Assessment of climate variability and change in semi-arid eastern Kenya

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Abstract A study was conducted to investigate the intra-seasonal climate variability and change in semi-arid eastern Kenya and also assessed the ability of the households to discern trends in climate and how the perceived trends converge with actual long term weather observations. The study utilised long term climatic data and data collected through interviews of 200 households using a structured questionnaire. The survey data was analysed through descriptive statistics using the Statistical Package for Social Sciences (SPSS) version 12.0. The results of long term climatic data indicated high year-to-year variation in seasonal rainfall with 49.0% and 58% negative anomalies observed in the long and short rainfall seasons respectively. No discernible increasing or decreasing trend in the long- seasonal rainfall was observed over the period of study. However, Long-term temperature data showed high year-to-year variation in annual mean maximum and minimum temperatures with maximum temperature increasing during the period. Long term rainfall data (51 years) showed that 31.4 and 35.3% of the long rains would be classified as good and failed seasons respectively, with the remaining percentage classified as moderate seasons. For the short rains, 15.7 and 43.1 % would be classified as good and failed seasons respectively, with the remaining percentage classified as moderate seasons. Farmers interviewed were able to recollect the past seasons fairly accurately especially the 'good' and 'failed' seasons which corroborated well with the meteorological records. Indigenous knowledge on weather forecasting was reported by 81% of farmers to be helpful in farming decision making especialy on the types of crops to be planted. A better understanding of farmers' perceptions of climate change, ongoing adaptation measures, and the decision-making process would important to inform policies aimed at promoting sustainable adaptation of the agricultural sector.

1 Introduction

Extreme weather events such as droughts and floods are predicted to become more frequent, adding to the global burden of hunger caused by poverty, weak governance, conflict and poor market access (Beddington et al. 2012). While climate change is broadly understood as an increase in global mean temperature leading to changes in regional climate patterns, it appears

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locally as, *inter alia*, hotter days, more intense storms, less rainfall, or changes in the onset and length of growing seasons. These climatic changes in turn affect local livelihood activities, economic enterprises, health risks, and so on. Thus global climate change is translated into localised phenomena in response to local geography and other environmental, economic and socio-political factors.

Droughts are the most common disasters affecting Kenya with 28 major droughts recorded in the last 100 years, three of them occurring during in the last decade. Some of the droughts that have occurred in Kenya particularly in the semi-arid areas include the 1952–1955, 1973–1974, 1983–1984, 1992–1993, and 1998–2000 droughts. The semi-arid lands occupy over 35% of the 582,646 km^2 of Kenya land area and support over 25% of the human population as well as more than 26% of livestock (Government of Kenya 2008). Rainfall occurrence in the region is bimodal with two distinct rainy seasons; the long rains occurring from March to May and short rains from October to December. Mean total annual rainfall ranges from as low as 500 mm in the lowlands to over 1050 mm in the hill masses. Temperature and evaporation rates are generally high in the region with February and September being the hottest months of the year. Evapo-transpiration exceeds the amount of rainfall and ranges from between 1200 to 1800 mm/year (Jaetzold et al. 2006). Inter-seasonal rainfall variation is large with coefficient of variation between 45 and 58%. Persistent and widespread drought is a recurrent feature in the semi-arid areas of Kenya that has contributed to severe hardship, poverty, hunger, dislocation and even famine yet there are examples of development and environmental management strategies employed by rural populations of elsewhere in the Africa that have increased the resilience of communities for coping with drought and its effects. Due to erratic and poor rainfall crop failure usually occurs in 7 out of 10 seasons. These harsh climatic conditions make the agro-pastoralists in the semi-arid region more vulnerable to climate change impacts. Poor social, economic and environmental conditions amplify their vulnerability to the negative impacts of climate change and reduce the capacity of the affected communities to cope with and adapt to climate hazards.

