously indicated climate change was real in the region.
Keywords: farmers, climate change, effects, perceptions, livelihoods, indigenous knowledge

1. INTRODUCTION

Trees play a critical role in regulating the earth's climate through the carbon cycle; removing carbon from the atmosphere as they grow, and storing carbon in leaves, woody tissue, roots and in more recalcitrant forms as organic matter in the soil (UNFCCC, 2011). Tree planting at farm level can reduce vulnerability and mitigate climate change (Insaidoo *et al*., 2014). Agroforestry systems and tree cover on agricultural land make an important contribution to climate change mitigation, but are not systematically accounted for in either global carbon budgets or national carbon accounting (Zomer *et al*., 2016). Although tree cover has been declining generally in the world, it has been necessary for human survival since the days of Adam and Eve. More than 10,000 years after the Agricultural Revolution started, millions of rural smallholders across the developing world still derive as much income from foraging tree cover and wildlands as from cultivating crops (Wunder *et al*., 2014); and these steady environmental income flows come often from tree cover, and are extracted by men and women alike. Adopting and establishing tree cover at farm level would reduce pressure on public forests and reduce the rate of deforestation (Siraj *et al*., 2018). While exploitation of tree cover by communities does not preclude the ongoing conversion of wildlands to agriculture, privileged access to high-quality environmental resources can become a strong local conservation motive (Wunder *et al*., 2014).

Recent research in Kenya by Quandt *et al*., (2018) shows that rural livelihoods were improved by both on-farm and off-farm livelihood diversification, and tree cover improved the overall quality of life for majority of respondents. A study in Kenya's arid north by Cuni-Sanchez *et al*. (2017) shows that understanding cultural preferences toward different ecosystem services is of great importance for understanding conservation and development planning, and that "while cultural preferences toward plant species have long been studied in the field of plant utilization, the effects of ethnicity on ecosystem services identification and valuation has received little attention". The challenge of climate change in Kenya is intensifying at an alarming rate as is evidenced by the increase in occurrence of extreme events such as floods, landslides, and irregularities in temperature and rainfall. For example, in 1997/98, the country experienced a flooding event while in the year 1999/2000, the country experienced a drought (Pramova *et al*., 2012). In more recent times, in 2018, severe flooding has been experienced in several parts of Kenya including the Athi Kapiti plains that form a part of Matungulu Sub-County, occasioning destruction of infrastructure such as roads and bridges. This has led to resurgence of disease and pests and other related environmental disasters. In Mt. Kenya, the disappearing glacier is evidence enough that the country is faced by global warming having lost up to 92% of her ice during the last 100 years (UNFCCC, 2011). Many people in Matungulu Sub-County have continually depended on indigenous mechanisms, including utilization of the few local trees and shrubs, to survive the debilitating effects of frequent famines long before any official famine relief reaches them. Tree cover is increasingly proving to be a veritable means of achieving sustainable development because of its multiple advantages to the environment, society, and economy (De Leeuw *et al*., 2014). The study was conducted in Matungulu Sub-County, Machakos County, South Eastern Kenya to assess farmers' perceptions of climate change and its effects on their local environment and livelihoods. The new information will be useful in providing authorities and development agencies with more opportunities for successful interventions in the mitigation of socio-economic and environmental effects of climate change in the sub-county.

2. RESEARCH METHODOLOGY

2.1 The study area

2.1.1. Location

Matungulu Sub-County, in Machakos County, lies in the semi-arid region of south eastern Kenya. The Sub-County covers an area of about 610.351 Km^2 and lies between Latitudes 1.076^0 and 1.358^0S and Longitudes 37.083 and 37.387^0E (Survey of Kenya, 2018).

2.2 Research design

The study adopted a mixed methods research design. This is an approach to inquiry that combines both qualitative and quantitative forms. The qualitative approach enabled an extensive investigation into the communities' perception of climate change and the tree cover changes over the last 30 years and the household characteristics that may have influenced the levels of tree cover in the study area. The use of both methods ensures that the overall strength of the study is greater than either qualitative or quantitative research (Creswell and Plano-Clark, 2007).

2.3 Target population

Two locations, Koma and Sengani, were selected for the study. The target population was the households in the locations. Sengani and Koma locations contained a population of 2,370 and 1,165 house-holds in the 2009 Kenya census (KNBS, 2010) adding up to a population of 3,535 households in total. The projected population for year 2017 was 4,341 households using a growth rate of 2.6% per year estimated for Kenya's population (KNBS, 2010).

2.4 Sample size and sampling procedures

For populations that are large, Kothari (1999) developed the equation below to yield a representative sample for proportions:

$N_0 = Z^2pq/e^2$

Where, n_0 is the sample size,

Z^2 is the abscissa of the normal curve that cuts off an area α at the tails (1-α equals the desired confidence level, in this case 95%),

e is the desired level of precision,

p is the estimated proportion of an attribute that is present in the population, and

q is 1-p.

The value for Z is found in statistical tables which contain the area under the normal curve. According to Mugenda and Mugenda (2003), social science researchers can use the formula to determine desired sample size if the target population is greater than 10,000. However, the rule of thumb should be to obtain as big a sample as possible. The bigger the sample size the higher the accuracy of the results. The calculation resulted in a minimum sample size of 384 households. However, this was set to 412 households distributed proportionately in the two study locations as shown in Table 2.1:

