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Climate change adaptive capacity and smallholder farming in Trans-Mara East sub-County, Kenya

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Abstract

Background: At the centre of smallholders' adaptation is a need to understand their perceptions on key climatic scenarios so as to glean helpful information for key decision-making processes. In Kenya at the moment, downstream information regarding these circumstances remain scanty, with many smallholders being 'on their own', in spite of the imminent threats from shifting precipitation patterns, rising temperatures, and intensifying droughts. At the sub-national levels, potential impacts of these situations are likely to deepen due to extensive cases of land use transformations, habitat degradation, plummeting water resources capacity and common inter-ethnic conflicts, among other negative externalities. The study examined current climatic situations in Trans-Mara East sub-County, to the south-western part of Kenya, as well as the smallholders' perceptions about the situations, their adaptation levels and constraints thereof.

Results: Pearson correlation coefficient, indicated a weak positive association between smallholder's perceptions and either their age, marital status, level of education, or livelihood streams ($r \leq 0.1$; $p \geq 0.05$, for all), unlike their climatic perceptions and farm sizes which showed a strong positive association ($r = 0.430$; $p \leq 0.01$). Key desired adaptation options, improving crop varieties, livestock feeding techniques and crop diversification, topped their options, with destocking being least desired. Education levels ($r = 0.229$; $p \leq 0.05$) and farm sizes ($r = 0.534$; $p \leq 0.01$) had a positively significant association with adaptive capacity, in addition to a significantly weak, association between their adaptive capacity and both their individual's marital status ($r = 0.154$; $p \geq 0.05$) and diversity of livelihood streams ($r = 0.034$; $p \geq 0.05$). The analysis also showed a weak negative association between their adaptive capacity and age ($r = -0.026$; $p \geq 0.05$). Amid the key constraints which emerged include high cost of farm inputs, limited access to credit and market uncertainties, among others. Pearson correlation coefficient showed a significantly strong negative association between smallholders' constraints and both ($r \geq -0.3$; $p \leq 0.01$) their level of education, and diversity of livelihood streams. A significantly strong positive association ($r = 0.280$; $p \leq 0.01$) was identified between smallholder's age and constraints, while marital status and farm sizes both ($r \leq -0.01$; $p \geq 0.05$) revealed weak non-significant negative association with the constraints.

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Conclusions: Trans-Mara East sub-County has been grappling with a number of climate-related challenges. These were manifested through increased rainfall uncertainties, intensifying droughts, and rising temperatures, with effects on crop and livestock performances in the area, accompanied by plummeting household food security and income positions. Besides, smallholders' perceptions intersected with various intervening subtleties. Smallholders' adaptive capacity in the area, was largely not associated with their socioeconomic characteristics as most of the respective components such as education, and livelihood streams, were barely fully-fledged. Moreover, the constraints against their adaptive capacity were mainly related to the existing policies and their respective implementations at the downstream levels with limited attribution to the farm-level interventions. It is thus incumbent upon the decision-makers, and other key stakeholders to explore avenues for amplifying the smallholders' desired adaptation schemes while down-sizing the existing adaptation bottlenecks in the area.

Keywords: Climate variability and change, Perceptions, Adaptation, Smallholders, Trans-Mara

Background

Global climate change manifested through rising temperatures, changing patterns of precipitation, and rising atmospheric carbon dioxide is poised to become a key driver of smallholder performances across many parts of the developing world in the current century (Campbell et al. 2016; Raworth 2007). Among the key socio-economic impacts of the scenarios include shifts in the productivity of major cereal and horticultural crops (Singh et al. 2015; Tittonell and Giller 2013) with a net adverse effects on the food security situations and income levels among many agricultural-dependent economies (Mertz et al. 2009b). For instance, in sub-Saharan Africa, this situation is likely to disrupt huge proportions of their economies whose main contribution emanates from agriculture dominated by smallholder output (Moyo et al. 2012; Mutunga et al. 2017). Specifically, in Kenya, rainfall-dependent smallholders are responsible for up to 70% of the agricultural output (Raworth 2007; Silvestri et al. 2015), which is essential to household food security and income flows in nearly all the rural areas (Mikalitsa 2015; Oluoko-Odingo 2011). Thus, the climatic shifts will not only affect the smallholders, but also the country's economy.

Nonetheless, adaptation (Field 2012) has been floated as the only immediate option for cushioning smallholders, among other vulnerable groups (Labbé et al. 2016; Opiyo et al. 2015), and ecosystems against the imminent impacts of climate change. As a result, various models (Gornott and Wechsung 2016; Hoetker 2007) have been put forward on smallholder responses to these situations, and are likely to drive the approaches to climate change adaptation and specific decisions regarding the mitigation plans (Le Dang et al. 2014; Labbé et al. 2016). But, significant actions by decision-makers and other key stakeholders may not be easily effected until there is a unified approach to the available knowledge and information regarding the actual state and trends at the downstream levels (Mertz et al. 2009a). Thus the need for more empirical studies such as this one.

The study was therefore set out to operationalize a number of objectives. The first objective entailed examining the existing meteorological data on rainfall and temperatures for the area from 1980 to 2015. Data resulting from such a process can easily help in understanding the existence and magnitude of any shift in the climatic situations. Secondly, the study sought to assess smallholder's perceptions about the area's climatic situations. The third objective targeted to evaluate current, and desired, adaptation options and ranking the resulting data using a Weighted Average Index (Ndamani and Watanabe 2015). Moreover, the final objective sought to assess smallholder adaptation constraints using the Problem Confrontational Index (Deressa et al. 2011).

The approach taken by this study i.e. looking at the situation at the downstream levels as opposed to the national level was deemed appropriate owing to the current systems of governance in Kenya (Thugge et al. 2011; Wiesmann et al. 2014). In particular, the implementation of environmental conservation and agricultural policies, among other key directives, have been largely decentralized to the sub-national levels of administration. Thus, adaptation constraints such as poor road networks and limited value addition options for agricultural output can easily be dealt with at the sub-national levels (Wiesmann et al. 2014).

Knowledge and information access on the status and trends in smallholder adaptation to climate change are critical to improving household food security and nutrition as well as income flows and reducing poverty and inequality across many parts of the developing world in a bottom-up approach (Oluoko-Odingo 2011; Wambua and Omoke 2014). And in the process of unpacking data to support such dialogues, it is imperative to understand the smallholders' perceptions about the climatic situations and associated risks at specific geographical locations, as this is fundamental to their preparedness and subsequent adaptation strategies which have been shown to subtly vary from one region to the other (Raworth 2007; Silvestri et al. 2015).

