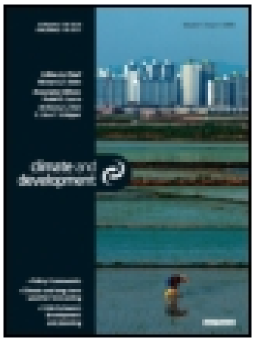

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Smallholder farmers in eastern Africa and climate change: a review of risks and adaptation options with implications for future adaptation programmes

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REVIEW ARTICLE

Smallholder farmers in eastern Africa and climate change: a review of risks and adaptation options with implications for future adaptation programmes

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This article reviews the published evidence of the climatic risks faced by smallholder farmers in eastern Africa and the adaptation strategies these farmers have so far adopted. In addition, the study draws on two detailed case studies in Kenya for a better understanding of the nuances of climate adaptation, requiring a range of measures to be adopted and institutions working together. Findings from the study reveal that the most consistent observation among farmers is that eastern Africa is experiencing increased temperature and decreased rainfall across all its agro-ecological zones. In response to their perceived climatic risks, smallholder farmers in the region are using both short-term and long-term strategies, with the former mainly consisting of coping mechanisms against climate chocks. In addition, the adaptation strategies implemented by the farmers are influenced by agro-ecological conditions which shape their farming systems and institutional settings including proximity to a major city and markets. The case studies highlight the importance of collaborative efforts between key local and external stakeholders in supporting adaptation to climate change. Key lessons are drawn from this study for the development of future adaptation programmes.

KEYWORDS: climate change; eastern Africa; Kenya; Ethiopia; Uganda; Tanzania; risks; adaptation strategies; barriers to adaptation

Introduction

The climate in Africa is changing. Sivakumar, Das, and Brunini (2005) point out that rainfall in tropical North Africa between the 30 years spanning 1960 to 1990 was substantially less than that of the '1930–1960' period. Similarly, rainfall has been decreasing over the twentieth century within the Sahel and in the semiarid and subhumid zones of western and southern Africa. In the Greater Horn of Africa, which encompasses Sudan, Ethiopia, Kenya and Uganda, rainfall has been decreasing over the past half-century (Williams et al., 2012). Temperatures have also increased across western and southern Africa between 1960 and 2000 (New et al., 2006).

Future climate in Sub-Saharan Africa is projected to be hotter with more frequent droughts (Bernstein et al., 2008; Cairns et al., 2012; Mariotti, Coppola, Sylla, Giorgi, & Piani, 2011). Average temperature is projected to increase by more than 2°C across the continent by 2050, but there is more uncertainty on rainfall (Cairns et al., 2013; Christensen et al., 2007; Sivakumar et al., 2005). More specifically, increases in temperature varying from 2 to 4°C in Africa are expected to lead to a wetter climate in eastern Africa and a drier climate in southern Africa, western Sahel and Guinea coast (James & Washington, 2013). Some uncertainty remains on weather extremes, although the models suggest an increase in the frequency of droughts in southern Africa (Orlowsky & Seneviratne, 2012; Sillmann, Kharin, Zwiers, Zhang, & Bronaugh, 2013).

Most farming systems in Sub-Saharan Africa rely on rain-fed agriculture, which is inherently highly vulnerable to climate change. Suitable land for agriculture in Africa is projected to substantially decrease due to climatic change; this, in turn, would lead to decreased production of key cereals (Kotir, 2011). By the 2050s, climate change will increase the probability of maize crop failure across Sub-Saharan Africa with the exception of eastern

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Africa (Elliott et al., 2013; Jones & Thornton, 2003). Some studies predict a reduction in crop yields and a subsequent increase in hunger risk across the continent by 2080 (Kotir, 2011), whereas others predict a worsening in food and nutrition security by the 2050s (Lloyd, Kovats, & Chalabi, 2011; Tesfaye et al., 2015).

While smallholder farmers in Africa have shown evidence in the past of being able to adapt to climatic risks, the predicted magnitude and pace of change in climate is unprecedented and will require both progressive and most likely transformative change. This paper focuses on eastern Africa and evaluates the current situation – the 'baseline' – from which appropriate further adaptive responses can be identified. The paper reviews the literature on perceived climatic risks and the adaptation strategies by smallholder farmers in eastern Africa. The study also draws on two case studies in Kenya to explore barriers to adaptation for smallholder farmers.

Methodology

Literature review on climate risks and adaptation strategies

A systematic review on climate risks and adaptation strategies was conducted using a realist review system. The realist review system attempts to explain why and how complex interventions succeed or fail in a particular setting (Pawson, Greenhalgh, Harvey, & Walshe, 2005). In this study, all the recommended steps of the realist review were followed. First, the review topic was identified as the risks and adaptation strategies related to smallholder farmers and climate change in eastern Africa and more specifically in Kenya, Tanzania, Uganda and Ethiopia.

Second, the search for primary studies was conducted using the Web of Science. The keywords used to gather primary studies on the climatic risks were in 'Topic': ('risk*' OR 'vulnerab*', OR 'food security') AND ('climat* change' or 'global warming') AND (Specific region/country) AND (smallholder). For the adaptation strategies, the keywords inputted in the Web of Science were ('coping' OR 'adapt*') AND ('climat* change' OR 'global warming') and (Specific region/country) AND (smallholder). All articles published up to the first trimester of 2016 were included and there were no restrictions on the publication types. The search yielded 69 papers for the climatic risks and 104 papers on adaptation strategies; some of the papers were counted more than once as they were retrieved under different sets of keywords (Table 1).

The papers were then assessed for their relevance in the third step of the realist method. All article titles, abstracts and conclusions were reviewed to exclude those articles that were not relevant to the themes stated above. To further refine the documents, full texts were assessed to confirm their relevance. In total, 20 papers were reviewed.

The publications retrieved from the Web of Science were complemented by reports from baseline studies conducted under the CGIAR Research Program on Climate Change and Food Security (CCAFS). The baseline studies targeted selected sites in eastern Africa, which were most vulnerable to climatic change based on some preliminary analysis. CCAFS sites in Eastern Africa were Nyando and Machakos, (Wote) in Kenya; Hoima and Rakai in Uganda; Borana in Ethiopia and Lushoto in Tanzania (CCAFS, 2014). The studies gathered farmers' perceptions of climatic risks and observed changes in their farming practices between 2000 and 2010/2011.

The final step in the realist review involved data extraction and synthesis. All publications under consideration were reviewed in detail and the following data extracted: the main topic(s) of the paper, the climate risks identified in the study, whether they were based on farmers' perceptions and/or measured weather data, and the adaptation strategies employed to tackle the effects of climate change.

All respondents targeted in the review studies were classified by district and agro-ecological (AEZ) zone in each country. Hence, in this study, a site refers to the AEZ within a district. In addition, climatic risks reported by 10% or more of respondents in target sites were included in this study; the same proportion was applied to reported adaptation strategies.

Findings from the studies were then classified to identify key trends and patterns. More specifically, the risks and adaptation strategies extracted from the studies were classified and analysed based on biophysical (agro-ecology) and institutional criteria (country, and distance to a major city). The AEZs were classified based on temperature (warm and cool) and rainfall (arid, semiarid, subhumid and humid). In addition, a site targeted in any of the reviewed studies was considered close to a major city if it was located within a driving distance of three hours or less from the major city.

Case studies on barriers to adaptation in Wote and Katuk-Odeyo: empirical data collection

The study sites were Wote and lower Katuk-Odeyo. Wote is in Makueni district, which falls in the semiarid AEZ in Kenya (Figure 1). Katuk-Odeyo is in the lower Nyando basin in western Kenya, which belongs to the humid to subhumid AEZ in Kenya (Figure 1). Average annual rainfall in Makueni and the lower Nyando basin is around 595 and 1900 mm, respectively. Average household size in Wote and Katuk-Odeyo is 5.5 and 5, respectively. The key sources of livelihood in the two areas are integrated cropping and livestock keeping.

The data were collected through Focus Group Discussions (FGDs), and key informant interviews in Wote and lower Nyando between November and December 2013. Ten FGDs were conducted in Wote and eleven in Nyando. Each of the FGDs was composed of 12 men and

Table 1. Literature search results using specific key words in all fields in the Web of Science.