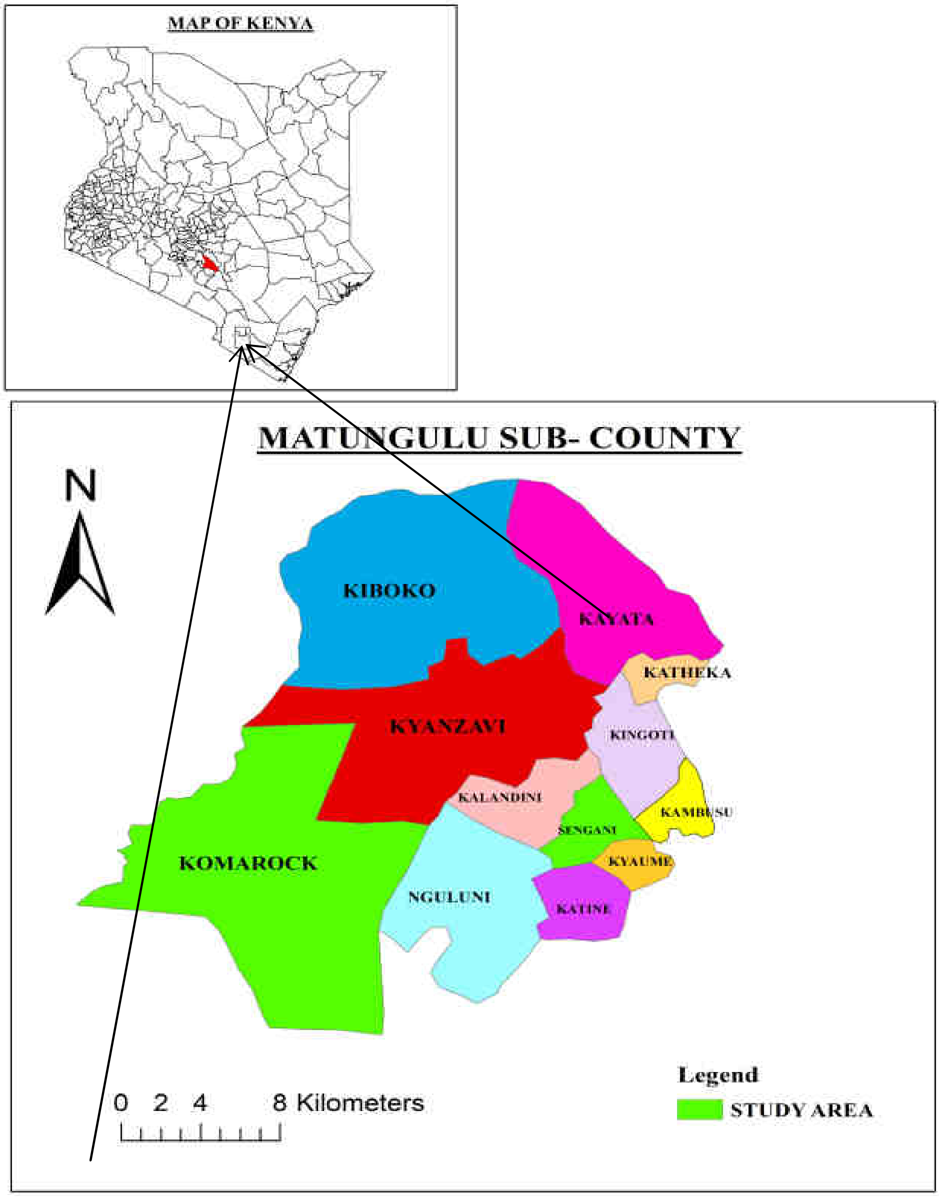

Figure 2. 1: A map of the study area showing the administrative locations

Table 2. 1: Sample size distribution in the study area

Location	Population (estimated 2017)	Sample size
Sengani	2910	276
Koma	1431	136
Total	4341	412

2.4.1 Non-probability Sampling

This is a sampling procedure where certain respondents are clearly preferred over others due to various reasons e.g. knowledge, experience, availability, heterogeneity or relevance to the study. Non-probability sampling or purposive sampling was used in the selection of two administrative locations and key informants for interview. Two administrative locations considered by stakeholders to have a demographic and agro-ecological variation and relatively sharp contrast in tree cover were selected in purposive sampling. The procedure has advantage in that it is objective, easy to administer, less costly and less time-consuming.

2.4.2 Probability sampling

Probability (or random) sampling is a sampling procedure where all the elements in the population have an equal chance of being selected (in a random fashion). Within each of the selected locations further sampling (systematic sampling) was done to obtain respondents per location for interview. This was based on records of households kept at the local Chiefs' offices. Sampling units were the households while the respondents were the household heads. A random number was picked to choose the first household for interview, and thereafter every third household in the list was selected, for example 3, 6, 9, 12, etc. A sampling method where a list exists for everyone in a population is termed systematic selection procedure (Weisburg *et al*., 1989). Men, who traditionally would be head of most households, may have been unavailable for the questionnaire administration in some cases. If the household head was completely unavailable, the second in-charge was chosen. Where both were absent simultaneously, a repeat visit was arranged. Repeat visits would ensure at least one of them was reached for questionnaire administration. Where it was not possible to administer questionnaire on a scheduled household (for whatever reason), a neighboring household would be selected for the same. Sensitive questions would be asked last after gaining respondents' confidence. Use of an interpreter where necessary would greatly ease the problem of language barrier and minimize errors in data collection.

2.5 Data collection methods

2.5.1 Ethical considerations

The researcher followed ethical guidelines as recommended by the office of Research Ethics, Kenyatta University. This included undergoing through a Research Ethics review process before engaging respondents to ensure the process was fair and unbiased to all concerned. Anonymity of participants was maintained and respected throughout the process. Enumerators were briefed on issues of professionalism, etiquette, respondent privacy, voluntary participation and disclosure following standard research ethics principles.
The following data collection instruments were used either singly or in combination to obtain all the necessary primary and secondary data required for the study.

2.5.2 The questionnaire

A pre-tested structured questionnaire with both fact- and opinion-questions, including open-and closed-ended ones were administered to the respondents. The household questionnaire incorporated direct questions to know the socio-economic profile of the house-holds (e.g. gender, age, literacy, family size). The questionnaire was divided into sections, each seeking specific kinds of data corresponding to the objectives and research questions of the study. These included farm level tree cover, role of tree cover in climate adaptation and mitigation by farmers, constraints to tree planting and methods to enhance tree planting. A pre-testing of the questionnaire was conducted before the actual data collection, and appropriate modifications made to the questionnaire. Research support staff and enumerators were trained on field procedures and strategies related to the questionnaire to enable quality and reliable data collection. Other aspects of training included research ethics, field quantification/ arithmetic skills (conversion of local units into standard units), probing and triangulation skills.

2.5.3 Key informant interviews

This method was used in addition to the questionnaire to collect further information. Key informants included the Ward Forestry Officers and their frontline extension staff in Koma and Sengani locations, the Ward and Locational Agricultural Extension Officers, Chiefs and Assistant Chiefs, women leaders, area elected representatives, school heads, representatives of NGOs and church organizations, and other community leaders.

2.5.4 Observations

Observations were used to enrich and supplement data collected via the questionnaire and key informant interviews. Observations were made of the various types of tree cover, tree arrangements, forestry practices and the tree species planted. As a reliable ground-truthing method, observation was used to counter-check and confirm information from respondents and key informants, and to assess the level of additional family resources around the household.