These perceptions can be assessed against the existing meteorological data in order to close any gaps thereto (Field 2012). Besides, it is also vital to examine the factors impinging smallholders against their quest to adopting various adaptation options, so as to properly inform the requisite priorities. Broadening such adaptation discourses through empirical research helps in making information more accessible with a high plausibility of enhancing the quality of key decision-making processes. In the end, the outcome of such actions will not only be of great benefit to the targeted smallholders, but also other vulnerable groups (Opiyo et al. 2015).

The present study identified Trans-Mara East sub-County in the south-western part of Kenya as an ideal case for making a contribution into current discourses about smallholders in the face of shifting climatic scenarios. This sub-County is one of the areas whose farming activities are likely to be affected by the overarching threats from climate change and variability, due to reported cases of land use transformations, habitat degradation, dwindling groundwater resources and common inter-ethnic conflicts (Kipsisei 2011; Nyamwaro et al. 2006). Such anthropogenic disorders have been shown to exacerbate the impacts of climate change on people and ecosystems (Mertz et al. 2009a; Raworth 2007).

Methods

Study area

Trans-Mara East sub-County, Kenya, is one of the five sub-Counties in Narok County that was carved out of Trans-Mara District in 2012. It borders Bomet County to the north, Nyamira and Kisii counties to the north-west, Trans-Mara West to the western part, and Narok West to both the eastern and southern parts (Wiesmann et al. 2014). It lies within latitude 0° 50′ and 6° 50′ south and longitudes 34° 35′ and 35° 14′ East, with a mean altitude of 1450 m above sea level, and area coverage of 320.5 km^2, and is divided into four administrative wards, i.e. Ilkerin, Kapsasian, Mogondo, and Ololmasani (Fig. 1). In the Kenya's 2009 national population census, the sub-County has a rural population of 94,115, with both the KNBS[1] and CRA[2] 2015 estimates being 105,879, out of whom 22,488 were smallholders distributed in each Ward as 6297 (Ilkerin); 5599 (Kapsasian), 4205 (Mogondo), and 6387 (Ololmasani). Besides, the sub-County falls within a transitional zone of agro-ecological zones III and IV, and is characterised by a bimodal rainfall of 450–900 mm per annum, which peak in March to May and November to December, with mean annual temperatures of 17.8 °C. It is also characterized by gently undulating landscapes which generally slope from west to east, with largely black cotton soils (Kipsisei 2011; Nyamwaro et al. 2006). The main crops grown in the area include cereals, pulses, fruit and vegetable crops, among others, while the main livestock rearing activities involve cattle, goats, sheep, donkeys, and chicken, with nearly all smallholders practicing mixed-cropping systems (Wiesmann et al. 2014).

Research methods

This study employed a cross-sectional survey (Kothari 2004) which captured data from the farming households across the four administrative Wards in Trans-Mara East sub-County between February and October 2016. Thus, from a sample population of 22,488 smallholders,

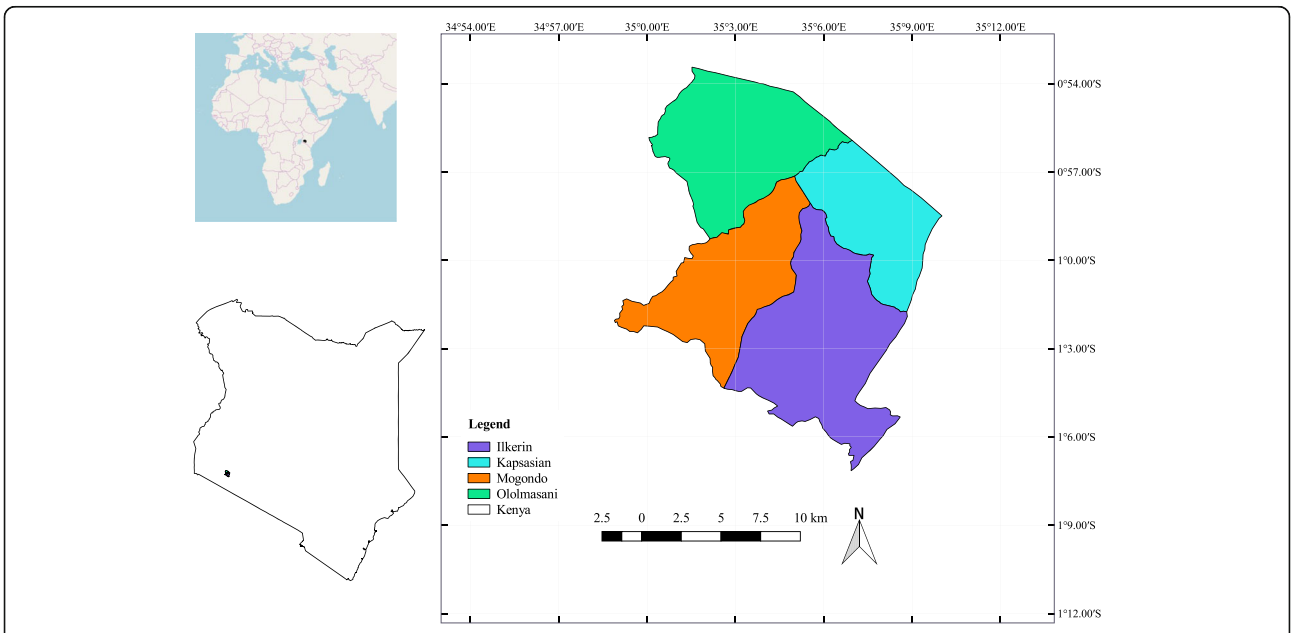

Fig. 1 A map showing location of the study area in Kenya (Source: Adapted from Survey of Kenya, 2017).

a sample size of 100 households was drawn using the Nassiuma (2000) model. Questionnaire surveys were then distributed according to the household densities per Ward, as 28 (Ilkerin), 19 (Mogondo), 25 (Kapsasian), and 28 (Ololmasani). This process was augmented with four focus group discussions – one per Ward, and 13 key informant interviews (Field 2009; Kothari 2004).