Site	Keywords in Web of Science	Results	Remarks
Eastern Africa	(‘risk*’ or ‘vulnerab*’ or ‘food security’) and (‘climat* change’ or ‘global warming’) and (East* Africa) and (smallholder)	18	Risks
Ethiopia	(‘risk*’ or ‘vulnerab*’ or ‘food security’) and (‘climat* change’ or ‘global warming’) and (Ethiopia) and (smallholder)	15	Risks
Kenya	(‘risk*’ or ‘vulnerab*’ or ‘food security’) and (‘climat* change’ or ‘global warming’) and (Kenya) and (smallholder)	20	Risks
Uganda	(‘risk*’ or ‘vulnerab*’ or ‘food security’) and (‘climat* change’ or ‘global warming’) and (Uganda) and (smallholder)	9	Risks
Tanzania	(risk*’ or ‘vulnerab*’ or ‘food security’) AND (‘climat* change’ or ‘global warming’) and (Tanzania) AND (smallholder)	7	Risks
Eastern Africa	(‘coping’ or ‘adapt*’) AND (‘climat* change’ or ‘global warming’) and (East* Africa) AND (smallholder)	16	Adaptation
Ethiopia	(‘coping’ or ‘adapt*’) AND (‘climat* change’ or ‘global warming’) and (Ethiopia) AND (smallholder)	10	Adaptation
Kenya	(‘coping’ or ‘adapt*’) AND (‘climat* change’ or ‘global warming’) and (Kenya) AND (smallholder)	10	Adaptation
Uganda	(‘coping’ or ‘adapt*’) AND (‘climat* change’ or ‘global warming’) and (Uganda) AND (smallholder)	3	Adaptation
Tanzania	(‘coping’ or ‘adapt*’) AND (‘climat* change’ or ‘global warming’) and (Tanzania) AND (smallholder)	5	Adaptation

women participants, who expressed their own knowledge and opinions on the major climate risks faced by their community in recent decades; the strategies used by individual households and communities to cope or adapt to the risks; the underlying causes of why some strategies were inadequate and alternative approaches. The FGD participants were purposively selected based on their contextual knowledge or experience of climate change risks over the years; skills on climate change and their vast experience on past climatic events and adaptation strategies. Participants were selected from across the target sites to represent the local mixed farming systems and were identified through consultations with local knowledgeable persons including leaders of active farmer entities, extension staff and field crops officers.

In addition, 12 key informants were interviewed in each of the two sites, with half of them being women. Data from these key informant interviews were triangulated with information from the FGDs. Key informants provided detailed descriptions of climate-related risks and their effects on different household livelihoods and gender relations. Respondents were persons with in-depth knowledge on the site-specific climatic challenges in agriculture. Semi-structured interview guides were used in FGDs and key informant interviews. Farmers were probed on their preferred adaptation strategies, given the climate risks they faced.

Results

Climate risks

Twenty studies were reviewed on the climatic risks faced by smallholder farmers in eastern Africa (Table 2). Seven studies were on Kenya; six on Ethiopia; two on Tanzania and five on Uganda. The 20 studies targeted 58 sites across eastern Africa: 19 sites in Kenya, 31 in Ethiopia, 6 in Uganda and 2 sites in Tanzania (Table 2). The studies also targeted all AEZs in the target countries (Table 2). However, most studied sites from the cooler AEZs (cool/humid; cool/subhumid; cool/semiarid) were close to major roads but far from major cities. In contrast, most studied sites from the warmer zones were close to major roads and also major cities (Figure 2(a)).

Two studies identified climatic risks on a national scale for Ethiopia and Uganda, using measured and/or simulated weather data (Mubiru & Kristjanson, 2012; NMSA, 2001). The NMSA (2001) reported increased temperature and decreased rainfall and more erratic rainfall across Ethiopia, whereas Mubiru, Komutunga, Agona, Apok, and Ngara (2012) reported increased temperature across all of Uganda.

Across all studies, the key climatic risks for smallholder farmers in eastern Africa were less rainfall and increased temperature (Figure 3(a)). All other climatic risks were reported at a frequency of 13% or less. Similarly, less rainfall and increased temperature were reported as climatic risks across all AEZs (Figure 3(b)). A third risk, which was also reported across all AEZs, was erratic rainfall, though in some zones, it was reported in less than 10% of the sites. The cool/subhumid zone, which is found in central Ethiopia, western Kenya and various parts of Tanzania (Figure 2(a)), is the only zone where all the risks identified for eastern Africa were reported (Figure 3(b)). Only three risks, namely less rain, increased temperature and erratic rainfall, were reported in the cool/arid zone. The cool/humid and warm/semiarid zones each had seven out of the nine identified risks (Figure 3(b)).

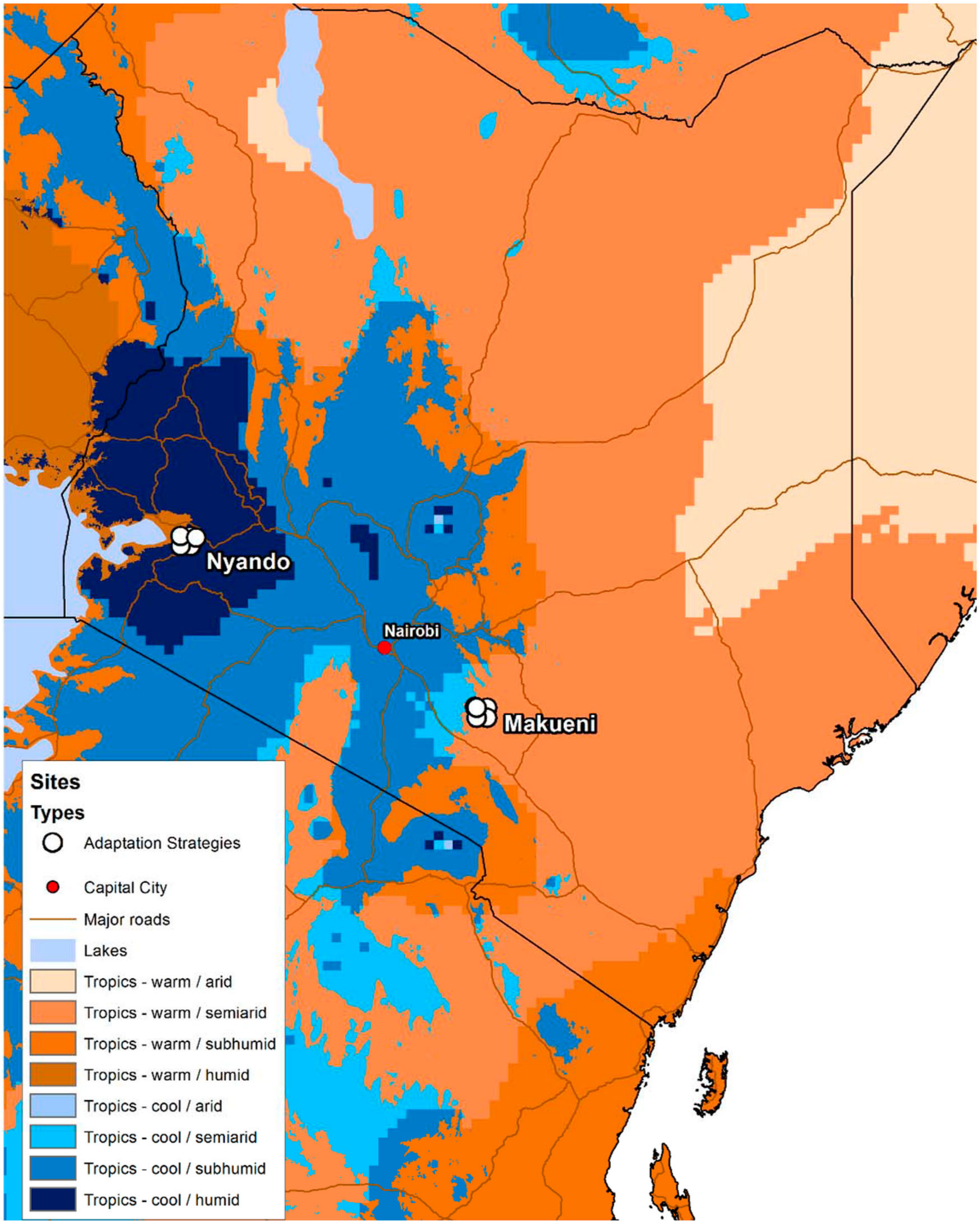

Figure 1. Illustration of sites targeted for case studies on climatic risks and adaptation strategies.

The higher number of risks in the cool/subhumid zone does not necessarily imply that this zone is more vulnerable to climatic change. For one, the zone had, by far, the highest number of studied sites (21). The second most studied zone was the cool/semiarid zone with nine sites. Hence, the sheer number of studies sites per AEZ might influence the number of reported risks.

The distribution of risks also varied across countries. The key climatic risks in Ethiopia were decreased rainfall and increased temperature; these two risks were reported each in 37% of the Ethiopian sites (Table 3). In Kenya, all identified climatic risks were reported, although the major risks were decreased rainfall, change in rain onset, increased temperature and erratic rainfall.

Table 2. Sites targeted in the reviewed literature on smallholder farmers and climate change in eastern Africa – climatic risks.