2.5.5 Focus group discussions

Two focus groups of ten people each were established in either location. Each group had a fair representation of either gender. Meetings, venues and timelines were agreed in advance and proceedings would have a moderator and a rapporteur. Meetings (in groups or plenary) often discussed topics/ questions (focus discussion guides) formulated prior to the meeting and other matters of mutual interest. The FGDs were also used to explore the meaning of survey findings that could not be captured statistically, the range of opinions/views on a topic of interest and to collect a wide variety of local terminology and knowledge. In bridging research and practice, FGD can be useful in providing an insight into different opinions among different parties involved in the change process, thus enabling the process to be managed more smoothly (Steward and Shamdasani, 1990).

2.6 Secondary data

This was obtained from the internet, office reports, development plans, research theses, pamphlets and other materials found in public offices, libraries and documentation centers. Data from the Meteorological Department was used to show climate trends (in terms of temperature and rainfall) graphically in the Sub-County between 1987 and 2017.

2.7 Data analysis and presentation

2.7.1 Questionnaire data

Collected data from the field was checked for completeness, clarity and consistency in responding to the questionnaires. The questionnaires were numbered, answers coded and indexed. A codebook was then developed, comprising of specifications like variable name (e.g. location), description of the variable and the variable type (e.g. ordinal, nominal, etc.). Most of the data that was captured under various objectives were numeric, categorical or in thematic form which were subjected to data cleaning and analysis using appropriate tools. Firstly, descriptive analysis was used to determine the frequency distribution and summaries, followed by bivariate and multivariate relationships which have been shown in the analysis matrix below (Table 2.2).

Table 2. 2: Data analysis matrix (summary)

Objective	Key Variables	Source of data	Test statistics/presentation
1) Farmers perception of effects of climate change on tree cover	Perceived changes in tree cover (species composition/ distribution) Perceived change in climate Time (Years)	Questionnaire Comparative studies	Factor analysis, climate trend analysis
2) Climate change	Temperature and rainfall patterns over last 30 years	Kenya Meteorological Department	Factor analysis of climate parameters, decadal changes in climate characteristics, comparative studies

2.7.2 Climatological trend analysis

Monthly data for minimum temperature, maximum temperature and rain fall was obtained from the Kenya Metrological Department (KMD) and analyzed for trends. Linear models were used to determine the trend in rainfall patterns over 3 decades. Cumulative decadal rainfall was determined by summing up rainfall within 10 year groups in the data, while temperature data was averaged within decade groups. The R software plotting commands were used to visualize the climate trends, first by year followed by a monthly analysis of trends.

3. RESULTS AND DISCUSSIONS

3.1 Effects of climate change on tree cover in Matungulu Sub-County

3.1.1 Farmers' perceptions of climate change in the study area

Table 3. 1: Description of climate characteristics over the last 30 years by farmers in Matungulu Sub-County

Climate measure	F	Minimum	Maximum	Mean	Std. Deviation
Rainfall amount	361	1	5	4.4	3.09
Early commencement of rainfall	341	1	5	4.3	3.08
Early cessation of rainfall	341	1	5	4.7	2.99
Low temperature	346	1	5	2.2	3.00
Shorter periods of rainfall	347	1	5	4.0	2.70
Number of seasons without enough rainfall	347	1	5	4.0	2.96
High temperature	354	1	5	4.0	2.75
Flooding	326	1	5	3.9	2.86
Long inter-seasonal dry spells	337	1	5	3.9	2.79
Low overall amounts of rainfall	335	1	5	3.7	2.50
Drought	302	1	5	3.5	3.08
Late commencement of rainfall	330	1	5	3.4	2.64

1=Very low frequency of occurrence, 2= Low frequency, 3=Medium frequency, 4=High frequency, 5=Very high frequency of occurrence

Climate characteristics here are as described by farmers over the last three decades. For example, farmers rated the occurrence of seasons without enough rainfall as generally high (4.0) implying that seasons without enough rainfall occurred frequently in Matungulu Sub-County. Rainfall amount (4.4) and early commencement of rainfall (4.3) were highly rated, while the occurrence of flooding (3.9) was tending to high frequency in the study area. Drought occurrence was rated high in Koma Location (4.1), compared to Sengani Location (2.2). The occurrence of long inter-seasonal dry spells were also rated high in both locations compared to three decades ago (Table 3.1). The results show that the climate was characterized by 3 main components which explained 57% of the total variance in perception of climate parameters by farmers. The first component describing farmer perception of the climate 3 decades ago was described by high temperature and dry-spells, coupled with low and late commencement of rainfall. The second component comprised of descriptions of flooding and drought, while the last component was a description of early commencement of rainfall.

Figure 3.1 below describes the changes in climate patterns according to farmer perception in Matungulu Sub-County, over a decadal time sequence as follows; 10 years ago, 20 years ago and 30 years ago. In regard to increased number of seasons without rainfall, 42% of the respondents said that this had happened 10 years ago, 17% said 20 years ago while 20% indicated 30 years ago. This implied that there was a general perception of increased seasons without rainfall in Matungulu Su-County.

Rainfall had decreased in Matungulu Sub-County according to 37% of the farmers (10 years ago), 42% of the farmers (20 years ago) and 36% of the farmers (30 years ago). These results regarding rainfall decrease depict a declining rainfall trend over the three decade period according to farmer perceptions.

In regard to late rainfall commencement, farmers recorded an increasing trend in the following order: 8% said in the last 10 years, 37% said in the last 20 years, and 40% said in the last 30 years. The proportion of those who believed in the occurrence of late rainfall commencement reduced considerably over the last 10 years. Nonetheless, this means according to farmers' perceptions, there was increase in late commencement of rainfall in Matungulu Sub-County over the last three decades. 60% of the farmers reported occurrence of shorter periods of rains 10 years ago, 45% 20 years ago, and 23% 30 years ago, respectively. This means farmers generally had perceived accelerated shortening of the rainy period in Matungulu Sub-County over the last two decades.