Field data collation and analysis was performed using Statistical Package for Social Sciences (version 21) described in Field (2009). The resultant frequency summary for the smallholders' demographics, livelihood streams, and adaptation status. The current adaptation measures in the area, with the perceived level of importance of the each of strategies, were analysed, from the data which required respondents to allocate scores based on a Likert scale of 0–3 as done by Ndamani and Watanabe (2015). And in this process, values 0 and 3 were used to denote the lowest and highest levels of importance, respectively. Besides, an evaluation of the practices was performed using a weighted average index (Devkota et al. 2017; Ndamani and Watanabe 2015), where each practice got a specific rank to denote their level of importance, as follows;

$$\text{Weighted Average Index (WAI)} = \sum(F_i W_i)/\sum F_i \quad (1)$$

(F = frequency of a score's occurrence; W = weight of each score; i = score).

To assess the magnitude of the bottlenecks limiting smallholders from adopting robust strategies against climate variability shocks in the area, a Problem Confrontational Index (PCI) was applied (Uddin et al. 2014). This index entailed a process of evaluating perceived constraints on a Likert scale from the least to the highly impactful elements. In the study, PCI value was obtained as follows:

$$\text{PCI} = [(P_n \times 0) + (P_1 \times 1) + (P_m \times 2) + (P_h \times 3)]/100 \quad (2)$$

(P_n responses grading an element as non-issue; P_1 responses grading an element as low; P_m responses grading the element as moderate; P_h responses grading the element as high).

Besides, Pearson Correlation analysis (Field 2009) was used to ascertain the magnitude and direction of relationships between key socio-economic variables and the farmer's perceptions, adaptation status, and constraints thereto. This process entailed a computation of correlation coefficient (r), obtained using Eq. 3 below:

$$r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{(N-1)S_x S_y} \quad (3)$$

where x = first variable; y = second variable; Sx = variance of the first variable, Sy = variance of the second variable.

Results and discussions

Features of the sample

Demographic characteristics

Majority of the smallholders encountered in the area were from age 35 and above (76%), with the youthful – in spite being the majority, constituting a small portion (24%) of smallholders in the area. Further, mean and median age of smallholders in the area were found to be 42 and 40 years, respectively. These observations agree with other studies across the sub-Saharan Africa and rest of the world, which have shown an "ageing farmer population". Such a situation harbour potentially adverse ramifications on the future food security and overall agricultural productivity, amidst the burgeoning populations in Kenya, as is the case in other developing countries. Bulging populations, especially in urban areas, demand commensurate upturn in food resources.

Further, of all the respondents, the males constituted 47%, while the females were 53%. All the males were found to be *de jure* house hold heads. On the contrary, female respondents were either sharing responsibilities with their male counterparts, as married couples (69.8%), or entirely being responsible for all household farming decisions as single mothers (30.2%). Many studies (Khisa et al. 2014; Mikalitsa 2010; Oluoko-Odingo 2011) have pointed out a possibly high vulnerability of single-headed households to weather-related challenges in farming. The current study, however, did not establish the plausibility of this claim. The situation in the study area could have differed from those of other studies as most of the single head households had additional off-farm livelihood streams.

Educational levels

Majority of the respondents had attained primary school level (55%) only, while the lowest part of their population had tertiary education (9%). Besides, access to education also varied with the respondents' age, with the younger members of the population being more educated than their older counterparts. Such scenarios are likely to affect the adoption of new farming technologies. Various studies (Kassie et al. 2014; Oluoko-Odingo 2009; Pérez et al. 2015) have revealed the existence of an association between the level of education and adaptation against adverse environmental challenges.

Livelihood streams

Majority of the smallholders (83%) entirely relied on farming as a source of livelihood, with only 17% of them having additional livelihood options from off-farm income streams, across the area. Farmers' response

capacity to impacts of climate variability and change have been shown to closely associate with diversity of their livelihood streams (Nielsen and Reenberg 2010). Thus, from the aforementioned observation, it is most likely that most of the farmers in the study area would easily have limited capacity to cope with the resultant impacts (Field 2012). Such a situation can be remedied by widening diffusion of innovative strategies that will dispose the smallholders to opportunities with which they can diversify their livelihood systems (Oluoko-Odingo 2011).

Farm sizes

The study found many of the respondents' (33%) owning farm sizes which ranged between 2.1 and 2.5 ha. Out of this figure, huge portions of the farm were set aside for maize cultivation and cattle rearing. Besides, a smaller segment of the farm was allocated to cattle rearing as compared to maize cultivation, which – according to the farmers, was as a result of the availability of crop residues which could be fed on animals. Other responses also indicated that the smallholders could still meet animal feed demands by hiring grazing fields from their neighbours who had larger land sizes.

The third largest portion of land went to the cultivation of beans and other pulses, though mostly in a mix with other 'friendly' crops. However, most of the drought-tolerant crops like sorghum, finger millet and sweet potatoes, among others, were allocated a smaller share of farm size. This is despite being regarded as 'saviour' crops, considering the current challenges[3] facing maize crop cultivation in the area. Such a situation demonstrates that adaptable crops (Tittonell and Giller 2013) are yet to be accorded proper attention, thus underlining the need for targeted awareness-raising schemes. Furthermore, it was found out that most of the farmers in the area were largely depending on 'free-ranging' livestock – a situation which exposes them to greater risks from climate uncertainties, through the resultant impacts on availability of animal feed resources.

Climate variability situations in trans-Mara east sub-county

Meteorological situations An analysis of rainfall data for the area indicated no major shifts in the mean annual amounts during the period 1980 to 2015, though the overall trend between 2000 and 2015 indicates a slight decline (Fig. 2). However, a detailed scrutiny of the monthly rainfall data for the area showed huge deviations from the long-standing regimes for the area. For instance, the area's established bimodal rainfall patterns, with the first peak in March to May and the second peak in November to December, have become highly irregular from a given year to the other. Considering the situations from 2000 to 2015, depicted that the first and second rainfall peaks were missed on six and four occasions, respectively. But in 1980 to 1999, the first and second rainfall peaks were missed on only three occasions for each peak.

Details of the mean annual temperature situations in the area between 1980 and 2015 also showed a generally rising trend, with an overall increase on 1.2 °C during the period (Fig. 2). An examination of the mean monthly maximum temperatures for the area showed a progressive increase between 2000 and 2015, as compared to between 1980 and 1999. The period 2000–2015 registered highest monthly maximum temperatures of more than 28.3 °C on six occasions (2000, 2005, 2006, 2009, 2011, 2015) whereas the 1980–1989 monthly maximum records only exceeded 28.3 °C on just four occasions (1981, 1982, 1983, 1997).