Reference	Country	District	AEZ
Ogalleh et al. (2012)	Kenya	Laikipia East	Cool/subhumid
Speranza (2013)	Kenya	Laikipia East, Meru and Buuri	Cool/subhumid
Andersson and Gabrielsson (2012)	Kenya	Nyando	Warm/semiarid
Bryan et al. (2013)	Kenya	Garissa	Warm/arid
	Kenya	Mbeere	Warm/semiarid; Warm/humid
	Kenya	Njoro, Mukurwe-ini, Othaya	Cool/subhumid
	Kenya	Gem, Siaya	Warm/humid
Rao et al. (2011)	Kenya	Kitui, Mutomo	Warm/semiarid
	Kenya	Mwingi	Warm/subhumid
	Kenya	Machakos, Makueni	Cool/subhumid
Bryan, Deressa, Gbetibouo, and Ringler (2009); Deressa et al. (2009)	Ethiopia	Atsbi Wonberta, Hawzein, Endamehoni, Debark, Wogera	Cool/semiarid
	Ethiopia	Limu, Nunu Kumba, Kersa	Cool/humid
	Ethiopia	Libo kemkem, Bichena, Quarit, Gimbi, Haru, Bereh Aleltu, Hidabu Abote, Bambasi	Cool/subhumid
	Ethiopia	Chilga	Warm/semiarid
	Ethiopia	Sirba Abbay, Wenbera, Gesha	Warm/subhumid
Gebrehiwot and Van Der Veen (2013)	Ethiopia	Hintalo Wajirat, Enderta, Kilte Awlaelo	Cool/semiarid
Debela, Mohammed, Bridle, Corkrey, and McNeil (2015)	Ethiopia	Yabello, Arero, Dire	Cool/subhumid
	Ethiopia	Arero, Moyale, Miyo	Warm/semiarid
Andersson et al. (2012)	Uganda	Tororo	Warm/humid
Hartter et al. (2012)	Uganda	Kibale national Park	Cool/humid; Cool/subhumid
Mango, Mideva, Osanya, and Odhiambo (2011)	Kenya	Nyando	Cool/humid
Mwangangi, Mutie, and Mango (2012)	Kenya	Makueni	Warm/semiarid
Lyamchai et al. (2011)	Tanzania	Lushoto	Cool/subhumid
Desta, Tezera, Gebru, and Kristjanson (2011)	Ethiopia	Yabello, Arero	Cool/subhumid
Mubiru and Kristjanson (2012)	Uganda	Hoima	Warm/humid
Kyazze and Kristjanson (2011)	Uganda	Rakai	Cool/humid; Warm/humid
Ojoyi and Kahinda (2015)	Tanzania	Morogoro	Warm/humid
NMSA (2001)	Ethiopia	All districts	All AEZs in country
Mubiru et al. (2012)	Uganda	All districts	All AEZs in country

Decreased rainfall was reported in 19% of all Kenyan sites; the other risks were reported in 18% each of the sites. Other risks, which were less common, as they were reported in fewer Kenyan sites, were increased floods and changing seasons. The major climatic risks reported in Uganda were decreased rainfall and erratic rainfall which were reported in 25% and 20% of all Ugandan sites, respectively. In Tanzania, the key climatic risks were less rainfall and increased dry spell frequency (Lyamchai, Yanda, Sayula, & Kristjanson, 2011; Ojoyi & Kahinda, 2015) (Table 3).

A look at the distribution of countries per reported risk gives a more nuanced picture. For example, Kenya accounts for 100% of the cases where ‘increased frosts’ was reported as a climatic risk (Table 3). Similarly, the increase in floods was mostly reported in Kenya. Ethiopia had the highest number of studied sites across all countries. However, the number of reported climatic risks was higher in Kenya compared to Ethiopia where decreased rainfall and increased temperature were the most reported risks. This discrepancy is partially explained by the fact that the range of climatic risks analysed varied between the studies targeting Ethiopia and the ones targeting Kenya. Most studies targeting Ethiopia focused on asking farmers’ perceptions on long-term changes in rainfall levels and temperature; on the other hand, studies targeting Kenya explored a larger range of long-term climatic changes with smallholder farmers.

An analysis of the risks per AEZ in each country reveals that decreased rainfall and increased temperature were also the major reported risks in all AEZs of Ethiopia (Figure 4(a)). However, in the warm/arid and cool/arid zones, only three risks were reported and they all had the same frequency of being identified as a climatic risk, 33%: erratic rainfall, increased temperature and decreased rainfall (Figure 4(a)).

Within Kenya too, the reported climatic risks varied across the AEZs. The cool/subhumid zone, which is found mainly in western Kenya (Figure 2(a)), had the highest number of reported climatic risks; the only risk not reported

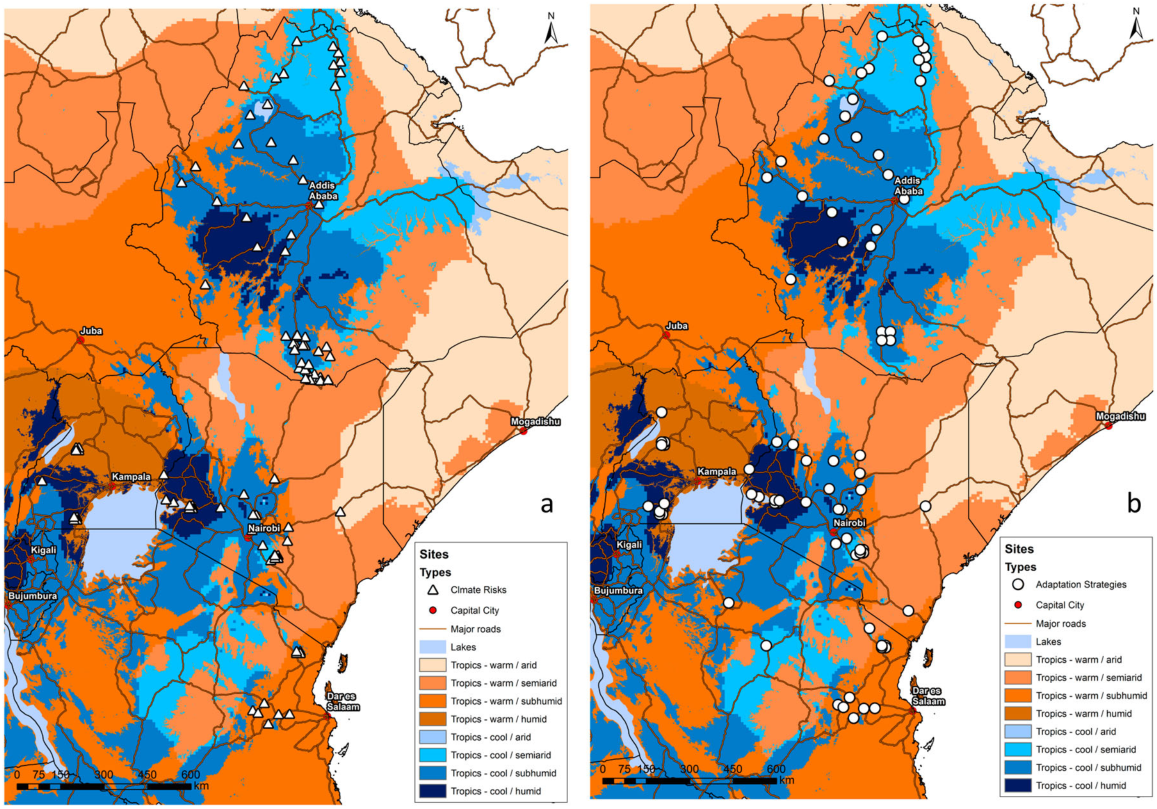

Figure 2. Illustration of sites targeted in reviewed literature on smallholder farmers and climate change in eastern Africa with a) sites for climatic risks and b) sites for adaptation strategies.

for the zone was increased rainfall (Figure 4(b)). The key reported risks in the zone were less rainfall, erratic rains, increased temperature and changes in rain onset. In the warm semiarid zone, which is mainly found in eastern and northern Kenya, seven climatic risks were reported (Figure 4(b)). The major risks were erratic rain and less rainfall. In the warm/arid and warm/humid zones, the same six risks were reported, each with the same frequency.

In Tanzania, climatic risks were reported in the cool/subhumid and warm/humid zones. The key risks in the warm/humid zone were less rainfall and increased droughts (Figure 4(c)). The same risks were reported in the cool/subhumid zone, in addition to erratic rain, increased rainfall, and changes in rain onset and/or cessation. Here, farmers report both an increase and a decrease in the amount of rainfall (Lyamchai et al., 2011), suggesting misunderstanding of climatic risks or misapplication of survey techniques.

In Uganda, the warm/humid zone (Figure 2), had the highest number of reported climatic risks (Figure 4(d)). However, the major risk in this zone was erratic rains. Other moderate risks were less rain, more droughts and increased rains. Surprisingly, as was also the case in Tanzania, increased and decreased rainfall were reported by smallholder farmers for the same site, Hoima (Uganda) over the same time period (Mubiru & Kristjanson, 2012). This highlights that smallholder farmers might misunderstand climatic changes or that survey tools were not applied correctly. In the cool/subhumid zone, which is mainly in south-western Uganda (Figure 2), three key climatic risks were reported, each with the same frequency: less rain, change in rain onset and increased temperature (Figure 4(d)). In the cool/humid zone, which is in western Uganda, the key climatic risk reported was less rainfall. In the warm/subhumid zone, which is in northern Uganda (Figure 2), the only reported risk, which was also identified for Uganda as a country using measured weather data (Mubiru et al., 2012), was increased temperature (Figure 4(d)).

Adaptation strategies

Sixteen studies were reviewed on the adaptation strategies that smallholder farmers have been implementing over time to address climate change. Six studies targeted Kenya; three, Ethiopia; two, Tanzania and two, Uganda. Another study targeted Kenya, Uganda and Tanzania; another one Kenya and Uganda and the last one Kenya and Tanzania. In addition, some of the studies tackling adaptation strategies also tackled climatic risks (Table 4).