3.2.2 Change in climate parameters according to farmers in Matungulu Sub-County over the 1987-2017 period

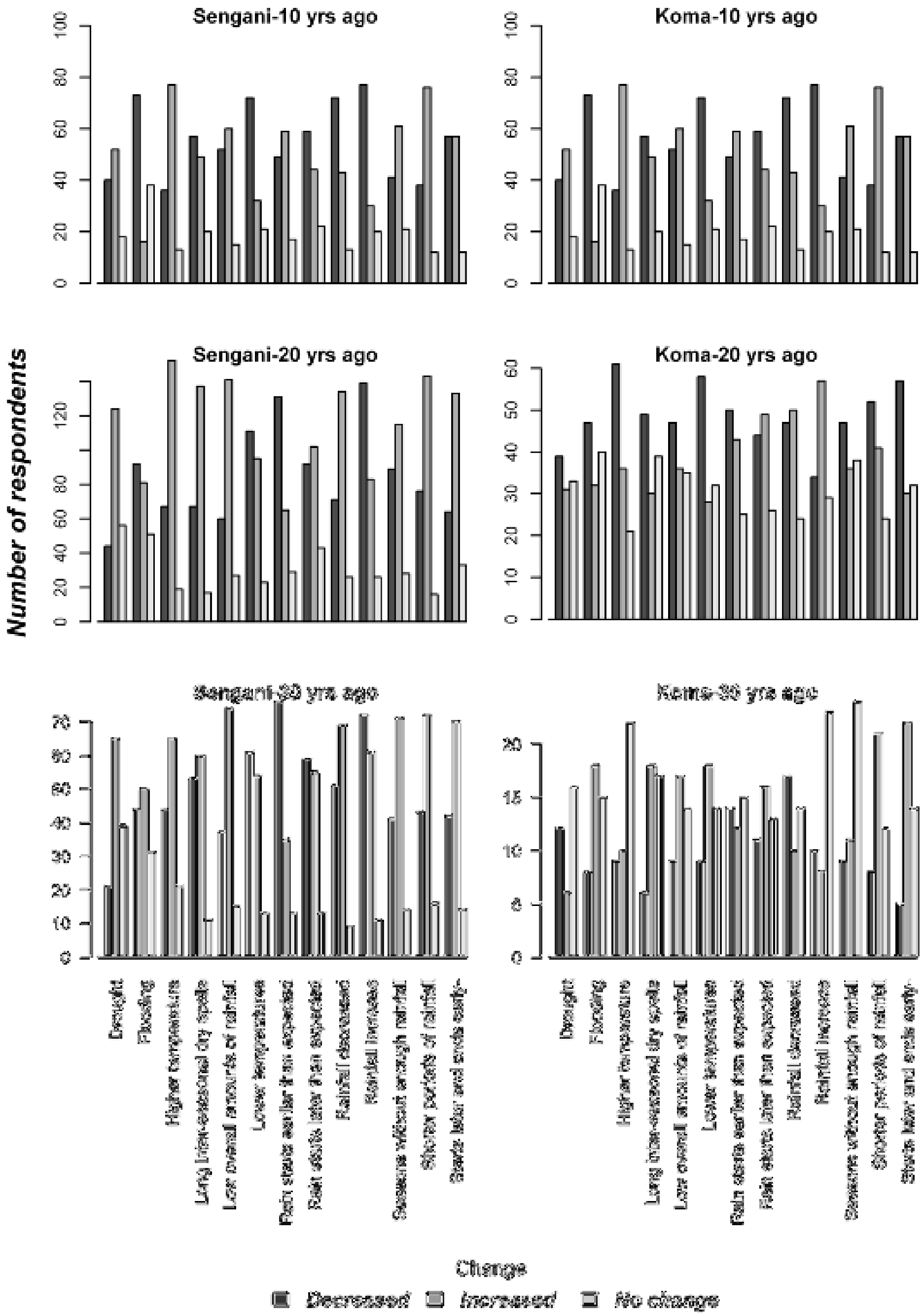

Figure 3. 1: Perceived changes in climate by farmers in Matungulu Sub-County (Koma and Sengani Locations) during the 1987-2017 period

About 38% of the farmers reported higher temperatures 10 years ago, 37% reported higher temperatures 20 years ago and 16% reported higher temperatures 30 years ago in Matungulu Sub-County. This means a higher proportion of farmers perceived occurrence of higher temperatures in their region with each passing decade.

In both study sites, there was perception of declining low temperatures, with time, implying that low temperatures had declined with time, changing from 30% (10 years ago), 27% (20 years ago), and 15% (30 years ago) in Matungulu Sub-

County. This is a manifestation that low or minimum temperatures had risen with time in the study area. In regards to inter-seasonal dry spells, these had increased as reported by 37% (10 years), 33% (20 years) and 15% (30 years ago) farmers in Matungulu Sub-County. The perceptions of drought were mostly from increasing events in the study area (16%, 30%, and 38%) over the 10, 20, and 30 year periods, respectively. Several studies on the changes in climate in the semi-arid zones of Eastern Kenya have reported rainfall and temperature changes, similar and consistent with the findings of the current study. The findings indicate that climate parameters were favourable for agricultural production activities three decades ago, compared to the current decade. Most of the farmers demonstrated that they had experienced some form of temporal historical change in temperature and rainfall characteristics. Farmers in the study area indicated that they experienced an increase in seasons without enough rainfall, while total rainfall amounts had decreased with time. The lateness in rainfall commencement dates had increased in frequency while temperature trends portrayed a pattern of increasing temperature with time. The frequency of inter-seasonal dry spells was also reported to have increased over three decades by the farmers in the Sub-County. The findings reported here are similar to those of Muriu-Ng'ang'a (2017), who reported similar trends in neighbouring Tharaka Nithi County, Kenya.

In a study examining farmer perception of climate change in the Sahel, 82% of the farmers reported a decline in annual rainfall and only 5% reported no change in a period of 20 years (Mertz, *et al*., 2009). Farmers generally reported temperature rise and a decline in precipitation in ten African countries (Maddison, 2006). Manandhar and Schmidt (2011) reported a correlation between farmers' perceptions of climate parameters and meteorological data, as does this study.