These climatic situations mirrored the area's farm-level experiences, covered in the next section of this study, which also showed decreasing rainfall amounts and increasingly rising temperatures in the area. The findings are also in tandem with other studies which have indicated increasing climate variability in Kenya (Khisa et al. 2014; Mutunga et al. 2017; Oluoko-Odingo 2011) and other parts of the world (Asseng et al. 2015; Labbé et al. 2016; Thornton et al. 2014). Such increasing climatic shifts have been shown to harbour potentially adverse implications on food security through the impact on crop output in Kenya and other parts of the developing world (Campbell et al. 2016; Cohn et al. 2016; Oluoko-Odingo 2011; Rigolot et al. 2017; Silvestri et al. 2015; Wambua and Omoke 2014).

Extensive crop and livestock performances Considering crop performances in the area between 2010 and 2015, maize crop emerged as the most negatively affected crop in the period, as compared to the crops, based on the *Weighted Average Index* (Fig. 3). Among the livestock enterprises in the area, donkeys and cattle were found to have been largely affected by climate-related feed shortages compared to goats and sheep (Table 1). These findings corroborate other studies which have reported the resilience of goats to varying climatic situations, due to their more diverse feeding habits compared to other farm animals (Opiyo et al. 2015).

Smallholder responses to challenges related to their output indicated climate variability as the top possible cause for depressed crop and livestock performances in the area (Fig. 4), and this was mostly manifested through prolonged droughts and rainfall uncertainties.

Delayed rainfall situations with irregular patterns affect planting seasons. Snowballing susceptibility of crops to the effects of destructive pests and disease outbreaks also occur (Mutunga et al. 2017; Okumu 2013). These affect the availability of livestock feed

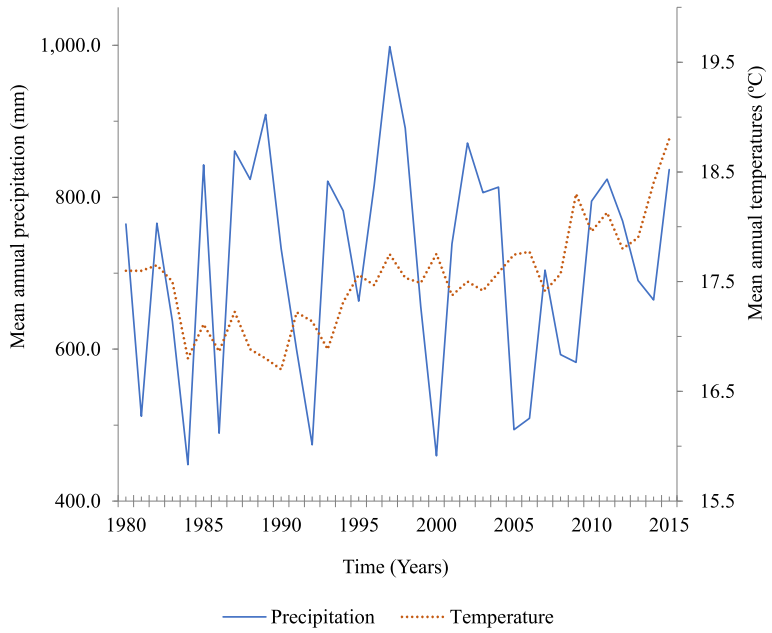

Fig. 2 Mean annual measurements for rainfall and temperature for Trans-Mara East. (Data source: Kenya Meteorological Department, 2017)

resources thus undermining on overall productivity (Field 2012).

Smallholders perception on climate variability and change

Perceptions about temperatures and rainfall situations

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; Raworth 2007).Thus, smallholders in Trans-Mara East sub-County were surveyed for their perceptions on climatic situations, particularly ascertaining their experiences with rainfall, drought, and temperature situations for the area between 2000 and 2015. 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

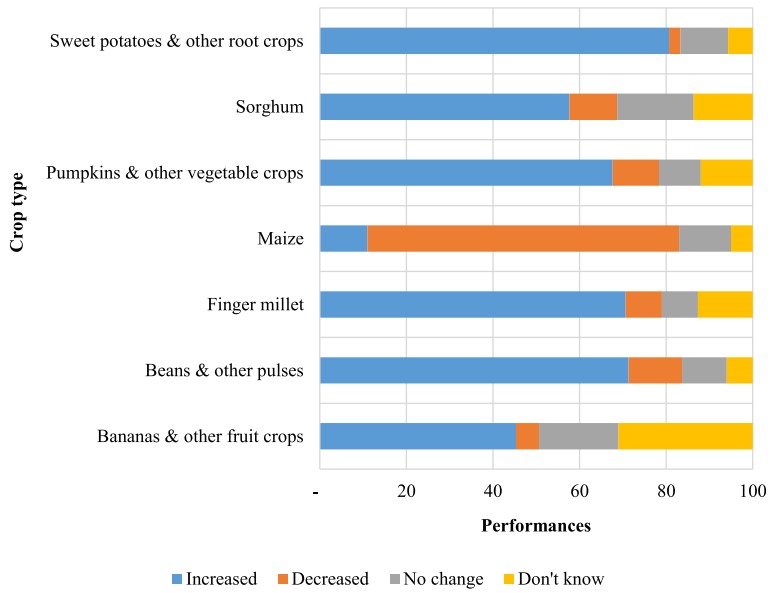

Fig. 3 Crop performances under different climatic situations in the study area between 2000 and 2015 (Source: Field Data, 2017)

Table 1 Climate variability-related feed shortages among livestock in the area (Source: Field Data, 2017)

Animal type	Very high	High	Low	None	WAI	Impact rank
Donkeys (*N* = 41)	12	21	5	3	2.02	1
Cattle (*N* = 93)	23	46	13	11	1.87	2
Sheep (*N* = 63)	9	27	13	14	1.49	3
Goats (*N* = 61)	0	10	19	32	0.64	4

Very high including loss of stock by death or pre-emptive sale, *High* overcame with sourced feed, *Low* with in-sourced feed

upward trend. Less than 10% of them reported either a decreased or unchanged temperature situations in the area (Fig. 5).