Ethiopia and Kenya had the highest number of studied sites compared to Tanzania and Uganda (Figure 2(b)). The majority of the studied sites were close to a major road;

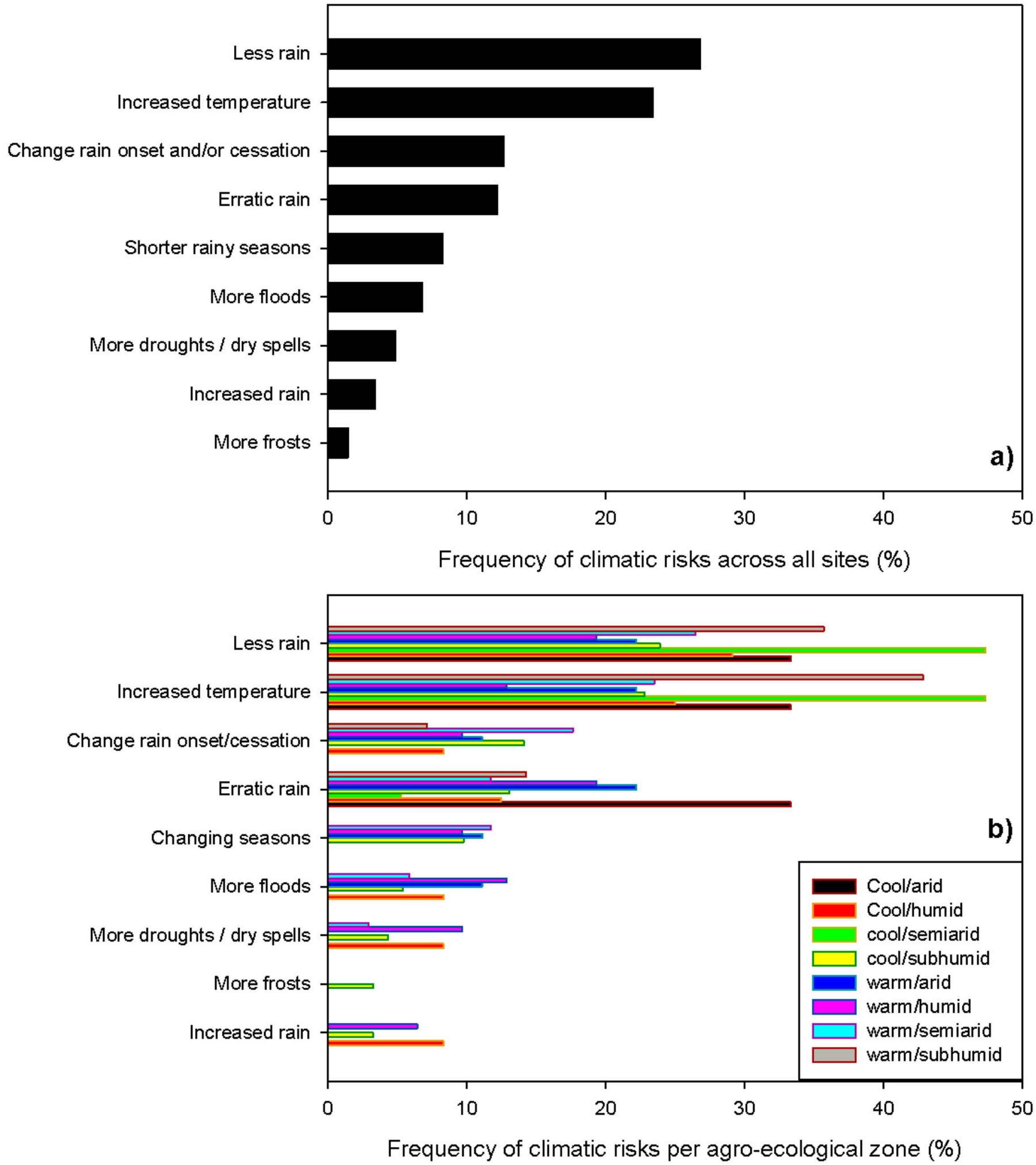

Figure 3. Frequency of climatic risks in eastern Africa.

however, fewer sites were close to a major city. About half of the sites in Kenya and Uganda were close to a major city. In Ethiopia, 2 sites out of 24 were close to a major city; whereas none of the studied sites in Tanzania were close to a major city.

The studies targeted all AEZs, except the cool/arid zone (Figure 2(b)). In the cool/subhumid zone, target sites were found in all countries. The AEZs, which had target sites in only one country, were the warm/subhumid and warm/arid zones. All other AEZs had sites in at least three countries, except for the cool/semiarid zone which had target sites in Ethiopia and Tanzania only.

Some of the studies, namely the baseline studies done under the research programme on Climate Change Agriculture and Food Security (CCAFS), did not identify adaptation strategies to climate change per se (Kristjanson et al., 2012). They instead identified the key changes in farming practices made by farmers within the last 10 years, as a response to climatic changes or other factors. All other studies used household surveys to identify

Table 3. Recorded climatic risks from reviewed literature for countries in eastern Africa.

Climatic risks	Ethiopia	Kenya	Tanzania	Uganda	Total
		Number of sites per country with reported risks			
Erratic rainfall	3	17	1	4	25
Less rainfall	30	18	2	5	55
Increased drought frequency	2	3	2	3	10
Change in rain onset and/or cessation	6	17	1	2	26
Increased temperature	30	17	0	1	48
Increased rainfall	2	1	1	3	7
Increased flood frequency	2	10	0	2	14
Increased frosts frequency	0	3	0	0	3
Changing seasons	6	11	0	0	17
Total	81	97	7	20	205
		Frequency of reported risks per country (%)			
Erratic rainfall	3.7	17.5	14.3	20.0	12.2
Less rainfall	37.0	18.6	28.6	25.0	26.8
Increased drought frequency	2.5	3.1	28.6	15.0	4.9
Change in rain onset and/or cessation	7.4	17.5	14.3	10.0	12.7
Increased temperature	37.0	17.5	0.0	5.0	23.4
Increased rainfall	2.5	1.0	14.3	15.0	3.4
Increased flood frequency	2.5	10.3	0.0	10.0	6.8
Increased frosts frequency	0.0	3.1	0.0	0.0	1.5
Changing seasons	7.4	11.3	0.0	0.0	8.3
Total	100.0	100.0	100.0	100.0	100.0
		Frequency of countries per reported risk (%)			
Erratic rainfall	12.0	68.0	4.0	16.0	100.0
Less rainfall	54.5	32.7	3.6	9.1	100.0
Increased drought frequency	20.0	30.0	20.0	30.0	100.0
Change in rain onset and/or cessation	23.1	65.4	3.8	7.7	100.0
Increased temperature	62.5	35.4	0.0	2.1	100.0
Increased rainfall	28.6	14.3	14.3	42.9	100.0
Increased flood frequency	14.3	71.4	0.0	14.3	100.0
Increased frosts frequency	0.0	100.0	0.0	0.0	100.0
Changing seasons	35.3	64.7	0.0	0.0	100.0

adaptation measures that farmers implemented in response to perceived climatic changes.

When all sites are pooled together, the most common adaptation strategy consisted of changes in crop management practices (Figure 5(a)): changes in planting time; enhanced soil management which involves practices from Conservation Agriculture; enhanced use of agricultural inputs; varietal changes; changes in planted crops; mixing long- and short-season crops and changing crop area. Changes in crop management practices were reported in 23% of the sites. The second most common strategy consisted of planting trees (agro-forestry), which was reported in 16% of all sites. The third and fourth most reported strategies were conservation agriculture and changes in livestock management practices, which were reported in 12% and 11% of the sites, respectively. The fifth most common adaptation strategy consisted of selling assets, such as livestock, firewood or household labour; this was reported in 9% of all sites.

When studies are separated between CCAFS and non-CCAFS studies, changes in crop and livestock management practices are the major changes that the smallholder farmers targeted in the CCAFS studies have undertaken over the years (Figure 5(b)). However, the non-CCAFS studies show that, in response to climatic changes, smallholder farmers in eastern Africa have primarily changed their crop management practices. Although most farming systems in eastern Africa are mixed crop-livestock, it is likely that the non-CCAFS studies did not put an emphasis on the changes in livestock management practices that farmers have undertaken in response to climatic changes. In addition, the non-CCAFS studies identified non-agricultural activities which smallholder farmers undertake in response to climate change, unlike the CCAFS studies that put an emphasis on agriculture. Some of these activities consist of relying on off-farm income and resources: salary and remittances from relatives and friends; trade and business activities; seasonal migration to town for urban jobs; food aid and relief; consumption of exotic fruits and illegal activities such as theft, smuggling and commercial sex. Another adaptation strategy identified in the non-CCAFS studies consists of changing livelihoods: switching from crop to livestock keeping; switching from crop to mixed crop-livestock system and starting fish farming.