3.2.3 Climatological characteristics and trends in Matungulu Sub-County between 1987 and 2017

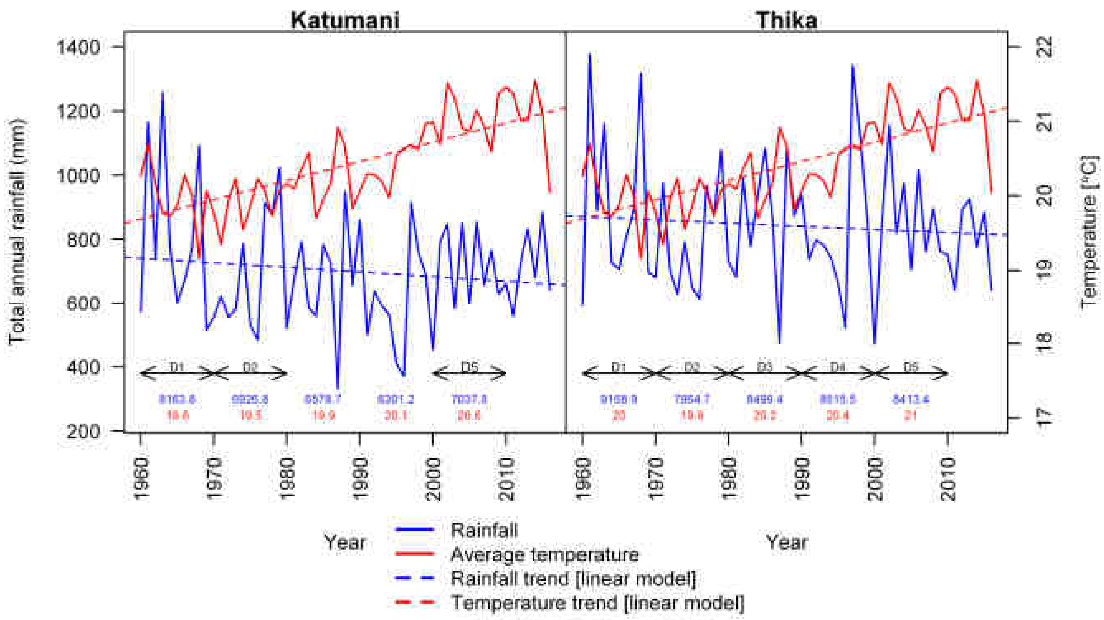

Figure 3. 2: Annual time series of rainfall and temperature in Matungulu Sub-County

Matungulu Sub-County had no reliable weather stations of its own at the time of study. Climatic data for Matungulu Sub-County was obtained from Kenya Meteorological Department's weather stations nearest to the study sites, which were Thika and Katumani.

Data used in the climatic trend analysis showed similar trends between the two stations (Figure 3.2). The two ten year average temperatures indicated that temperatures had changed from 19.6°C (1960s), 19.5°C (1970s), 19.9°C (1980s), 20.1°C (1990s), and 20.6°C (2000s) in Katumani, a general increasing trend.

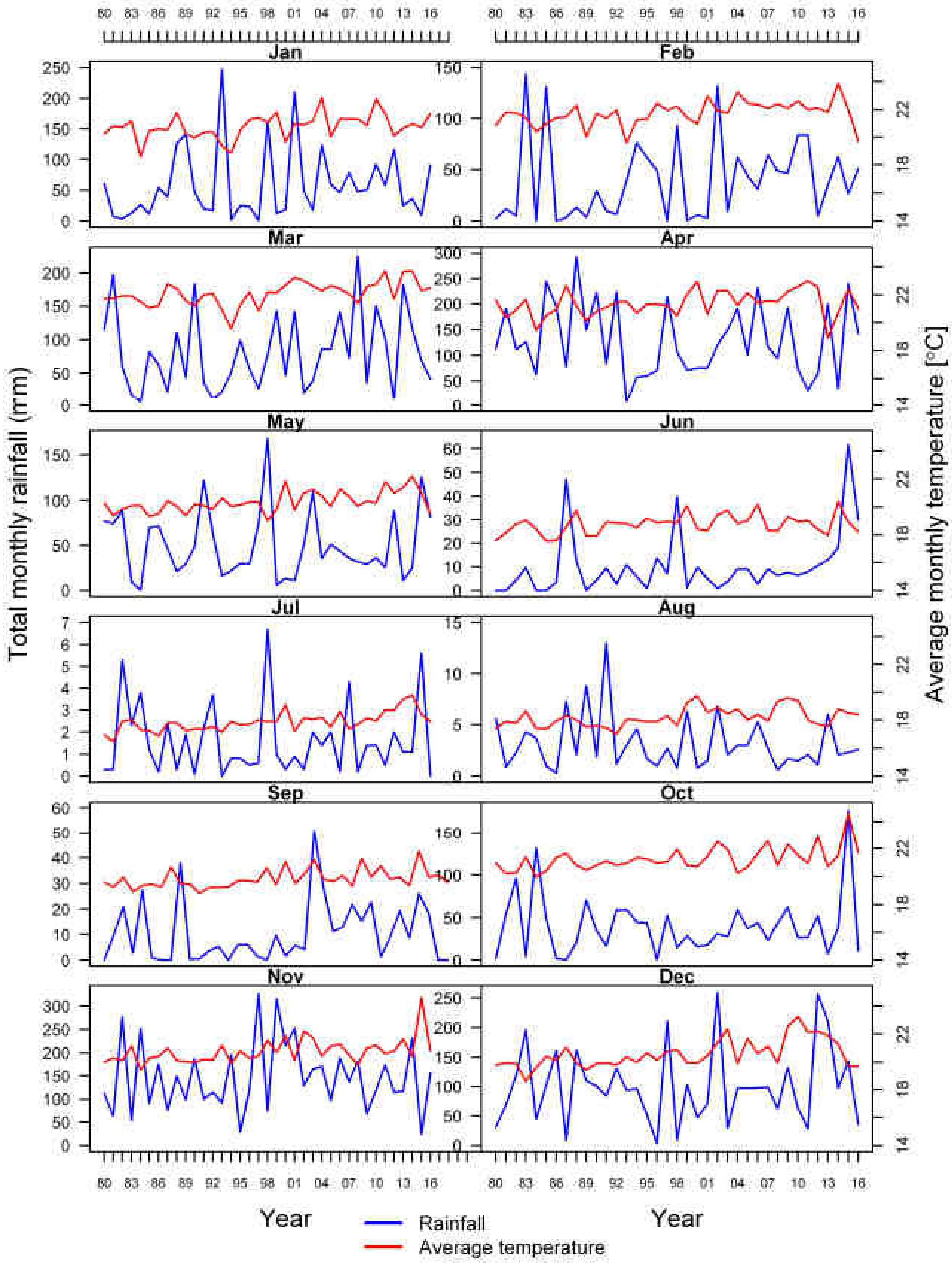

Figure 3. 3: Total monthly rainfall and average monthly temperature pattern in Matungulu Sub-County (according to Katumani station)