Their experiences with rainfall situations were also surveyed in terms of the amounts, duration, and frequency. Responses showed a majority of them (> 65%) had observed a downward trend. This was in addition to a less than 20% reporting either an increasing or unchanging precipitation during the period. Besides, smallholder experiences about drought situations were surveyed for the same period. The responses indicated that the area had experienced moderate to severe incidences of drought, at increasing rates (Table 2).

Drought situations undermine the smallholders' capacity to fight poverty and progress (Barrett and Carter 2013; Kithia 2014; Oluoko-Odingo 2009). This will likely jeopardise on the journey towards realising the much desired sustainable development objectives at the downstream levels (Kassie et al., 2015; Labbé et al. 2016; Wambua and Omoke 2014). Diminishing household livelihood situations in rural areas is largely attributed to climate uncertainties which constrict crop and livestock performance (Mertz et al. 2009a; Oluoko-Odingo 2011). The resulting destitution and scarcity of essential life elements, like food, often trigger other socio-economic concerns such as household-level conflicts, plummeting health situations, and environmental degradation (Le Dang et al. 2014; Field 2012; Mutunga et al. 2017; Tittonell and Giller 2013; Wiesmann et al. 2014). These circumstances are already commonplace in the area.

The observations clearly demonstrate a congruence between smallholders' perceptions and metrological indicators of the climatic situations in the area. These indicate that there is an increasing unpredictability of rainfall patterns in the study area. The findings thus reinforce other reports on the climatic situation in Kenya (Khisa et al. 2014; Marenya and Barrett 2007; Mutunga et al. 2017; Okumu 2013; Wambua and Omoke 2014) and other parts of the world (Deressa et al. 2011; Kassie et al. 2013; Labbé et al. 2016; Muzamhindo 2015; Ndamani and Watanabe 2015; Uddin et al. 2014). Reports about the Kenya's situations have shown rising temperatures across country, with rainfall patterns becoming more irregular and unpredictable (Klisch et al. 2015; Mutunga et al. 2017). For instance, national meteorological reports indicate a warming trend in the temperatures between 1961 and 2009, with overall rise in minimum and maximum temperatures of 0.7–2.0 °C and 0.2–1.3 °C, and the warmest records in the period occurred being between 2000 and 2009.

Dwindling rainfall situations in Trans-Mara East, corroborate with other studies from the rest of Kenya (Barrett and Carter 2013; Kithia 2014; Oluoko-Odingo 2009). Such circumstances can destabilise smallholders' capacity to fight poverty and progress towards local-level sustainability objectives (Kassie et al., 2015; Labbé et al. 2016; Wambua and Omoke 2014). The resulting adverse impacts will in the long run affect both the human

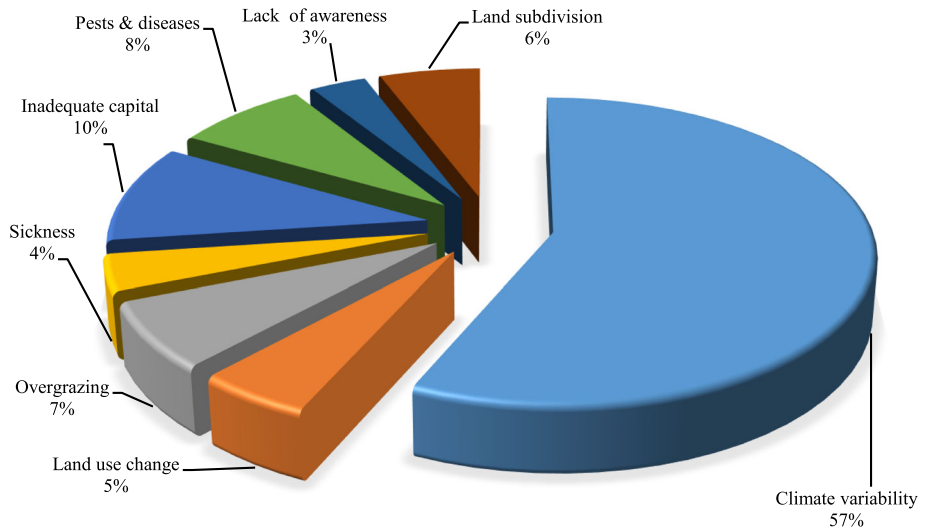

Fig. 4 Key factors attributed to depressed crop and livestock output in the area (Source: Field Data, 2017)

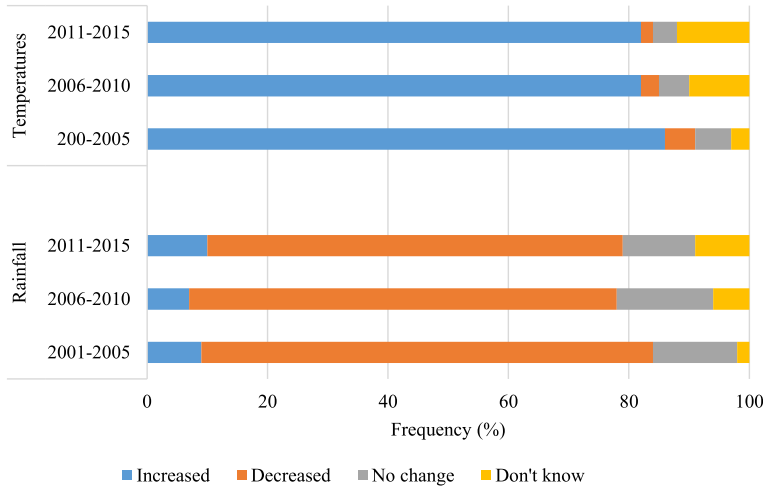

Fig. 5 Smallholders perception about the temperature and rainfall situations in Trans-Mara East between the years 2000 and 2015 (Source: Field Data, 2017)

well-being, at household level, and the overall health and productivity of natural ecosystems (Mikalitsa 2015; Nyamwaro et al. 2006; Oluoko-Odingo 2011). These circumstances are reportedly common in many parts of rural Kenya.

Perceptions and smallholders' socio-economic strata

A Pearson correlation analysis on the association between smallholder's perceptions and their socio-economic strata indicated a weak positive association ($r < \pm\ 3$, $p \geq 0.05$) between smallholder's perceptions and either their age, marital status, level of education, or livelihood streams. However, there was a strong positive association ($r = 0.430$, $p \leq 0.01$) between their perceptions on climate variability and farm sizes.