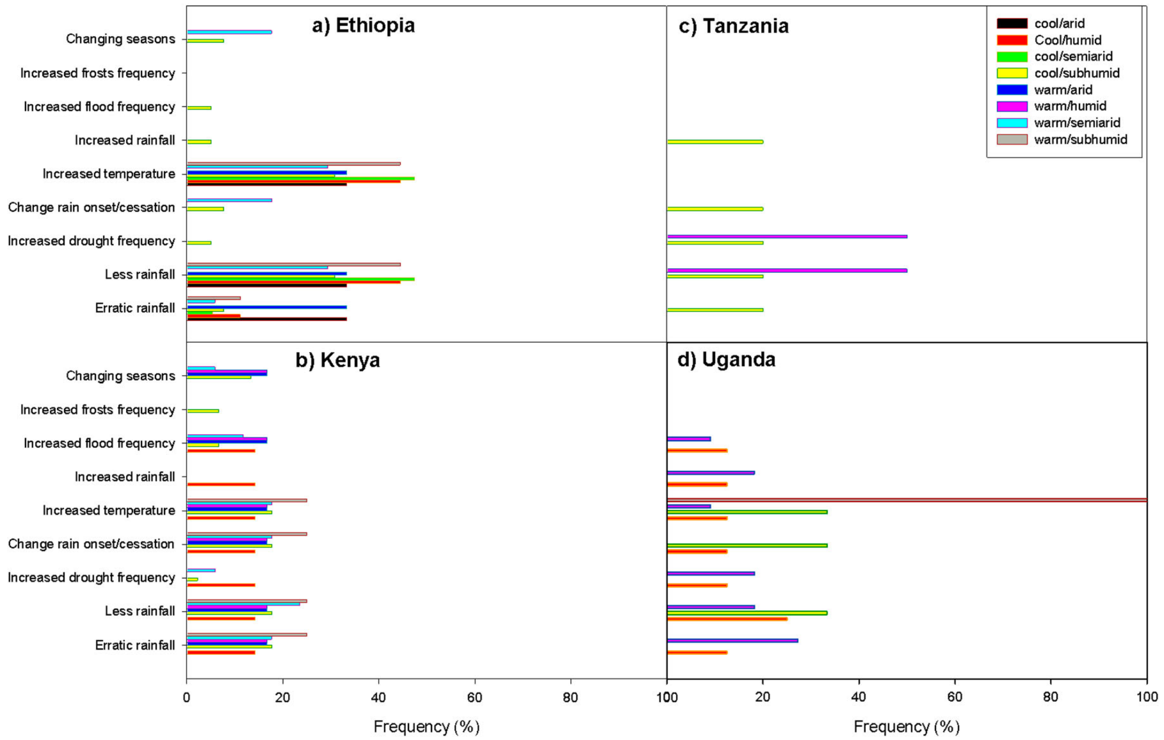

Figure 4. Frequency of climatic risks per AEZ in target countries in eastern Africa.

The analysis of the adaptation strategies per AEZ gives a more nuanced understanding of the strategies used by smallholder farmers in response to climate change. Just as was the case with the climatic risks, the cool/subhumid zone had the highest number of adaptation strategies, although one of the strategies, namely the enhanced use of weather forecast information, was not reported in the zone (Figure 5(c)). In the cool subhumid zone, the most common adaptation strategy consists of changes in crop management practices. Other strategies, which were reported in more than 10% of the sites in the cool/subhumid zone, consist of planting trees; changes in livestock management practices and the adoption of conservation agriculture practices.

In the warm/humid zone, which is found in central Uganda, some parts of central Kenya and in Tanzania (Figure 2), eleven adaptation strategies were reported, just like in the cool/subhumid zone, although frequencies were much lower in the warm/humid zone (Figure 5(c)). The most common adaptation strategy in the warm/humid zone consisted of changing crop management practices which was reported in 17% of the sites. In the warm/semiarid zones, 10 out of the 12 adaptation strategies were reported, and the most common adaptation strategy consisted of selling assets. The next most common strategies consisted of changing crop management practices and relying on off-farm income and resources. Changing livestock management practices followed and was reported in 11% of the sites in the warm/semiarid zone; planting trees was also reported in 11% of the sites.

In the cool/humid zone, 9 out of the 12 adaptation strategies were reported and the most common ones were changes in crop management strategies; planting trees, sale of assets; saving cash or storing grain to enhance resilience against future climate shocks and practising conservation agriculture (Figure 5(c)). Saving cash and storing grain was reported as a strategy to minimize the shocks caused by drought (Rufino et al., 2013).

In the cool/semiarid zone, which is mainly found in Ethiopia and Tanzania (Figure 2), the most common adaptation strategies were changes in crop management practices, planting trees and the adoption of conservation agriculture practices (Figure 5(c)). In the warm/arid zone, which is mainly found in eastern Kenya and Ethiopia (Figure 2), only one site in Kenya was studied (Figure 2) and the reported adaptation strategies in the site were changes in crop and livestock management practices; reliance on off-farm income and resources and collective action. In the warm/subhumid zone, which is mainly found in western Ethiopia, only three adaptation strategies were identified: changes in crop management practices, planting trees and the adoption of conservation agriculture (Figure 5(c)).

Another comparison involving the distance of the sites to major cities shows that the proportion of reports on the use of an adaptation strategy were usually higher for the sites closer to a major city compared to the ones which were far (Figure

Table 4. Sites targeted in the reviewed literature on smallholder farmers and climate change in eastern Africa – adaptation strategies.

Reference	Country	District	Agro-ecology
Ogalleh et al. (2012)	Kenya	Laikipia East	Cool/subhumid
Speranza (2013)	Kenya	Laikipia East, Meru and Buuri	Cool/subhumid
Andersson et al. (2012)	Kenya	Nyando	Warm/semiarid
	Uganda	Tororo	Warm/humid
Bryan et al. (2013)	Kenya	Garissa	Warm/arid
	Kenya	Mbeere	Warm/semiarid; Warm/humid
	Kenya	Njoro, Mukurwe-ini, Othaya	Cool/subhumid
	Kenya	Gem, Siaya	Warm/humid
Eriksen et al. (2005)	Kenya	Mwingi	Warm/semiarid
	Tanzania	Same	Warm/semiarid
Bryan et al. (2009); Deressa et al. (2009)	Ethiopia	Atsbi Wonberta, Hawzein, Endamehoni, Debark, Wogera	Cool/semiarid
	Ethiopia	Limu, Nunu Kumba, Kersa	Cool/humid
	Ethiopia	Libo kemkem, Bichena, Quarit, Gimbi, Haru, Bereh Aleltu, Hidabu Abote, Bambasi	Cool/subhumid
	Ethiopia	Chilga	Warm/semiarid
	Ethiopia	Sirba Abbay, Wenbera, Gesha	Warm/subhumid
Gebrehiwot and Van Der Veen (2013)	Ethiopia	Hintalo Wajirat, Enderta, Kilte Awlaelo	Cool/semiarid
Rufino et al. (2013)	Kenya	Kwale, Samburu	Warm/semiarid
	Kenya	Baringo	Cool/subhumid; Warm/humid
	Kenya	Machakos, Kajiado, North Pokot	Cool/subhumid
	Kenya	West Pokot	Cool/subhumid; humid
	Tanzania	Kishapu	Cool/subhumid; Warm/humid
	Tanzania	Singida	Cool/semiarid
	Uganda	Mbarara	Cool/subhumid; humid
	Uganda	Nebbi	Warm/humid
	Uganda	Masaka	Cool/humid
Mango et al. (2011)	Kenya	Nyando	Cool/humid
Mwangangi et al. (2012)	Kenya	Makueni	Warm/semiarid
Lyamchai et al. (2011)	Tanzania	Lushoto	Cool/subhumid
Desta et al. (2011)	Ethiopia	Yabello, Arero	Cool/subhumid
Mubiru and Kristjanson (2012)	Uganda	Hoima	Warm/humid
Kyazze et al. (2011)	Uganda	Rakai	Cool/humid; Warm/humid
Ojoyi et al. (2015)	Tanzania	Morogoro	Warm/humid

5(d)). More specifically, the sites which were close to a major city had higher proportional counts for 7 out of the 12 adaptation strategies (Figure 5(d)). This result suggests that it is slightly easier for smallholder farmers who are closer to a major city to access and implement a range of adaptation strategies. In addition, in the sites which were not close to a major city, the most common adaptation strategies were mainly related to agricultural practices and consisted of changes in crop management practices, planting trees and practising conservation agriculture. In the sites which were close to a major city, the key adaptation strategies, which were reported in at least 10% of the sites, consisted of changes in crop and livestock management practices, selling assets, tree planting and water management practices. Moreover, the enhanced use of weather forecast for farming decisions was reported only in the sites which were close to a major city (Figure 5(d)). However, the reports on the use of weather forecast occurred only in Uganda, where respondents in Hoima and Rakai reported having access and using weather forecasts (Kyazze & Kristjanson, 2011; Mubiru & Kristjanson, 2012).

Country level analysis shows that in Ethiopia, smallholder farmers have been using three key strategies to adapt to climate change: changes in crop management practices which is reported in 37.3% of the sites, planting trees which is reported in 29.9% of the sites and conservation agriculture (soil conservation) which is also reported in 29.9% of the sites (Table 5). In Tanzania, the key adaptation strategies consist of selling assets; and saving cash or storing grains. These strategies are mainly coping strategies used relative to climate shocks, and two of the four studies targeting Tanzania analysed adaptation strategies relative to climatic shocks (Eriksen, Brown, & Kelly, 2005; Rufino et al., 2013).