Various reports indicate that when communities adopt appropriate measures, they are better able to adjust to climate change effects and cope with adverse consequences (Speranza et al. 2008; Boko et al. 2007; IPPC Report 2001). Adaptation measures are those strategies that enable the individual or the community to cope with or adjust to the impacts of the climate in the local areas (Nyong et al. 2007). Such strategies include the adoption of efficient environmental resources management practices such as the planting of early maturing crops and selective keeping of livestock in areas where rainfall is inadequate. Other strategies include the use of technological products that enable the individual to function in the "new" condition. Obviously, adaptation strategies are expected to be many, and their combinations in various ways will be required in any given location. The objectives of this study were therefore; i) to assess long term climatic trends and variability ii) to assess the ability of the households to discern trends in climate and how the perceived trends converge with actual long term weather observations. A better understanding of farmers' perceptions of climate change, ongoing adaptation measures, and the decision-making process is important to inform policies aimed at promoting successful adaptation of the agricultural sector.

2 Materials and methods

2.1 Description of the study area

The study was conducted in three purposively selected locations in Katangi, Ikombe, Ndalani and Yatta in Machakos County where season-to-season variability in rainfall dictates

productivity and profitability for marginal farmers with limited financial resources. (Fig. 1). Machakos County stretches from latitudes 0°45'S to 1°31'S from north to south and from longitudes 36°45'E and 37°45'E from east to west. The study sites were selected to represent the various settings throughout the semi-arid region of eastern Kenya in which climate change and variability are having or are expected to have substantial impacts and where people are most vulnerable to such impacts. Katangi and Ikombe fall mainly within agro-ecological zone (AEZ) V with small portions bordering Yatta in AEZ IV. All sites exhibit low and variable rainfall with a bimodal rainfall pattern, with rains occurring from March to May, and from October to December and experience regular drought-related harvest failures. Mixed crop-livestock production systems are the main enterprises with the major crops being maize, mung beans, pigeon peas and sorghum. Indigenous chickens, small East African goats and zebu cattle are the main livestock species reared. In Yatta both rainfed and irrigated agriculture are practised. Irrigation is facilitated through the Yatta furrow canal constructed in the 1950s. The predominant soils are the luvisols, acrisols and ferralsols derived from the pre-Cambrian 'basement-complex' rocks consisting of mainly granites, gneisses and sometimes sandstones or phyllitic shales and are inherently deficient in N and P and have low organic matter (de Jager et al. 1998).

2.2 Long-term climatic data

Annual mean rainfall for both Long and Short rains recorded at Katumani weather station at 1580 m above seal level (ASL) were analysed for temporal trends and spatial variation patterns
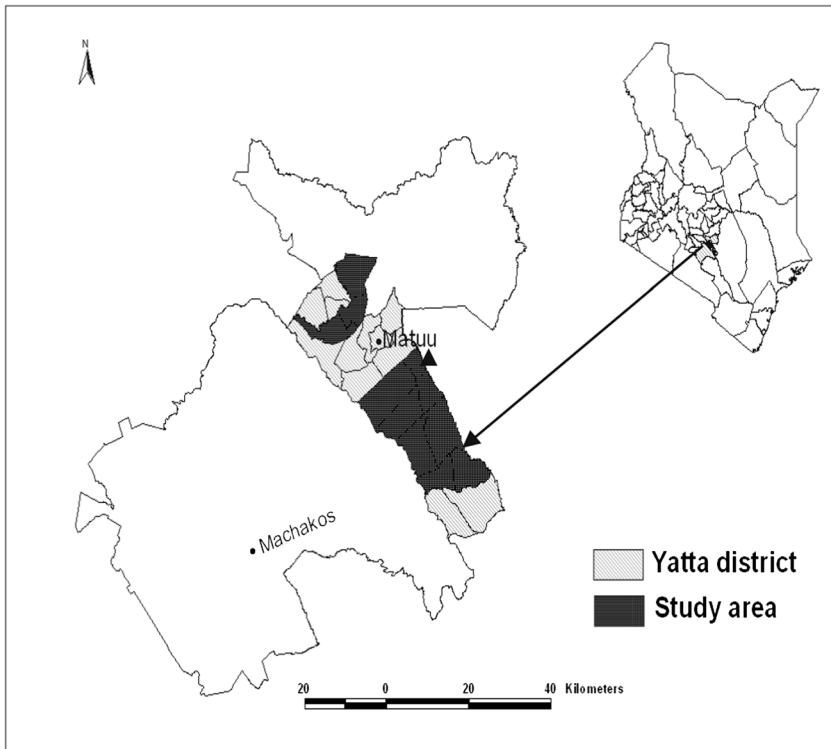