Rapidly evolving information technology (Musingi and Ayiemba 2012; Thugge et al. 2011) play a vital role in availing a wide range of information-access platforms to people, with a greater likelihood to influence their subsequent perceptions and decisions. In the study area, smallholders had a wide range of options within their disposal, through which they could easily access climate- and agricultural-related content. These scenarios could have influenced their perceptions across their demographic and socio-economic strata, as indicated by the weak association between their perceptions and their ages, level of education, marital status, and livelihood streams. Access to information in Kenya has been bolstered the rapid penetration of mobile phone technology, which currently stands at over 30 million handsets in an entire population of 45 million people (Klisch et al. 2015; Thugge et al. 2011; Wiesmann et al. 2014). Given that these mobile phones have the capability to receive signals from FM radio stations, and internet, information access across the country has been greatly enhanced thus levelling key socio-economic and demographic underpinnings.

On the other hand, smallholder's farm size had a strong positive relationship with their perceptions. Conversely, smallholders who had much smaller farms (≤ 1.0 ha) were found to be practicing intensive mixed-cropping systems with easy options for manual watering, in case of prolonged droughts. These observations could have been influenced by greater worries and "bad" experiences by the smallholders with larger farms who were found to mostly had mono-cropping of maize which are prone to weather-related challenges (Okumu 2013).

Table 2 Drought occurrences in Trans-Mara East sub-county from 2000 to 2015

Date (Years)	Duration (Months)	Severity[a]	Response frequency (%)
2000	4	Very high	61
2003	3	Very high	73
2005/6	3	High	65
2011	5	Very high	69
2013	2	Low	62
2015	3	Low	71

Severity[a]: *low* reduced human and livestock feed resources and water, *high* depleted human and livestock feed resources and water, *very high* leading to direct and indirect loss of livestock and human lives. (Source: Field Data, 2017)

Smallholders' adaptive capacity

Smallholders' desired adaptation strategies As a precautionary measure against impending effects of climate variability, farmers often employ various strategies. These measures are largely dependent on their perception, level of awareness, education, and affordability – tied to their levels of income (Ndamani and Watanabe 2015; Oluoko-Odingo 2011). In Trans-Mara East, the

Table 3 Smallholder's ranking of the adaptation strategies employed in Trans-Mara East sub-County, as per their perceived importance levels

Adaptation strategy	Very important	Moderately important	Less important	Not important	WAI	Rank
Improving crop varieties	79	20	1	0	2.78	1
Improving livestock feeding techniques	76	21	3	0	2.73	2
Crop diversification	73	24	2	1	2.69	3
Irrigation	72	21	5	2	2.63	4
Improving post-harvest management	68	27	4	1	2.62	5
Off-farm income streams	71	19	7	3	2.58	6
Adjusting planting dates	59	27	11	3	2.42	7
Agroforestry practices	61	21	13	5	2.38	8
Destocking	53	29	10	8	2.27	9

Not important 0; *Less important* 1; *Moderately important* 2; *Very important* 3; *WAI* Weighted Average Index. (Source: Field Data, 2017)

current smallholders' adaptation strategies include those related to cushioning, and enhancing the productivity of, their cropping and livestock rearing practices.

Notwithstanding the presence of these measures, smallholders in the area indicated a desire for additional adaptation schemes (Labbé et al. 2016; Silvestri et al. 2015) according to their perceived level of importance (Table 3). For example, improving crop varieties appeared to be the most desired adaptation strategy possibly due to their aspiration for a maize variety which is free from the effects of climatic, and other external, variances. These include Maize Lethal Necrosis disease reported in the area its environs in 2011, and since then, a tangible remedy is yet to be found (personal communication with experts from KARLO[4] and CIMMYT[5]).

Crop diversification, among other crop management strategies, was also highly ranked as a potentially viable adaptation strategy. This is a good strategy since having different types of crops in one's farm can easily act as a security against the failure or poor yield performances. Many studies have also highlighted crop diversification options as suitable adaptation measures (Le Dang et al. 2014; Mutunga et al. 2017; Ndamani and Watanabe 2015; Uddin et al. 2014).

Besides, improving livestock feeding techniques also appeared among the highly desired strategies as compared to destocking of the animals as they find them being a huge source of livelihood, and form of 'security' against emergencies such as healthcare and children's education, hence would prefer to have more stock under improved feeding strategies which can sustain and even enhance their productivity and market value. These findings agree with other studies (McKune et al. 2015; Rigolot et al. 2017) on the options for smallholder against climate-related challenges.

Adjusting planting dates, irrigation, and enhanced post-harvest management techniques, also featured among the highly desired crop management practices in the area as compared to agroforestry. This could be probably as a result of the farmer's perceived changes in rainfall patterns which directly affect the availability of crop moisture requirements (Mertz et al. 2009b). The farmers would prefer to reconfigure their planting dates to possibly avoid being disadvantaged by the shifting rainfall regimes. This was in addition to having irrigation as an alternative avenue for meeting crop water demands during long dry spells. However, options such as irrigation are capital intensive despite being the ideal strategy against rainfall uncertainties. Therefore, most of the smallholders cannot afford to adopt them unless they are collectively supported by the government and other key stakeholders in the agricultural sector. This can be addressed through a public-private-community partnership approach as it has been shown to work elsewhere (Raworth 2007). Moreover, and in line with the smallholders highly ranked adaptation measures in Trans-Mara East, enhanced post-harvest management practices constitute one of the key measures which can be harnessed at the farm-level to curtail key losses of farm produces. For example, annual grain losses in the sub-Saharan Africa exceeds 20% of the harvested yields (Field 2012; Iizumi and Ramankutty 2016), yet these adverse scenarios can easily be contained through suitable transportation and storage methods.

Smallholder's adaptive capacity and their socioeconomic levels Results from the Pearson correlation analysis, targeting to ascertain the veracity of association between the smallholder's adaptive capacities against their socio-economic state of affairs, were also revealing. Education levels ($r = 0.229$; $p \leq 0.05$) and farm sizes ($r = 0.534$, $p \leq 0.01$) were found to have positively significant association with their adaptive capacity. There was also a positive, but significantly weak, association between their adaptive capacity and individual's marital status ($r = 0.154$, $p \geq 0.05$) and diversity of livelihood streams ($r = 0.034$,

$p \geq 0.05$). Association between smallholder's adaptive capacity and their age though negative, was also weak and not significant ($r = -0.026$, $p \geq 0.05$).