A higher number of adaptation strategies were implemented in Uganda, Kenya and Tanzania compared

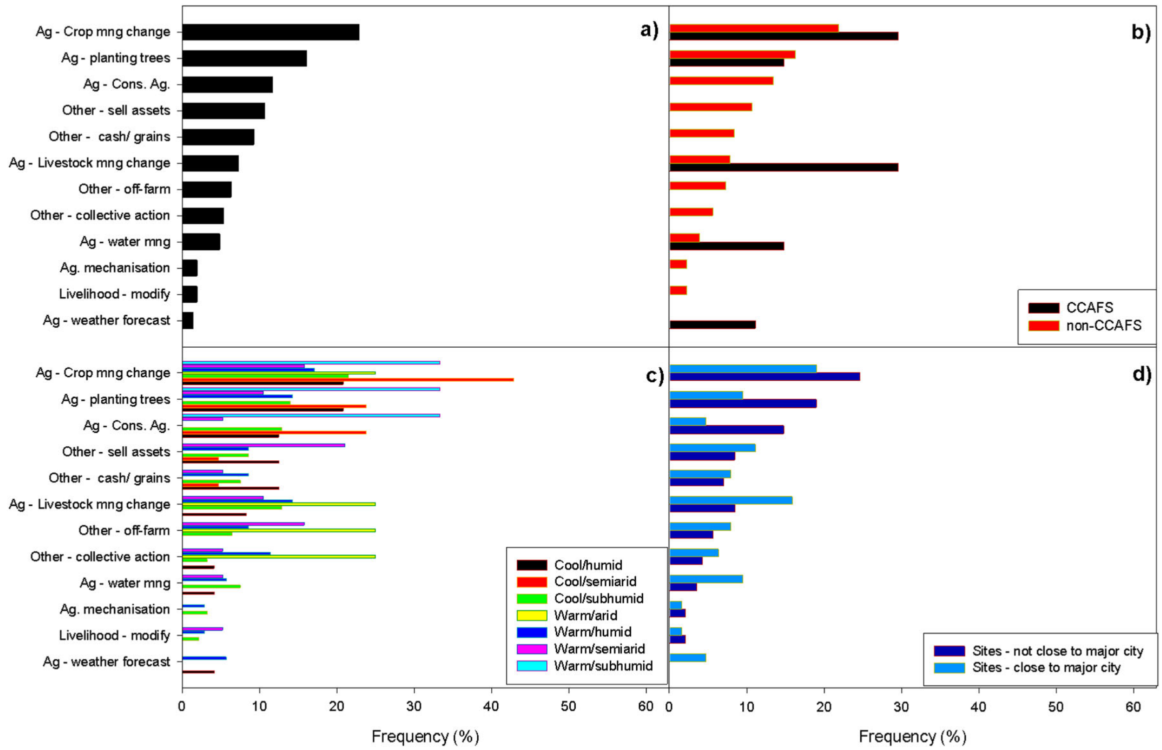

Figure 5. Frequency of plausible adaptation strategies for eastern Africa.

to Ethiopia (Table 5). In addition, all reported strategies had a frequency of less than 20% each in Kenya and Uganda. In Uganda, three strategies were each reported in 17.4% of the sites: changes in crop management practices; selling livestock, labour and firewood; and saving cash or storing grain to minimize the negative effect of future climate shocks. These three strategies were closely followed by two other strategies which were reported in 13% of the sites: changes in livestock management practices and enhanced use of weather forecast. In Kenya, changes in crop and livestock management strategies were each reported in 16.2% of the sites. They were closely followed by two other strategies: reliance on off-farm income and resources with 12.1%; and selling livestock, labour and firewood with 11.1%.

The distribution of countries per adaptation strategy implies that Kenya had the highest proportional count for most adaptation strategies (Table 5). For example, all reports on changing livelihoods as an adaptation strategy were made in Kenya only. This is consistent with the fact that more studies targeted Kenyan sites.

The analysis of the distribution of the adaptation strategies per AEZ in each country reveals some consistency for Ethiopia. Changes in crop management practices, planting trees and the adoption of conservation agriculture (soil conservation) were the key adaption strategies at the national level (Table 5), but they were also the key strategies across all AEZs in Ethiopia (Figure 6(a)). In Kenya, the distribution of the adaptation strategies per AEZ reveals more nuanced results compared to the analysis done at the national level. More specifically, in the warm/semiarid zone, the most common adaptation strategy consists of selling livestock, labour and/or firewood; this strategy was reported in 21% of the sites in the zone (Figure 6(b)). In the cool/subhumid zone, the two most common adaptation strategies were changes in crop and livestock management practices.

In Uganda, reported adaptation strategies at the national level were numerous and five of them were most popular (Table 5). However, an analysis at the level of AEZs reveals that only two adaptation strategies were reported in the cool/subhumid zone of Uganda: selling assets, and saving cash and storing grains (Figure 6(d)). These two strategies were also the most common in the cool/humid zone. The study on the cool/subhumid zone targeted only one site and put an emphasis on the adaptation strategies relative to climate shocks (Rufino et al., 2013). In the warm/humid zone, the key adaptation strategies consisted of changes in crop and livestock management practices; and enhanced use of weather forecast.

Given that Kenya and Uganda have the highest proportion of sites close to a major city (Figure 2(b)), the two countries were chosen to delve deeper into the relationship between the reported adaptation strategies and the proximity of the sites to major cities. In Uganda, the number of reported adaptation strategies was much higher for sites located close to a major city (Figure 7). Such result held even when looking at the distribution of the

Table 5. Adaptation strategies in target country.

Adaptation strategies	Ethiopia	Kenya	Tanzania	Uganda	Total
		Number of sites with reported adaptation strategy			
Other – off-farm	0	12	1	0	13
Other – cash/grains	0	8	3	4	15
Other – sell assets	0	11	4	4	19
Ag – weather forecast	0	0	0	3	3
Livelihood – modify	0	4	0	0	4
Other – collective action	0	9	0	1	10
Ag – Crop mng change	25	16	2	4	47
Ag – water mng	0	7	2	2	11
Ag – planting trees	20	9	2	2	33
Ag – Cons. Ag.	20	4	0	0	24
Ag. Mechanization	0	3	1	0	4
Ag – Livestock mng change	2	16	1	3	22
Total	67	99	16	23	205
		Frequency of adaptation strategies per country (%)			
Other – off-farm	0.0	12.1	6.3	0.0	6.3
Other – cash/ grains	0.0	8.1	18.8	17.4	7.3
Other – sell assets	0.0	11.1	25.0	17.4	9.3
Ag – weather forecast	0.0	0.0	0.0	13.0	1.5
Livelihood – modify	0.0	4.0	0.0	0.0	2.0
Other – collective action	0.0	9.1	0.0	4.3	4.9
Ag – Crop mng change	37.3	16.2	12.5	17.4	22.9
Ag – water mng	0.0	7.1	12.5	8.7	5.4
Ag – planting trees	29.9	9.1	12.5	8.7	16.1
Ag – Cons. Ag.	29.9	4.0	0.0	0.0	11.7
Ag. mechanization	0.0	3.0	6.3	0.0	2.0
Ag – Livestock mng change	3.0	16.2	6.3	13.0	10.7
Total	100.0	100.0	100.0	100.0	100.0
		Frequency of countries per adaptation strategy (%)			
Other – off-farm	0.0	92.3	7.7	0.0	100.0
Other – cash/grains	0.0	53.3	20.0	26.7	100.0
Other - sell assets	0.0	57.9	21.1	21.1	100.0
Ag – weather forecast	0.0	0.0	0.0	100.0	100.0
Livelihood – modify	0.0	100.0	0.0	0.0	100.0
Other – collective action	0.0	90.0	0.0	10.0	100.0
Ag – Crop mng change	53.2	34.0	4.3	8.5	100.0
Ag – water mng	0.0	63.6	18.2	18.2	100.0
Ag – planting trees	60.6	27.3	6.1	6.1	100.0
Ag – Cons. Ag.	83.3	16.7	0.0	0.0	100.0
Ag. mechanization	0.0	75.0	25.0	0.0	100.0
Ag – Livestock mng change	9.1	72.7	4.5	13.6	100.0
Total	32.7	48.3	7.8	11.2	100.0

adaptation strategies per AEZ in the country. This suggest that a smallholder farmer in Uganda who is close to a major city would more likely be able to implement a diverse range of adaptation strategies, compared to the one who is far from a major Ugandan city.

In Kenya, the number of reported adaptation strategies was high and similar between the sites which were close to a major city and the ones which were not (Figure 8). In addition, the sites which were closer to a major city had much smaller proportional counts of reporting 'planting trees', 'changing livelihoods' and 'collective action' as an adaptation strategy. However, these sites had much higher proportional counts of reporting 'selling assets', 'save cash and/or store grains' and 'water management practices' as adaptation strategies. Within the cool/subhumid zone in Kenya, sites, which were close to a major city, had much higher proportional counts on reporting changes in crop management, collective action, enhanced water management and relying on off-farm income as adaptation strategies. The sites, which were not close to a major city, had much higher proportional counts of reporting changes in livelihood, planting trees; conservation agriculture and selling assets as adaptation strategies. In the warm/humid zone, the number of reported adaptation strategies was much smaller for the sites which were close to a major city. However, most of strategies reported in the sites, which were far from a major city, mainly involved changing farming practices.