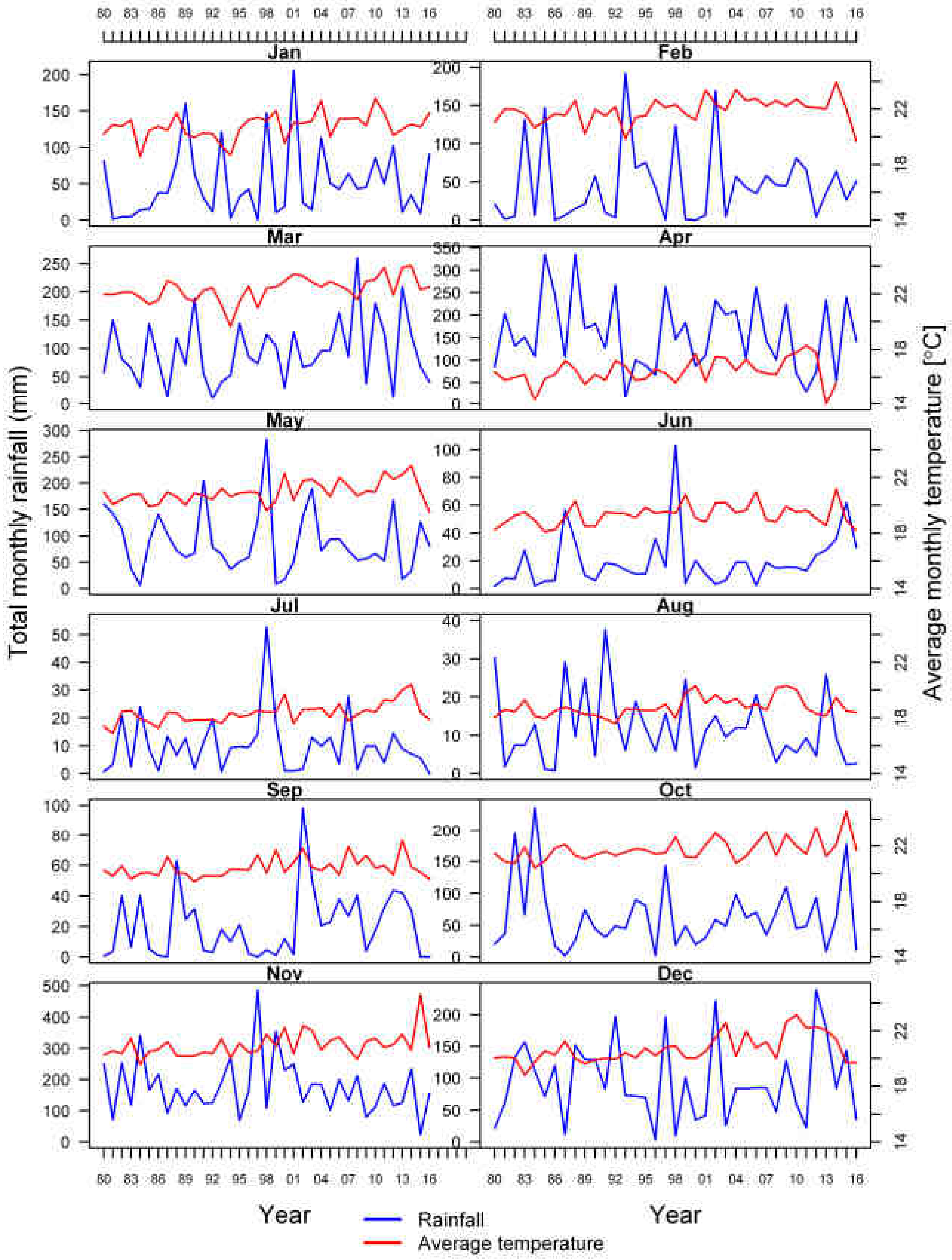

Figure 3. 4: Total monthly rainfall and average monthly temperature pattern in Matungulu Sub-County (according to Thika station)

The cumulative 10-year rainfall (sums) in Katumani reduced from 8163 mm (1960s), 6927 mm (1970s), 6579 mm (1980s), 6301 mm (1990s), and increased slightly to 7038 mm (2000s). In Thika and Katumani, the ten year cumulative rainfall and linear model indicated a decline in rainfall with time. The rainfall declined from 9169 mm (1960s cumulative rainfall), to 7965 mm (1970s), 8499 mm (1980s), 8516 mm (1990s), and increased slightly to 8413mm (2000s) in Thika. In regards to temperatures, the average decadal temperature first declined from 20.0°C (1960s) to 19.9°C (1970s), then increased successively thereafter: 20.2°C (1980s), 20.4°C (1990s) and about 21.0°C (2000s) in Thika. Figures 3.3 and 3.4 above show the rainfall and temperature patterns for the perod 1960 -2017, on a monthly basis in Katumani and Thika meteorological weather stations, which are the nearest KMD stations to the study sites. The rainfall patterns for all months showed high variability between 1960 and 2017 in Katumani and Thika, while temperatures showed a slow increase with time. During the month of October (start of short rain season), the rainfall reduced drastically from its former levels in the early 80s to the current levels in both Katumani and Thika.

Annual temperatures have increased in both sites, while total annual rainfall has declined over the last 3 decades. The monthly data demonstrated a consistent increase in temperatures during the month, but a highly variable rainfall trend within months in both study sites. Research interest on rainfall seasonal patterns by evaluation of its variables including rainfall amount, rainy days, lengths of growing seasons and dry spell frequencies has increased in the recent years, especially in semi-arid agro-ecozones (Mugalavai *et al*., 2008; Ngetich *et al*., 2014). Studies by Sivakumar (1991) and Tilahun (2006) noted high variations in annual and seasonal rainfall totals and rainy days in neighbouring Ethiopia and Sudano-Sahelian regions. The Sub-Saharan Africa sub-region is characterized by tropical and subtropical climate (Field, 2014) and has been characterized as a mostly semi-dry region with significant inter-annual, inter-decadal and multi-decadal climate and rainfall variability (Davis, 2011). Several studies (Lesolle, 2012) have found evidence that across large areas of Sub-Saharan Africa, temperatures are increasing, whereas rainfall is declining. In addition, the region has experienced several climatic hazards and extreme events that represent significant departures from the 1961 to 1990 average state of the climate system (Funder *et al*., 2013).