Fig. 1 Location of study area

during the period 1961–2011. In addition, annual mean maximum and minimum surface air temperatures were also analysed for trends and spatial variation patterns during the period 1978–2011. Examination of the changes in variation patterns in the past can not only establish a foundation for a better understanding to recent climatic changes, but may also provide a historical analog that can be used to estimate the range of possible responses of the climatic system to global warming.

2.3 Household interviews

The assessment of farmers' ability to recollect the seasonal conditions that occurred during the past 20 years, their source of weather information and constraints to adaptation on the farming community in the four study areas was assessed using field surveys conducted on individual household interviews in September 2014 using a structured questionnaire. From each of the selected locations of Katangi, Ikombe, Ndalani and Yatta of Machakos County, 50 house-holds were randomly selected from a list of house-holds provided by the area chiefs. A systematic random sampling was carried out until the desired sample size was achieved. Face-to-face single visit interview, discussion and observation were used to collect the information. A total of 200 questionnaires were administered in the four locations in Machakos County of Kenya.

3 Data analysis

3.1 Long-term climatic data

The data were subjected to a vigorous quality assessment procedure to eliminate any spurious values. Great efforts were made to ensure that extreme values within the data set are true events, rather than errors. Temperature and seasonal rainfall trends were fitted using a regression method in MS Excel 2007 software. Inter-annual variability in rainfall and temperature was evaluated by calculating the standardised anomalies for rainfall (SRA) and temperature (STA) using the following equation (Oliver 1980).

$$SRA = Pt - Pm/\sigma$$

Where Pt is annual rainfall in year t, Pm is long-term mean annual rainfall over the period of observation and σ is standard deviation of rainfall. For calculation of standardised anomalies for temperature (STA), rainfall in the above equation was replaced with temperature.

To contrast the perceptions of farmers on the nature of past seasons with scientific data, the seasons were classified into two categories, based on the deviation from the long-term mean. Seasons with in excess of 25% of the long-term mean were classified as good and those with rainfall less than 25% below the long-term mean as poor.

3.2 Household interviews

The data collected was analysed through descriptive statistics using the Statistical Package for Social Sciences (SPSS Inc. 2003) version 12.0. Descriptive results of the household survey related to farmers' climate change perceptions and climatic information options are presented.

4 Results and discussion

4.1 Rainfall trends and standardised rainfall anomalies

Results of the long-term (51 years) rainfall data for Katumani weather station analysed for broad trends are shown in Fig. 2a, b. Cyclic variations in long- and short-season rainfall obtained by constructing standardized rainfall anomalies are shown in Figs. 3a, b. There was high year-to-year variation in seasonal rainfall with 49.0% and 58% negative anomalies observed in the long and short rains rainfall respectively. After the 1970s, the fluctuations in rainfall are dominated by short period cycles of about 5-year durations that normally coincide with the swings in the El Niño/La Niña-Southern Oscillation. No discernible increasing or decreasing trend in the long- rains rainfall was observed over the period of study.

4.2 Season rainfall classification

To contrast the perceptions of farmers on the nature of past seasons with scientific data, the seasons were classified into two categories, based on the deviation from the long-term mean. Seasons with a rainfall in excess of 25% of the long-term mean were classified as good and those with rainfall less than 25% below the long-term mean as failed seasons. Long term rainfall data (51 years) showed that 31.4 and 35.3% of the long rains would be classified as good and failed seasons respectively, with the remaining percentage classified as moderate seasons. For the short rains, 15.7 and 43.1 % would be classified as good and failed seasons respectively, with the remaining percentage classified as moderate seasons (Figs. 4a, b).