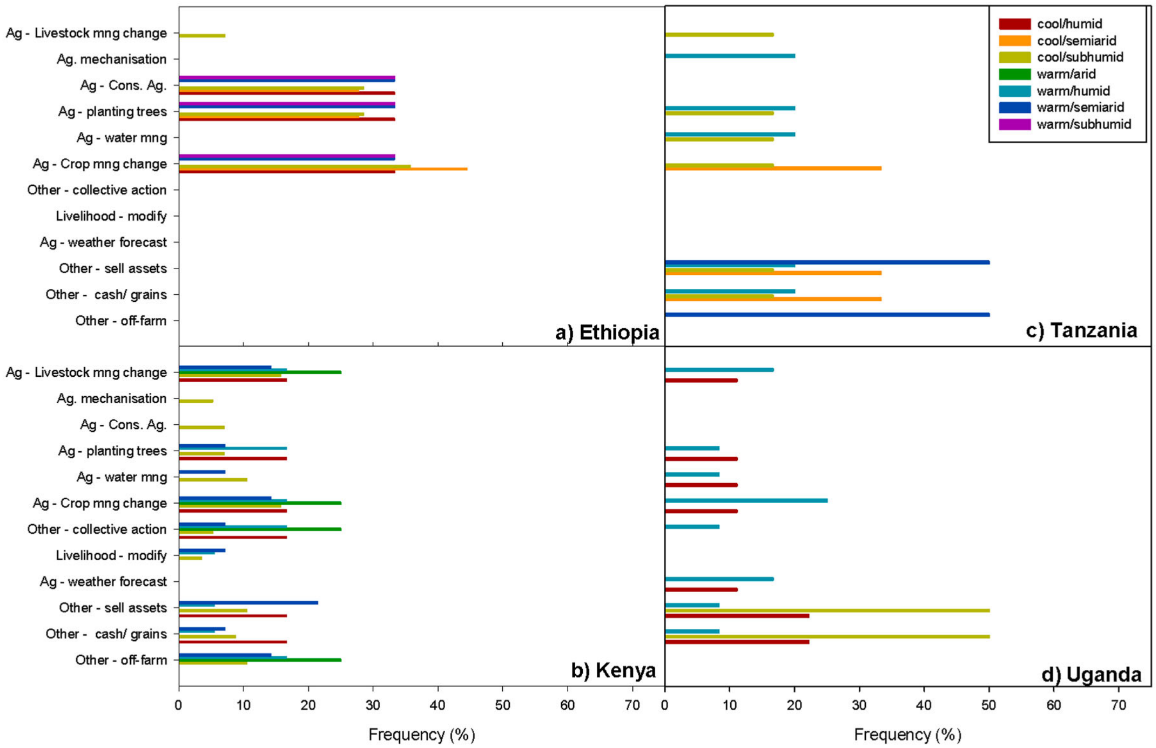

Figure 6. Frequency of plausible adaptation strategies per AEZ in countries of eastern Africa.

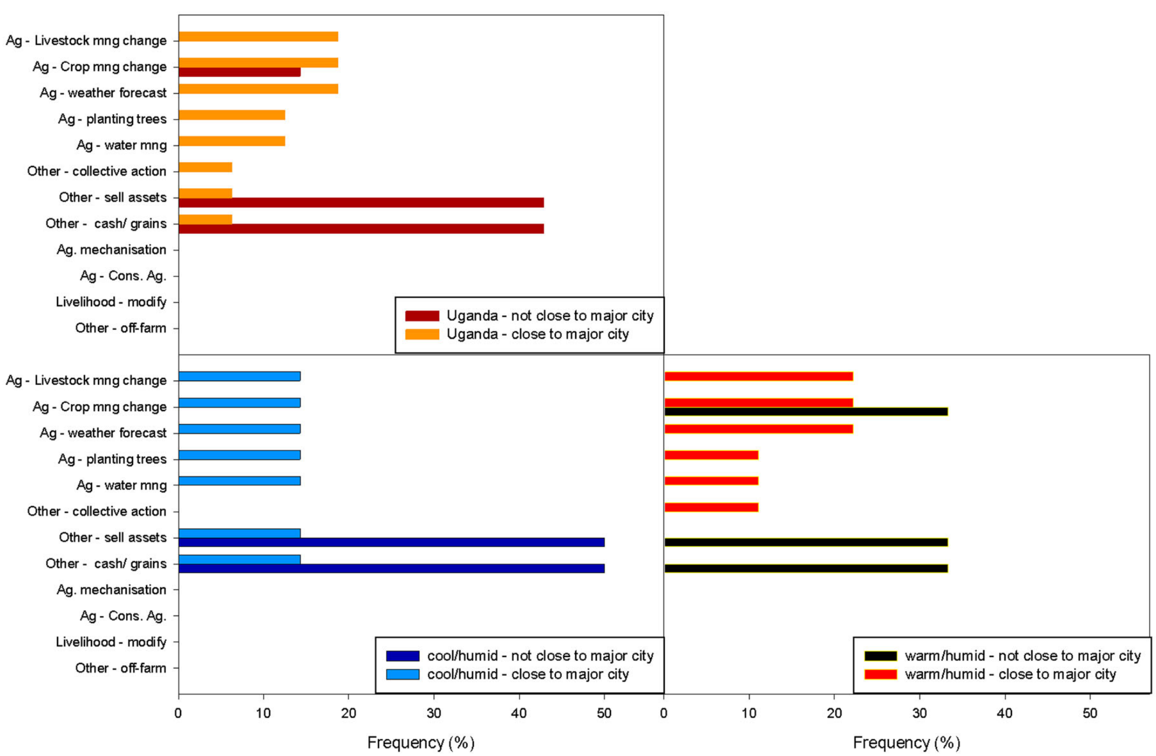

Figure 7. Frequency of plausible adaptation strategies depending on a site's proximity to a major city – Uganda.

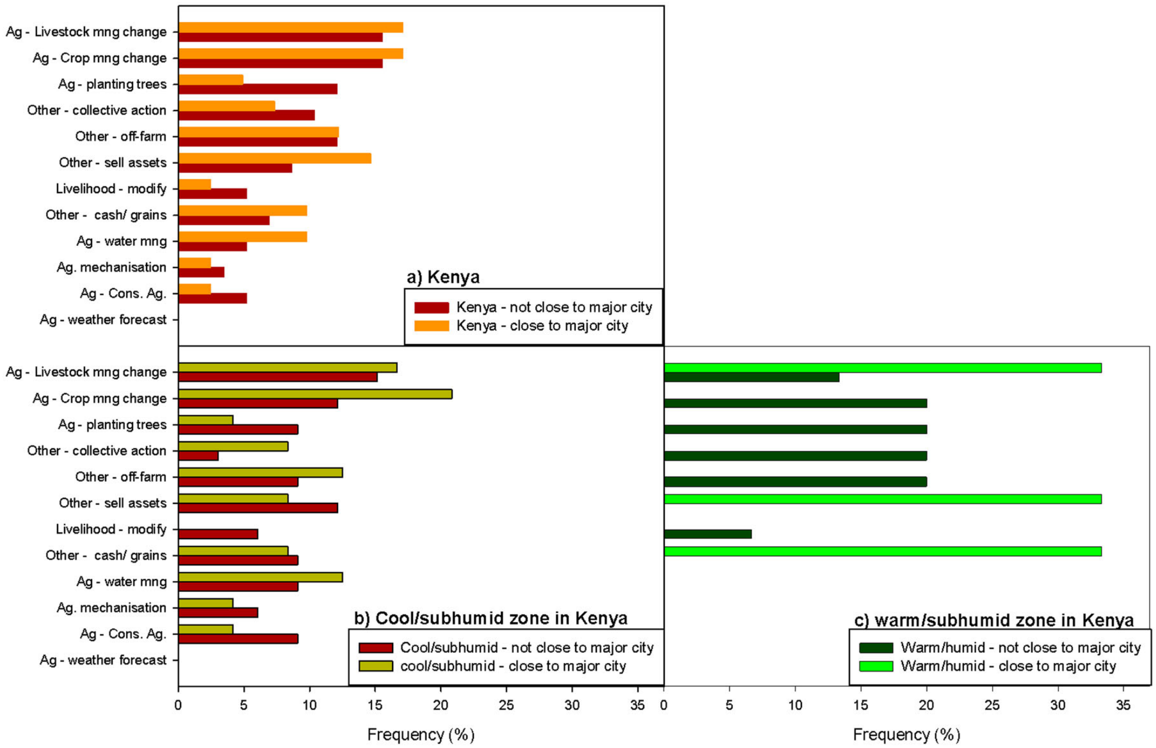

Figure 8. Frequency of plausible adaptation strategies depending on a site's proximity to a major city – Kenya.

Barriers to adaptation

Based on the survey in the case study sites, the key climatic risks faced by farmers consist of floods and droughts for lower Nyando and drought and pests and diseases for Wote. Drought was a climate-related risk that was reported in both Wote and lower Nyando, implying that drought was a cross-cutting risk across both study sites and gender. Over 60% of both men and women perceived drought as a critical climate risk to their agricultural livelihood. In both sites, the preferred adaptation strategies, as identified by farmers, would ensure that a household can meet its basic nutritional requirements through the production of food security crops and can also invest in high-value crops so as to be able to get enough income to support the implementation of flood and/or drought management strategies (Table 6). The ideal adaptation strategy in lower Nyando would consist of a triple approach to control floods, adapt to droughts and invest in high-value crops. To adapt to floods, the farmers in lower Nyando would invest in water control barriers such as terraces and water check dams/reservoirs to control the speed of the water. They would also invest in micro-irrigation and use the water collected during floods for watering high-value crops during droughts. The income invested in the water control barriers and micro-irrigation would come from growing high-value crops such as water melon, onion and tree seedlings. In addition to the triple approach, the ideal adaptation strategy in Lower Nyando would involve investing in improved crop varieties which are early maturing and drought resistant for food security; such crops include sorghum, drought-tolerant maize and cassava.