Successful implementation of desired adaptation has been shown to be largely associated to a number of socio-economic dynamics which include the smallholder's age, marital status, their wellbeing, educational levels, farm sizes, and diversity of livelihood streams (Le Dang et al. 2014; Silvestri et al. 2015).These studies are in agreement with the strong positive association between the adaptive capacity and educational levels and well as farm size in the study area. Education for instance, enhances skill acquisition among individuals, and in the process their possibility to occupy societal positions which can dispose them to a wide range of information, on adaptation, and more meaningful income streams.

Larger farm size also allow smallholders to allocate different portions of their land into various adaptable crop and livestock enterprises, thus raising their adaptive capacity (Fisher et al. 2015). This possibly underpin the significantly strong positive correlation between the smallholder's farm sizes and their adaptive capacity in Trans-Mara East.

Besides, the weak positive association between smallholder's marital status and adaptive capacity, as well as their livelihood systems could be as a result of other intervening dynamics in the area (Kipsisei 2011; Nyamwaro et al. 2006). For example, most of the single women in the area had additional off-farm income streams, including monthly stipends from a national social safety net programme. Such policy driven programmes have been shown to reduce societal inequality gaps. These scenarios possibly explain the contrasting observations -on marital status, between this study and other studies (Moyo et al. 2012; Oluoko-Odingo 2011; Uddin et al. 2014) which show negative association between marital status and adaptive capacity. However, those who largely relied on off-farm livelihood streams in Trans-Mara East, were receiving low wages, as most of them were engaged in poorly-paying ventures, including as casual labourers. Such meagre income streams is mostly exhausted by the competing household demands with limited surplus that would have been injected into more productive and sustainable initiatives to boost their adaptive capacity. This elucidates on the weak positive association between adaptive capacity and diversity of income streams in the area.

Farm productivity has been shown to deteriorate with the farmer's age, especially among the rural smallholders who largely rely on their own physical labour to execute many farming responsibilities (Deressa et al. 2011; Labbé et al. 2016; Uddin et al. 2014). These observations corroborate with the findings on negative – though weak, correlation between age and adaptive capacity in the study area. Owing to such observations in other parts of the world, a number of studies and key global-level stakeholders, have sounded alarm bells on the future peril of food security. This is depicted by documentations indicating that the median age of farmers have been continually rising, contrary to the dropping median age of overall populations in many developing countries.

Constrains to smallholders' adaptation

Key adaptation constraints

In spite of the smallholders' desire to put in place workable safeguards against the potentially adverse impacts of climate variability and change, a number of challenges stand in their way. These hurdles include those emanating from both the downstream and upstream (policies and programmes) levels (Iizumi and Ramankutty 2016; Raworth 2007) (Table 4).

High costs of farm inputs, limited access to microcredit facilities, uncertain commodity prices, and poor road networks, featured among topmost concerns for smallholders against their quest for robust adaptation options. Specifically, they decried of "very expensive" planting materials for various crops such as beans and maize seeds in the retail stores, as well as the "skewed circulation" of the GOK[6]'s subsidised fertilisers, and as a result, they often opt to "cheaper" alternatives like establishing new crops using yields from previous harvests and planting without fertilisers. However, such practices have been shown to increase crop's vulnerability to pests and diseases, in addition to reducing their overall vigour and eventual yields (Mertz et al. 2009b; Tittonell and Giller 2013).

Besides, their constrained livelihood systems, compounded by limited of access to credit facilities, diminishes their ability to raise funds for the adoption of meaningful adaptation strategy due to cost implications. Inadequate access to client-friendly credit facilities inhibit people's abilities to venture into more rewarding enterprises (Barrett and Carter 2013; Oluoko-Odingo 2011). This is the case for smallholders in Trans-Mara East. Such a state of affairs inhibits their abilities to broaden livelihood streams through more rewarding on-farm and off-farm schemes – a situation which directly impacts on their ability to instil climate-smart practices in their farms (Raworth 2007; Silvestri et al. 2015).

Roads are the only available transportation networks in Trans-Mara East, relied upon by smallholders to reach the markets. However, the sorry state of these roads, as per the farmers' experiences, and the researcher's own notes in the area, constitute a key impairment to obtaining the actual market value for the smallholders' produce. This affects the farmer's morale, especially in relation to the need to venture into potentially adaptable farming options. The challenge is

Table 4 Key challenges constraining smallholders from taking up adaptation measures against climate variability in Trans-Mara East ($N = 100$)

Constrain	High	Moderate	Low	Non-issue	PCI	Rank
High cost of farm inputs	75	21	4	0	2.71	1
Limited credit facilities	66	31	2	1	2.62	2
Market uncertainties	69	24	6	1	2.61	2
Poor road networks	74	13	10	3	2.58	3
Limited livelihood streams	56	42	2	0	2.54	5
DWIS[a]	71	16	7	6	2.52	6
Inadequate adaptation extension services	67	13	14	6	2.41	7
Limiting farm size	61	12	10	17	2.17	8
Land tenure issues	55	11	19	15	2.06	9
Inter-ethnic conflicts	43	21	25	11	1.96	10

High = 3; Moderate = 2; Low = 1; Non-issue = 0. DWIS[a] = Disjointed Weather Information Streams
(Source: Field Data, 2017)

exacerbated by the absence of yields' value addition opportunities in the area (source: FGDs and key informants).

Disjointed access to weather-related information and agricultural extension services, disposes the smallholders to perils of adverse climatic situations in the area (Le Dang et al. 2014). For instance, most of them rely on vernacular radio stations for farming-related information, yet these channels offer limited deliberations on matters climate change. Besides, the farmers also indicated that they "rarely see" the taxpayer-funded agricultural extension officers, who are supposed to be the first-line promoters of sustainability practices at the farm-level. Such situations impede the penetration, and subsequent adoption, of tangible adaptation measures among smallholders (Mutunga et al. 2017; Oluoko-Odingo 2011; Silvestri et al. 2015).

Limited farm sizes, land tenure and common inter-ethnic conflicts in the area also contribute to slow pace in adopting sustainable farming practices in the area (key informant interviews and Kipsisei 2011). Further, and with the burgeoning human populations in the area, demand for more land under cultivation is continually rising. This challenge is perpetuated by long-held traditions on father-to-son land inheritance – the outcome being a continued subdivision of land into uneconomical units (Wiesmann et al. 2014).