4.3 Temperature trends and standardised anomalies

Long-term (31 years) temperature data for Katumani weather station showed that there was high year-to-year variation in annual mean maximum and minimum temperatures. The 12 years 2000–2011 were the warmest period with 2010 being the single hottest year (Figs. 5a and 6a). The main contribution to the warming trend was from the maximum temperature values,
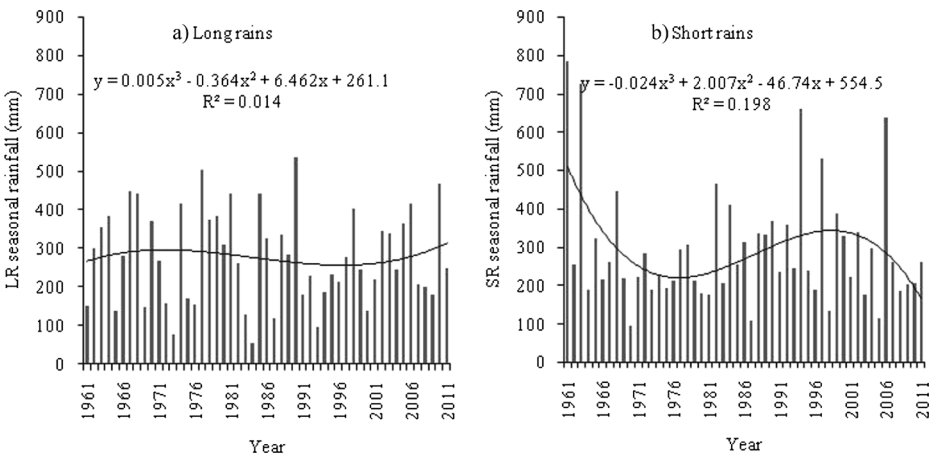

Fig. 2 Seasonal rainfall trends **a)** Long rains (LR) and b) short rains (SR)
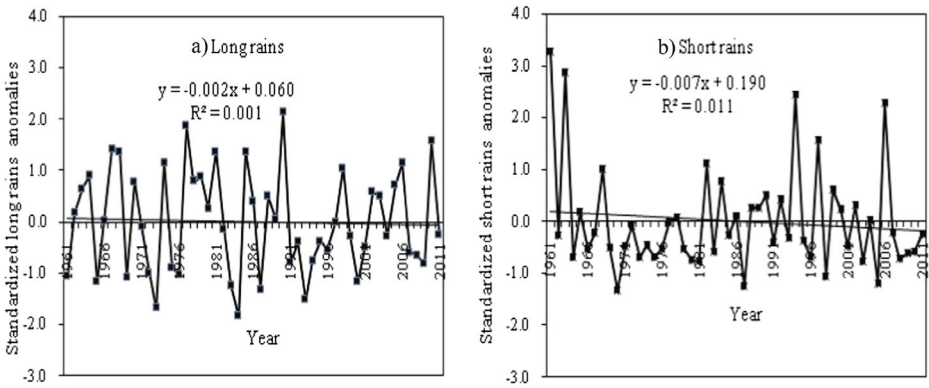
Fig. 3 Standardized rainfall anomalies **a)** Long rains **b)** short rains