On the other hand, the ideal adaptation strategy in Wote would involve a double approach to adapt to drought and invest in high-value crops as well. Profitable activities would involve planting high-value crops such as mango and orange. The income generated from selling the high-value crops would be invested in implementing

Table 6. Preferred adaptation strategies for a typical farmer in Wote and lower Nyando.

Lower Nyando	Wote
Food security crops	Food security crops
Maize	Maize
Sorghum	Cowpea
Cassava	Green grams
Sweet potato	
Drought and flood management strategy	Drought management strategy
Tree planting	Zipits
Water terraces	Shallow pits
Water check dams	Roadside water channels
Micro-irrigation	Internal water channel
High-value crops	High-value crops
Trees	Mango orchard
Watermelon	Orange orchard
Onions	

Source:FGD.

water conservation infrastructures such as terraces, zipits, shallow pits; roadside and water channels. Zipits are two interconnected pits which are located near selected trees in orchards and whose purposes are to gather and channel rainwater. In addition, the smallholder farmer would ideally invest in using improved seed varieties that are early maturing and drought resistant for food security; these crops include drought-tolerant maize, cowpeas and green grams.

In both Wote and lower Nyando, there is piecemeal adoption of the preferred adaptation strategies described by farmers. Some have adopted water harvesting techniques alone, while others have largely invested in growing drought-tolerant food security crops. Other farmers were still waiting to reap benefits from investing in high-value crops, as they were planning to invest such benefits into better water harvesting and management techniques. So far, only one farmer among the respondents in lower Nyando had implemented a more comprehensive package of the preferred adaptation strategy as described by farmers in the region. The successful farmer in lower Nyando was a member of a community-based organization (CBO). Through the CBO, the farmer had been able to easily access agricultural credit; receive training on improved agronomic practices and soil as well as water conservation techniques for improved drought and flood management. The CBO was also supported by external institutions, including the Ministry of Agriculture, the Ministry of Livestock, World Neighbours, VI Agroforestry and CCAFS.

The fact that farmers in Wote and lower Nyando could describe their preferred adaptation strategies but had not yet been able to fully implement these strategies suggests the presence of adaptation constraints. One of these constraints was limited land holdings. Most farmers in the target sites owned very small pieces of land; this limits the economic profitability of high value crops and hence makes it difficult for them to invest into strategies for drought and/or flood management. Weak institutional arrangements for climatic changes are another critical constraint. Some of the adaptation strategies, such as flood management, require community effort; everyone needs to participate and if this does not happen, one person cannot take it up. Apart from weak local institutions for enhancing adaptation to climate change, another constraint consists of poor farm planning. Most of the surveyed farmers believed they need a lot of land to invest in the adaptation strategies. However, the highlighted case from Nyando with the complete package of adaptation strategies had only two acres of land, which also comprises his homestead. Lack of capital investment, either through credit or other means is another constraint to adaptation. Without financial resources, it is difficult for a farmer to invest into high-value crops, generate some income and use such income to implement adaptation strategies.

Discussion

Smallholder farmers in eastern Africa are being affected by climate change; the key risks they have experienced over the years include decreased rainfall and increased temperature which have negatively impacted their livelihoods. Erratic rains form another key climatic risk that has been affecting smallholder farmers in selected agro-ecologies of eastern Africa. In response to the changing climate, farmers have used a range of adaptation strategies which include both short-term coping strategies and long-term strategies aimed at maintaining sustainable livelihoods.

The strategies implemented so far vary across agro-ecological conditions since the latter influence livelihoods. For example, in the cool/subhumid and cool/semiarid zones of eastern Africa, the main livelihood consists of mixed crop-livestock agriculture for smallholder farmers. Hence, not surprisingly, changes in crop management practices and tree planting are the most reported strategies in these zones. Conservation agriculture practices form another key strategy reported in the cool/semiarid zone. Only one study was conducted in the warm/arid zone, where pastoralism dominates (Figure 5(c)). The study targeted Garissa, Kenya and found that most smallholder farmers in the zone reported changes in livestock management practices as their key adaptation strategy (Bryan et al., 2013).

The adaptation strategies already implemented by smallholder farmers in eastern Africa are also influenced by institutional settings. Being closer to major cities increases opportunities for adapting to climate change. In addition, the strategy of 'relying on off-farm income' was mostly reported in Kenya possibly reflecting the greater opportunities for off-farm income in Kenya (Table 5). Similarly, the adoption of 'conservation agriculture' was mostly reported in Ethiopia most probably reflecting the main focus of development programmes in the region and/or their greater effectiveness in promoting CA in Ethiopia.

Most of the review studies highlight the importance of indigenous knowledge and skills in climate change adaptation (Andersson & Gabrielsson, 2012; Eriksen et al., 2005; Ogalleh, Vogl, Eitzinger, & Hauser, 2012; Oluoko-Odingo, 2011). Indeed, smallholder farmers in eastern Africa are already adapting to climatic change, from crop diversification in Laikipia and Nyando districts in Kenya (Ogalleh et al., 2012; Oluoko-Odingo, 2011), to selling charcoal and relying on remittances and salaries when coping with a catastrophic drought in Saweni, Tanzania (Eriksen et al., 2005). However, their decisions are heavily influenced by their appraisals of the climatic risks they face and the options available locally to address these risks (Gebrehiwot & van der Veen, 2015; Johansson et al., 2013). New tools are being developed to assist farmers in assessing the effectiveness of adaptation strategies (Chaudhury, Helfgott, Thornton, & Sova, 2014; Sieber et al., 2015).

Indigenous knowledge, though critical in developing and implementing adaptive strategies, is not always consistent (Cooper et al., 2008; Hartter et al., 2012; Rao, Ndegwa, Kizito, & Oyoo, 2011) when it comes to detecting climate patterns and can lead to less than optimal adaptive strategies. This is clearly illustrated for the study in Hoima (Uganda) and Lushoto (Tanzania) where some farmers reported decreased rainfall, whereas others reported increased overall rainfall for the same site (Lyamchai et al., 2011; Mubiru & Kristjanson, 2012). Rao et al. (2011) also found that farmers in five Kenyan districts tend to overestimate the frequency of negative weather events, such as dry seasons; as a result, these farmers prefer farming techniques that require low financial investments, and thereby cannot fully benefit from improved technologies. Hartter et al. (2012) found that farmers' perceptions in Kibale (Uganda) suggested decreased and more erratic rainfall; however, measured weather data implied no significant changes in rainfall levels, although it corroborated farmers' perceptions of increased erratic rainfall. In this case, water harvesting measures could be useful in enhancing water allocation to crops throughout the growing season. These two studies highlight the importance of accurate climate information in supporting farmers' decisions relative to identifying and implementing adaptive strategies to climatic change.

The reviewed literature also suggests that despite being aware of climatic changes, a good proportion of farmers are not implementing adaptation measures. In a study targeting farm households in four AEZs in Kenya, Bryan et al. (2013) found that 19% of surveyed farmers did not implement any adaptation strategy relative to climatic change. The authors identified two reasons for non-adaptation: farmers do not view climatic change as a risk and they do not have the resources and information necessary to adapt. Similarly, Deressa, Hassan, and Ringler (2009) found that 42% of farmers in the Nile Basin of Ethiopia did not adapt to climatic change due to lack of climate information; lack of financial resources; labour or land shortage and poor irrigation potential for their farms.

Our case studies provide examples of the range of measures adopted by farmers in order to adapt to changing climate and highlight the importance of collaborative effort between local and external organizations. In both Wote and lower Nyando, the preferred adaptation strategies identified by smallholder farmers involve a strong component of agroforestry; this might reflect the priorities of projects carried out in the area and not necessarily the optimal adaptation strategies for farmers in these two regions. Moreover, the sole farmer who has so far adopted the most comprehensive range of adaptive measures version of the preferred adaptation strategy in Wote and lower Nyando benefitted from the services rendered through a strong alliance of local and external organizations. This confirms that the result is in line with that of Johansson et al. (2013) who explain how leaving out government extension agents from the Vi Agroforestry Program (ViAP) led farmers to have a negative perception of agroforestry and hence slowed down the adoption of this adaptation strategy in the Mara region of Tanzania.

Conclusion

This study provides lessons to consider in designing programmes aimed at supporting climate change adaptation for smallholder farmers in eastern Africa. For one, such programmes need to consider the variations in institutional settings across the region; more specifically, they should take into account that farmers located far from major cities in eastern Africa tend to have fewer opportunities for adapting to climate change. The programmes also need to develop strategies adapted to current and projected future agro-ecologies as the latter influence the livelihoods of smallholder farmers. In addition, they need to incorporate farmers' knowledge since various studies demonstrated that farmers' decision to adapt to climate change is influenced by their perceptions of climatic risks and plausible adaptation strategies. Given that farmers' knowledge can be inaccurate, the programmes on climate change adaptation would also benefit from providing targeted farmers with improved weather services and information on the costs and benefits of plausible adaptation options. In addition, the programmes need to foster collaborative effort between key local and external stakeholders who can influence farmers' perceptions and hence their decision to adapt to climatic change.

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