3.2.4 Perceived effects of climate change on tree cover in Matungulu Sub-County

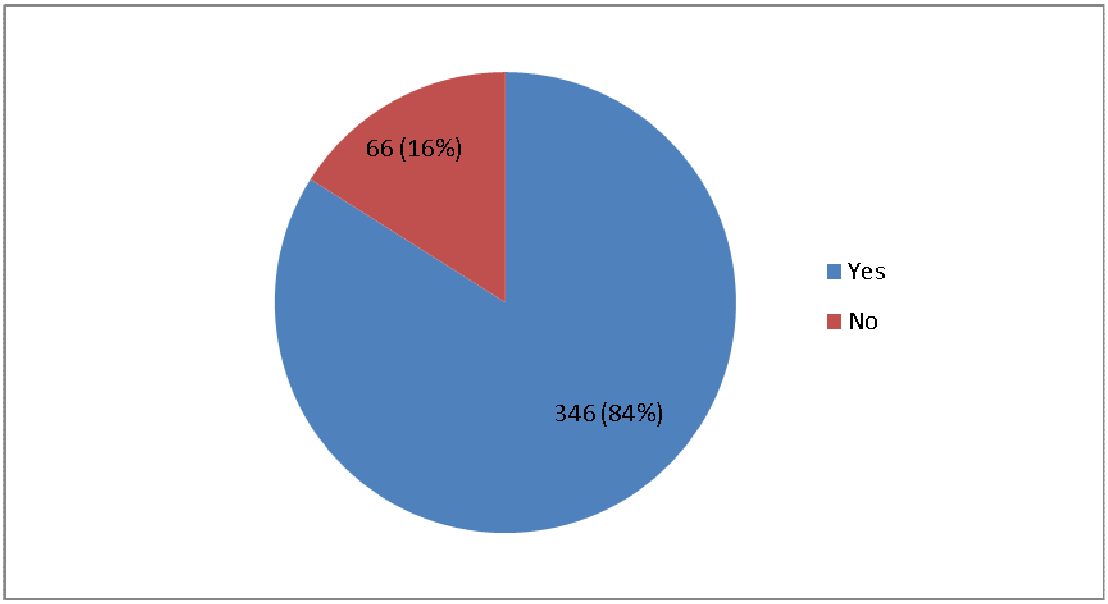

Figure 3. 5: Has climate change affected tree cover in Matungulu Sub-County?

Overall, most (84%) of the respondents thought climate change had impacted tree cover in the study area (Figure 3.5). These farmers went ahead to explain how tree species composition and density had changed in the locality over the same period, attributing it to climate change.

Table 3. 2: Farmer responses on changes in tree cover by species over the 30-year period

Affected species	Ten years ago			Twenty years ago			Thirty years ago		
	No change	Increase	Decrease	No change	Increase	Decrease	No change	Increase	Decrease
Acacia kirkii	2	5	3	1	6	2		2	2
Acacia mellifera	3	4	8	7	5	3	5	1	2
Acacia nilotica	1	8	18	4	21	2	6	14	1
Acacia seyal	31	15	47	39	33	19	27	12	9
Acacia xanthophloea	2	1	2	2	1	2	2	-	2
Annona senegalensis		3			3			-	3
Azadirachta indica	2	3	6	3	6	2	3	-	
Balanitesa egyptiaca	2	1	7	3	5	1		3	
Callistemon citrinus	5	4	4	10	3		9	1	
Carica papaya		2	4	1	3	2		1	
Casimiroa edulis			2		2			1	
Casuarina equisetifolia	5	1	10	5	10	1	7		
Citrus species	2	10	3	1	10	4	1	5	1
Combretum molle	2	1	4	1	1	5	1	1	1
Croton megalocarpus	20	38	50	21	47	39	12	27	7
Cupressus lusitanica		4	5		1	8			2
Dovyalis caffra	2	1	3	2	3	1	2		1
Eriobotrya japonica		2	3		5			5	
Eucalyptus saligna	23	127	99	33	123	90	26	46	53
Euphorbia tirucali		1	5	1	4	1		1	1
Ficus sycomorus	5	6	7	6	12		3	2	
Grevillea robusta	20	151	84	30	155	65	28	61	55
Jacaranda mimosifolia	9	24	8	5	12	23	2	2	
Landolphia buchananii		1				1			1
Macadamia integrifolia		1			1			1	
Mangifera indica	11	123	71	13	147	42	15	58	57
Morus alba		3	2		4	1		2	1
Passiflora caerulea		1	3			4			
Persea Americana	11	85	54	4	120	25	10	52	47
Pinus patula	8	11	19	20	14	4	14	4	2
Psidium guajava	1		3	1	1	1			
Schinus molle			1		1				
Spathodea campanulata	1	1		1		1			
Syzygium cumini		4	2	1	4	1		2	2
Terminalia brownii	3	5	5	3	1	9	3	1	4
Terminalia mentalis	1	8	11	9	7	4	4	2	1
Vangueria madagascariencis		2	1			3		2	
Overall farmer responses	172	657	554	227	771	366	180	309	255

Of note to farmers was the gradual replacement of a vital and resilient indigenous (natural) tree cover by a vulnerable exotic (artificial) one in the study area during the 30-year period. The respondents felt that high temperatures decreased tree cover (63%) and low temperatures would have been more or less favourable for tree cover.

According to the farmers, high rainfall increased tree cover (74.6%), while low rainfall reduced tree cover (44%). Farmers variously reported observed changes in both natural (indigenous) and planted species composition in Matungulu Sub-County over the last thirty years (Table 3.3). Some species were reported to have decreased in numbers while others have increased over the period. Respondents also reported a marked increase in overall tree cover ten years ago and twenty years ago compared to 30 years ago, mostly attributed to planted trees. The trends for major tree species in the study area showed an increase in planting of *Grevillea robusta*, *Eucalyptus saligna*, *Mangifera indica*, as indicated by farmer responses. Figure 4.12 below illustrates the overall responses and respective causes of change of tree cover species as perceived by farmers in the study area. Any preparedness towards a potentially adverse situation, including climate change, has been shown to correspond to perceptions and awareness levels among the affected individuals and/or groups (Le Dang *et al*., 2014). A similar study in Transmara, Kenya by Dallimer *et al*. (2018) found that temperature experiences surveyed in terms of length and frequency of the warmest seasons, and the associated actual feel, indicated a majority of the respondents (> 80%) perceived an upward trend and a negative impact on the environment.