which increased during the period (Fig. 5a). There was a general increase in maximum temperature by 1 °C (Fig. 5a) and 0.3 °C for minimum temperature (Fig. 6b) between 1978 and 2011 which is consistent with the IPCC temperature projections (Christensen et al. 2007) for eastern Africa. The trend slope of maximum temperature anomalies was more than twice that of the minimum temperature anomalies, equivalent to a rate increase of 0.1 °C/10 years as compared to a rate of 0.3 °C for every 10 years in the maximum temperature anomalies (Figs. 6a, b). This warming may exacerbate evaporation and crop water deficits while the rainfall is declining. Global circulation models predict that global warming will lead to increased temperatures of about 4 °C and cause variability of rainfall by up to 20% in Kenya by the year 2030. From these predictions, the two extreme climate events that may adversely affect the agricultural sector are drought (crop water stress leading to declining yields). The overall adverse weather events that may occur because of the projected climate change could
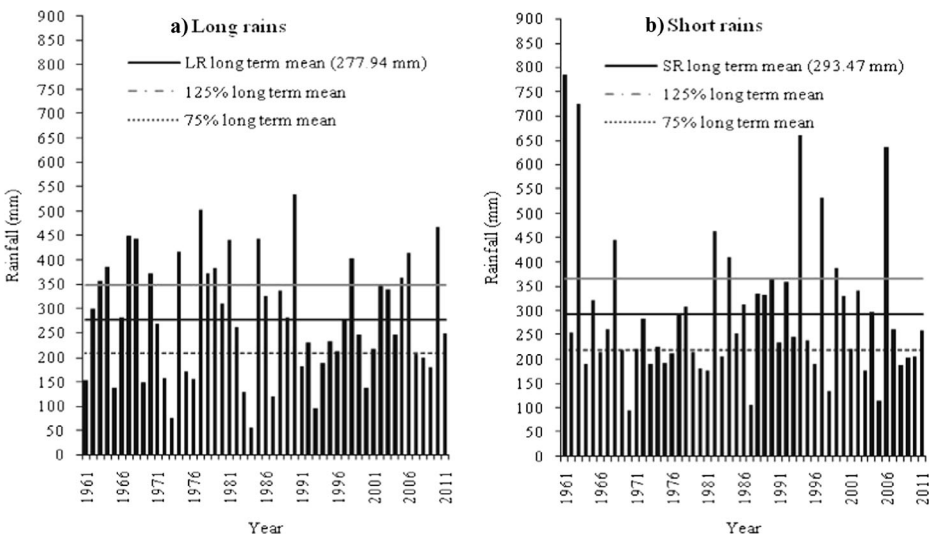

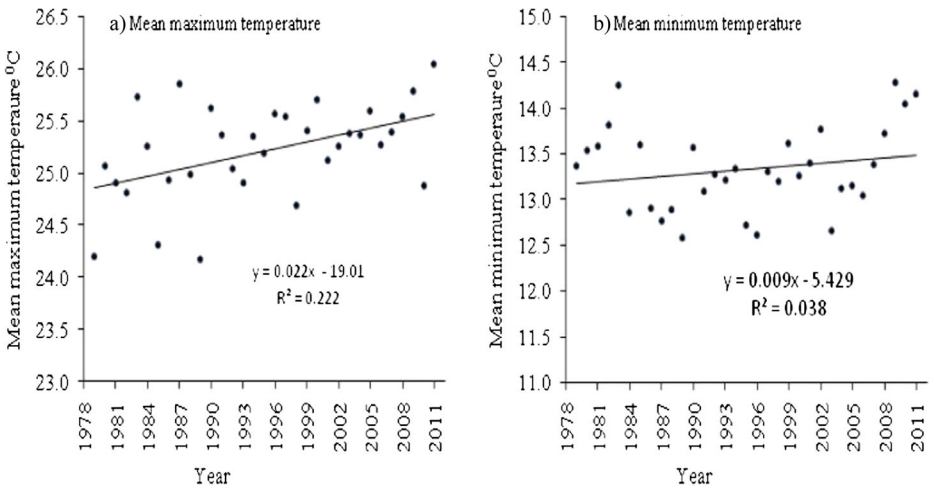**Fig. 4** Seasonal rainfall classification **a)** Long rains **b)** short rains

Fig. 5 Annual mean temperature trends a) Maximum temperature b) Minimum temperature

have severe socio-economic impacts such as food, water and energy shortages, shortage of other essential basic commodities, and long-term food insecurity.