Consequently, a meagre output from these units drives many of them into destitution and despondency. These conditions have been associated to the rampant cattle rustling and inter-ethnic conflicts in the area (Kipsisei 2011; Nyamwaro et al. 2006). The factors combined, affect any incentive to invest in long-term adaptations measures in the area (Le Dang et al. 2014). The current observations agree with Mutunga et al. (2017) and Opiyo et al. (2015) who recorded similar concerns in their research in other parts of Kenya as well as Deressa et al. (2011) and Ndamani and Watanabe (2015) in Ethiopia and Ghana, respectively.

Adaptation constraints and socioeconomic strata

Pearson correlation analysis (Field 2009) for the association between the smallholder's adaption constraints in the area, indicated a significantly strong negative ($p \leq 0.01$, $r < 0$) correlation with level of education, and diversity of livelihood streams. However, there was also a significantly strong positive association ($p \leq 0.01$, $r > 0$) between age and the adaptation constraints, while both the marital status and farm size exhibited weak non-significant negative association with the constraints ($p \geq 0.05$, $r < 0$).

With an enhanced access to higher levels of education, one is likely to acquire more skills useful in solving life-related challenges, both at individual and societal levels, thus broadening their social and technical capital (Godfray et al. 2010; Musingi and Ayiemba 2012). Besides, increasing more skills is likely to enable individuals to access various livelihood streams. This then enables them to build a stronger financial and technical capital, resulting in lowered socioeconomic constraints related to their undertakings (Thornton et al. 2014; Wambua and Omoke 2014; Wilkinson 2015). The observations, thus, explain the strong negative relationship between smallholder's adaptation constraints with their level of education, as well as with their livelihood streams in Trans-Mara East.

Moreover, younger- to mid-age segments of the populations have been shown to be more endowed with social, technical, and financial capital, compared to the older segments of the populations (Nielsen and Reenberg 2010; Wilkinson 2015). These forms of capital as elucidated in (Brand 2009; Raworth 2007) accords individuals, including smallholders, an upper-hand in confronting any abrupt or projected socio-economic challenges, at household to societal levels. And this case applies to smallholders across many parts of the world (Deressa et al. 2011; Moyo et al. 2012; Ndamani and Watanabe 2015; Uddin et al. 2014), as their access to the aforementioned forms of capital enable them to leapfrog any farm-related constraints. These

records vindicate the strong positive association between smallholder's age (25–64 years) and adaptation constraints in the study area.

Smallholder family labour and decision-making input constitutes a key social capital, which when harnessed constructively enhances farm enterprise performances while at the same time constricting any potential constraints (Mertz et al. 2009a; Oluoko-Odingo 2011). This is especially so among female-headed households compared to male-headed (McKune et al. 2015; Mikalitsa 2010). For instance, single mothers' societal roles in the sub-Saharan Africa are often constrained by the ensuing cultural practices such as those pertaining to land tenure and labour utilisation. Such situations are likely to create gender-based capital discrepancies with synchronised results in farm-level responses and constraints to key challenges led by climate variability. These observations support the current study's findings on a generally negative association between the smallholder's constraints and their marital status, as well as their farm sizes in the study area.

Conclusions

The above findings indicate that Trans-Mara East sub-County has been undoubtedly experiencing climate variability challenges between 1980 and 2015. The key manifestations for these situations include increased rainfall uncertainties, intensifying droughts, and rising temperatures. These scenarios have largely affected crop and livestock performances in the area, with corresponding negative effects on household food security and income positions.

Moreover, smallholder's perceptions about the climatic situations in the area were in tandem with the meteorological records and existing literature. Besides, their perceptions were largely not associated with their socioeconomic characteristics including marital status, age, level of education, and livelihood streams. This was due to other intervening subtleties such as the rapidly increasing penetration of information technology systems into the Kenyan rural areas, which possibly shaped the association. Farm sizes only appeared to magnify the magnitude of losses associated with climatic uncertainties thus the increasing strength and direction of the relationship between it and smallholder's perceptions.

Smallholder's adaptive capacity indicated a dynamic community with a higher scale of readiness to make requisite adjustments against climate variability and its associated impacts, given financial, technical and social support. Among their cues for readiness include current crop diversification options, adjusted livestock feeding techniques, as well as attuned key household diets, with their most desired adaptation options being improved crop varieties, livestock feeding techniques and crop diversification. Further, in the area, smallholder's education levels and farm sizes had a positive association with their adaptive capacity. This was, however, with a significantly weak, association between their adaptive capacity and both their individual's marital status and diversity of livelihood stream, and between their adaptive capacity and age.

Among the key constraints against smallholder's adaptive capacity in the area included high cost of farm inputs, limited access to credit, market uncertainties, poor road networks, limited livelihood streams, and disjointed agricultural- and climate-related information systems, as well as farm sizes, land tenure issues and inter-ethnic conflicts in the area. Moreover, through Pearson correlation analysis, there was significantly strong negative correlation between their constraints and their level of education, as well as the diversity of livelihood streams, with a notably strong positive association between age and the constraints, unlike either their marital status or farm sizes. Education and livelihood diversification, for instance, can enhance peoples' capacity to combat various environmental challenges, including climate change.

Endnotes

[1]Kenya National Bureau of Statistics.
[2]Commission for Revenue Allocation.
[3]Maize farming in the area is also "at cross-roads" due to losses attributed to Maize Lethal Necrosis disease.
[4]Kenya Agricultural Research and Livestock Organization.
[5]International Maize and Wheat Improvement Centre.
[6]Government of Kenya.

Abbreviations

CIMMYT: International maize and wheat improvement centre; CRA: Commission for revenue allocation; DWIS: Disjointed weather information streams; FGDs: Focus group discussions; GoK: Government of Kenya; KARLO: Kenya agricultural research and livestock organization; KNBS: Kenya National Bureau of Statistics; PCI: Problem confrontational index; WAI: Weighted average index

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Availability of data and materials

The datasets supporting the conclusions of this article is have been included within the article with the additional data being available in the Open Science Framework repository [unique persistent identifier and hyperlink to dataset(s) in https://osf.io/5bwfg/.

Authors' contributions

HKS conceived the study, worked on the study design, data collection, analysis, interpretation and drafting of the manuscript. SMM reviewed and

contributed to the study design, data collection, analysis, interpretation and drafting of the manuscript. BNW reviewed and contributed to the study design, data collection, analysis, interpretation and drafting of the manuscript. All authors read and approved the final manuscript.

Competing interests
The authors declare that they have no competing of interests.

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