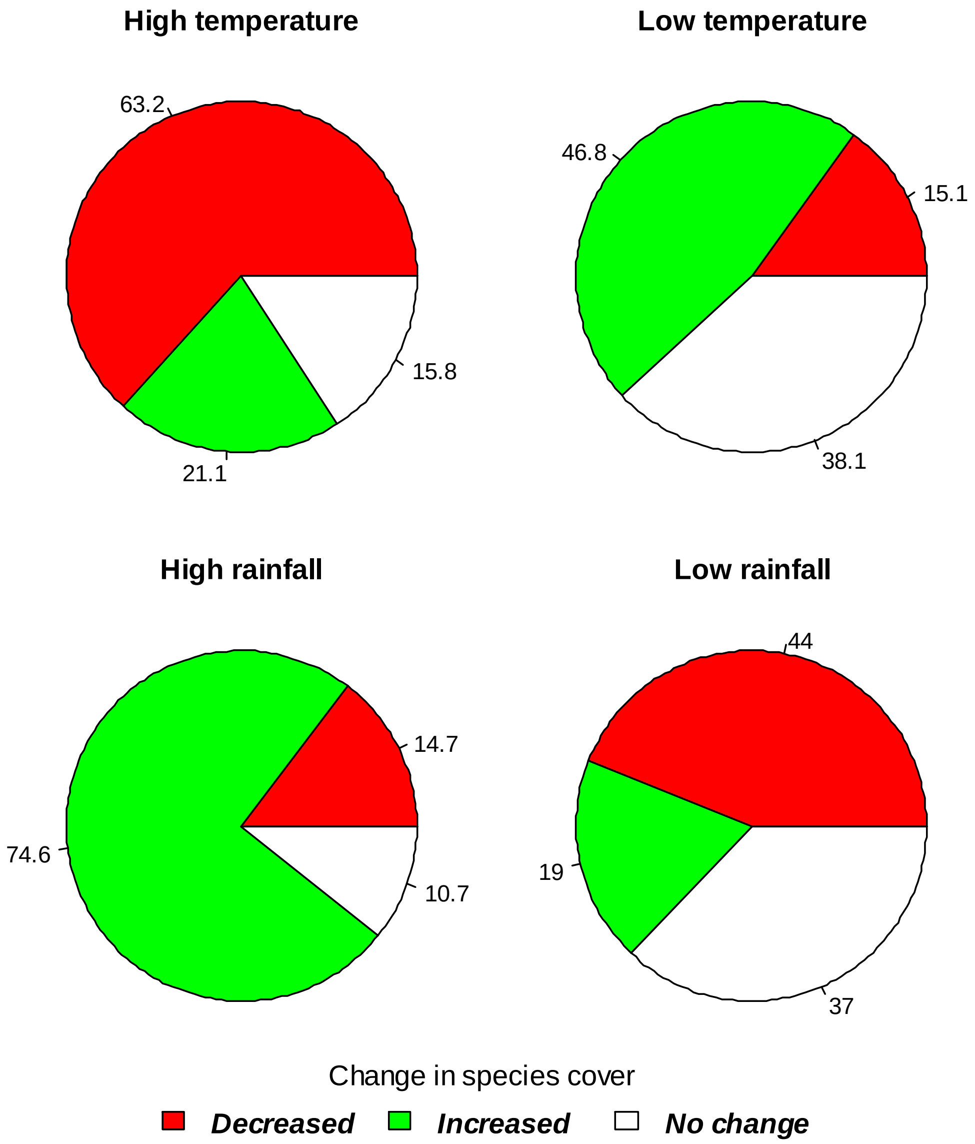

Figure 3. 6: Farmers' perception on tree cover (all species) changes and possible causes

Farmers indicated that there was an increase in the cultivation of exotic species and fruit trees in the study area, while climate changes had affected indigenous tree cover (Figure 3.6). Farmers indicated that rising temperature had reduced tree cover while decreased rainfall had reduced tree growth in some instances. Changes of average values and extremes of climate parameters that affect plant growth, development and survival, such as solar radiation, temperature, precipitation and vapour pressure deficit have been observed in Sub-Saharan Africa (Munalula *et al*., 2016). Evidence of strong relationships between tree growth and climate, particularly water availability and temperature, has been found in several studies under Sub-Saharan Africa conditions. Due to expected climate changes of increasing temperature and reduced rainfall, trees are expected to grow under more limiting conditions in future in most of the Sub-Saharan Africa region. Several researchers have used the presence of growth rings in some tropical trees to provide a means of understanding how growth and wood anatomy have been influenced by climate variability and change over time thus allowing a prediction of how tree growth can be affected by climate changes in the future (Munalula *et al*., 2016).

Mapping showed that tree cover, especially forest areas and indigenous tree cover reduced in Matungulu area from 1987 onwards, while the area under farming and settlements increased during the same period. This increase in farm-land can explain the concomitant increase in exotic tree cover, compared to indigenous trees as farmers include profitable and market-oriented tree enterprises in their farms, including Mango, Eucalyptus, Avocado and Grevillia trees. Legilisho-Kiyiapi (1995) showed that there is a growing trend in Kenya showing expansion of planted/ exotic tree cover and species diversification in farming systems which include trees, while the natural tree cover within both farmland and forested areas has continued to reduce with time. The reduction in indigenous tree cover is a concern which should be addressed by multi-pronged and multi-sectoral approaches including conserving indigenous tree species. The reported trend in increasing temperature and declining rainfall in both sites according to farmer perception has been confirmed by climatological analysis of rainfall and temperature data in Matungulu. While rainfall and weather station data was not sufficiently available for finer levels of analyses, the farmer and agro-climatic datasets in Matungulu area were consistent in describing the long-term climatic scenario in the study area.

4. CONCLUSION

Based on the foregoing results, the study concludes that farmers in Matungulu Sub-County fully perceived, understood and appreciated the phenomenon of climate change and its effects on the environment and local livelihoods. Their perception of the changing climate patterns was collaborated by analysis of scientific data obtained from local weather stations. Climate change, according to the farmers, was real. Temperatures had increased while rainfall had decreased or become less reliable. Natural indigenous tree cover had either disappeared over the last three decades or had been replaced by exotic species at farm level. The farmers are engaged, within their own limitations, in climate change adaptation and mitigation activities albeit with numerous challenges. Future climate change intervention measures should incorporate this rich indigenous knowledge of the local communities.

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