4.4 Characteristics of the household heads

Previous research has identified social characteristics such as gender, age, wealth status and education that are associated with vulnerability and has distinguished between vulnerable groups in society (Eriksen et al. 2005). Independently or combined, these determinants shape the way in which people are able to reduce exposure to, cope with, and/or recover from negative impacts of climate change or, alternatively, take advantage of the opportunities afforded by climate change. Table 1 shows the characteristics of farmers in the study area. The main occupation of household head was farming (73%) with 93% of them having formal education. The age of household heads varied from 28 to 80 years with a mean of 51 years.
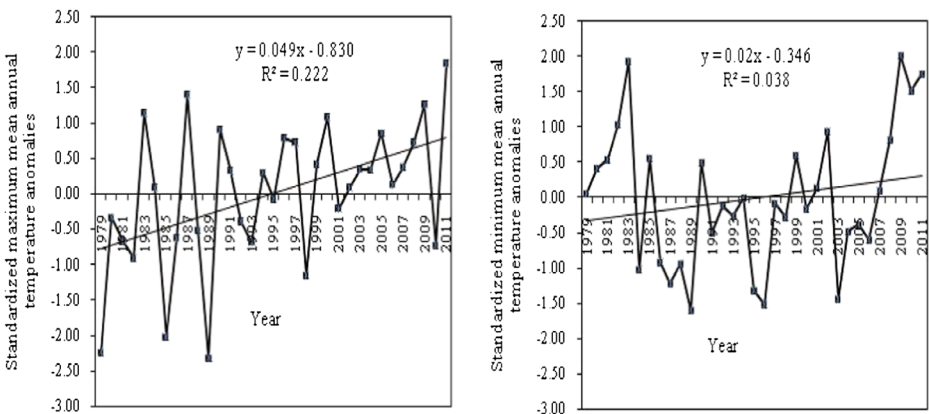

Fig. 6 Standardised temperature anomalies a) Maximum temperature b) Minimum temperature

Table 1 Socio-demographic characteristics of the household heads

Characteristic	% of households
Gender	
Male	79.8
Female	20.2
Education level of household head	
None	7.1
Primary	48.5
Secondary	33.7
Post secondary	10.7
Main occupation of household head	
Farming	73.1
Formal employment	11.2
Self employment/business	15.7
Characteristic	Mean
Age (years)	51.3 (9.8)
Farm size (acres)	10.4 (11.1)
Area under crops (acres)	5.8 (4.1)
Area under pastures (acres)	3.9 (2.7)

Number in parenthesis is the standard deviation

Farm sizes varied from 0.8 to 52.2 hectares with a mean of 4 hectares while the mean area under crops was 6 acres.

4.5 Farmers perception of climate change

While all 200 farmers interviewed were able to recollect how the season that preceded the survey was, only 42, 27, and 13% of the interviewed farmers were able to recollect the conditions that existed during the past 5, 10 and 20 years, respectively. On perception of climate change 98.5% of farmers reported that there has been an increase in temperature and
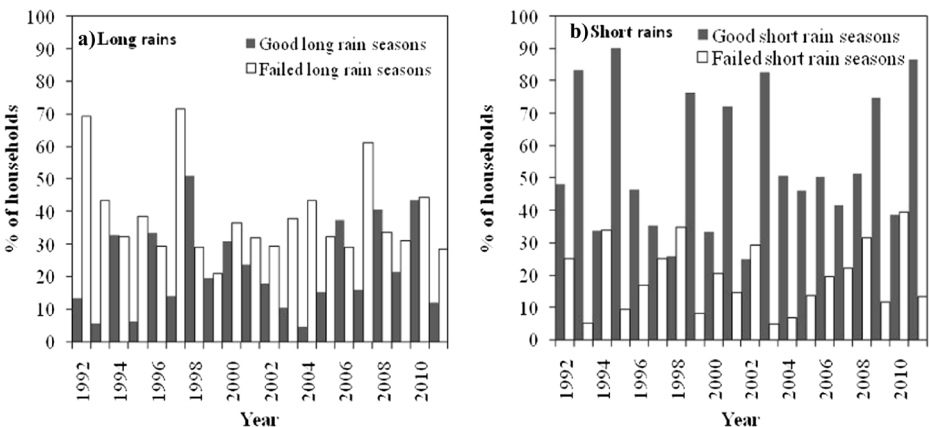

Fig. 7 Farmers' perception on nature **a)** long rains seasons **b)** short rains seasons over 20 years

98% reported a decrease in rainfall amount over the period they could recall. Concerning rainfall variability, 98% of farmers reported late onset of rains and 96% reported that rainfall had become more erratic while 90% reported prolonged drought periods. These findings are consistence with other results reported elsewhere in Africa indicating that a majority of the farmers have identified declining rainfall and increased variability in the distribution of rainfall within and across the seasons as major problems (Bryan et al. 2011; Nyong et al. 2007; Thomas et al. 2007).

Figures 7a, b show farmers' classification of good and failed long and short rain seasons from 1992 to 2010. Understanding the trends in complex and variable phenomena such as rainfall is not straightforward and doubts have been expressed on the ability of farmers to accurately discern climate trends from their casual observations, the completeness of their assessment since they represent simplified versions of a complex reality (Sattler and Nagel 2010). Further, farmers' perceptions are also likely to be shaped by the agro-economic performance of crops and other farm enterprises that affect their livelihood where climate is only one of the many bio-physical and socio-economic factors that affect productivity (Cooper et al. 2008). Though the local people may not understand the science of climate change, they rightly observe and feel its effects. Farmers cited reduced crop yields and inability to grow some crops that they were growing before which perhaps in addition to climate change could be as a result of declining soil fertility and greater land use intensity.

Farmers interviewed were able to recollect the past seasons fairly accurately especially the 'good' and 'failed' seasons which corroborated well with the meteorological records. This can be expected considering the high impact these events have on overall performance of the farming system particularly on maize production which is grown by all farmers in all seasons. For instance, over 30% of farmers classified the years 1994, 1996, 1998, 2000, 2006, 2008 and 2010 long rains seasons as 'good' (Fig. 7a). From analysis of rainfall data (Fig. 4a), only 1998, 2005, 2006 and 2010 long rains can be classified as 'good'. Over 50% of farmers classified the years 1993, 1995, 1999, 2001, 2003, 2004, 2006, 2008, 2009 and 2011 short rains season as 'good' (Fig. 7b), whereas from meteorological data (1992–2011), only 1994, 1997, 1999 and 2006 short rains seasons are classified as 'good' (Fig. 4b). However, these perseptions may be subjective mainly due to the compounding interactions between climate and other factors such as soil fertility, soil water and land use change that determine the climate's overall influence on crop productivity. Overall, majority of famers perceive shorts rains to be more reliable than long rains (Figs. 7a, b). Temperature increases that have been observed in the region (Fig. 5a) have a significant impact on water availability, thus exacerbating drought conditions. Therefore, farmers' perceptions may be based on a decrease in water availability. Perceptions may also be influenced by more recent climate trends such as the prolonged and severe droughts and rising temperatures during the 1990s (Ogutu et al. 2007) and. by the agro-economic performance of crops and other farm enterprises that affect their livelihood where climate is only one of the many bio-physical and socio-economic factors that affect productivity. Farmers' concerns about changes in rainfall variability are warranted given that rainfed agriculture is the dominant source of staple food and cash crop production and livelihood for the majority of the rural poor. Climate variability, in particular the occurrence of drought is a robust determinant of agricultural performance as well as general economic performance in Kenya (Herrero et al. 2010).

4.6 Climate information

Climate information is an important determinant for changing planting dates in response to changing weather patterns. The main type of climate information that farmers reported having

access to were daily weather forecasts, advisories and alerts/early warning. Daily weather forecasts were accessed through radio (97%), while advisories and alerts were accessed through *barazas* (gatherings convened by local administrators) (56%). Though not reliable as reported by 65% of farmers, daily weather forecasts were the most easily accessible and timely climate information. Alerts/early warning was more relevant as reported by 72% of farmers and was easily accessible. Seventy two percent of farmers indicated that they had indigenous knowledge and skills (ITS) on weather forecasting and could predict a wet and a dry season based on the behaviour of animals and plants. Indigenous knowledge on weather forecasting was reported by 81% of farmers to be helpful in farming decision making especialy on the types of crops to be planted. Traditional knowledge of local communities represents an important, yet currently largely under-used resource. Empirical knowledge from past experience in dealing with climate-related natural disasters such as droughts as well as longer term trends in mean conditions can be particularly helpful in understanding the coping strategies and adaptive capacity of communities relying on oral traditions. The role and value of this local indigenous knowledge in designing appropriate research and development of practical and realistic approaches that facilitate smallholder farmers in adapting to impacts of current and future climates is well documented (Agrawal 1995; Chambers et al. 1989; Richards 1985; Pretty et al. 1999).

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