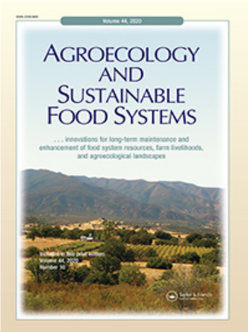

Agroecology and Sustainable Food Systems

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/wjsa21

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To cite this article: Ylva Nyberg , Mattias Jonsson , Emmeline Laszlo Ambjörnsson , Johanna Wetterlind & Ingrid Öborn (2020) Smallholders’ awareness of adaptation and coping measures to deal with rainfall variability in Western Kenya, Agroecology and Sustainable Food Systems, 44:10, 1280-1308, DOI: 10.1080/21683565.2020.1782305

To link to this article: https://doi.org/10.1080/21683565.2020.1782305

AGROECOLOGY AND SUSTAINABLE FOOD SYSTEMS
2020, VOL. 44, NO. 10, 1280–1308
https://doi.org/10.1080/21683565.2020.1782305

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Smallholders' awareness of adaptation and coping measures to deal with rainfall variability in Western Kenya

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ABSTRACT
Farmers in Kisumu and Trans Nzoia counties, Kenya, were aware of more adaptation than coping measures for dealing with rainfall variability both on and off-farm. Interviews with female and male farmer groups revealed that they all experienced challenges related to increasing rainfall variability whether or not they had regular access to advisory services. Men identified more measures than women and had better access to learning sources. Farmers in Kisumu were aware of more measures than those in Trans Nzoia but thought them less effective. Money, knowledge and labor were the most limiting factors preventing the uptake of adaptation measures.

KEYWORDS
Advisory services; gender; land-use change; Vi Agroforestry

Introduction

For smallholder farmers, the distribution of rainfall is critical in rainfed agriculture, and seasonal rainfall variability can lead to crop failures (Ndehedehe, Agutu, and Okwuashi 2018; Rockström et al. 2010). Even if rainfall variability is often more challenging than changes in mean rain amounts for local communities, it is often neglected in research and advisory work (Thornton et al. 2014). For both researchers and local farmers, it can be difficult to determine whether local weather phenomena reflect normal variations or long-term climate change (Howe et al. 2013). However, adaptation measures are available (Ryan and Elsner 2016) and reported adaptation initiatives in Africa are increasing (Ford et al. 2015). There have been attempts to differentiate between adaptation and coping measures, with the main distinction being whether the measure is long term or short term, respectively (Mengistu 2011; Mertz et al. 2009; Rakshit, Padaria, and Bandyopadhyay 2016). The effects of adaptation and coping measures can differ widely, and it is therefore important to analyze them separately. Here, *adaptation* measures are defined as 'initiatives to reduce the vulnerability of natural and human systems against actual or expected climate change effects' (IPCC

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2007), and involve planning. *Coping* measures, on the other hand, are defined as survival-orientated, short-term solutions that are used because of lack of alternatives (Dazé, Ambrose, and Ehrhart 2009). Using adaptation measures can be the difference between being food secure or not among smallholders when rainfall variability is non-favorable (Kuhn et al. 2016). Building livelihood resilience, through the use of adaptation measures, is a way for smallholders to be better prepared for upcoming challenges in their production (Quandt, Neufeldt, and McCabe 2018). And to reach livelihood resilience, all five capitals (natural, social, produced, cultural and human) need to be considered (Bebbington 1999).

Long-term trends in East Africa show increasing temperatures and variations in rainfall where some areas showed decreasing trends. But Western Kenya showed a rainfall increase of on average 2.3 mm $year^{-1}$ between 1962 and 2001, especially in the highlands (Gebrechorkos, Hülsmann, and Bernhofer 2019; Githui et al. 2009). East Africa is predicted to experience a temperature increase of 3.2°C (range 1.8–4.3°C) and a rainfall increase of 7% (range −3 to +25%) during the period 1980–2090 (IPCC 2007). However, the rainfall increase is expected mainly in the highlands (Thornton et al. 2006), and Kenyan national staple food production is estimated to decrease overall because of higher evapotranspiration (Herrero et al. 2010). Still, changes in the average annual quantities of rainfall often play a smaller role than changes in variability (Ndehedehe, Agutu, and Okwuashi 2018; Thornton et al. 2014). Agricultural management now requires making both short-term and long-term adjustments to variations in rainfall. In addition to climate variability, land use, especially in the Lake Victoria basin, has been greatly affected by population growth. Since 1970, agriculture has expanded into former grazing land and wetlands, and agricultural land use has intensified on hill slopes that were previously covered by trees (UNEP 2006). More frequent and severe floods and droughts have occurred during the same period (Herrero et al. 2010), partly as a result of land-use changes (Öborn et al. 2015).

Rural services, agricultural advisory services in particular, are often seen as a necessity to reduce farmers' vulnerability to climate-related impacts (Below et al. 2012; Farnworth and Colverson 2015). Kenya's vision for 2030 also proposes adaptation and mitigation options to climate change and variability, including enhancement of farmers' and advisors' knowledge and skills and effective interaction between these (Mohamed et al. 2013). Due to limited positive results from earlier advisory systems in Kenya (Amudavi 2003; Gautam 2000; Niang, Jama, and Nyasimi 2001; Odhiambo et al. 2019), there is a need for more research that can capture positive and negative examples and help the extension system improve its efficiency and impact, including advice on adaptation and mitigation in a socially, economically and environmentally acceptable way (Klein, Schipper, and Dessai 2005). For example, Kenya's current vision for 2030 uses the words 'adaptation' and 'coping' interchangeably

(Mohamed et al. 2013), which could cause confusion and lack of understanding among both advisors and farmers. However, it is important not to narrow down adaptation to knowledge and technology alone (van Aalst, Cannon, and Burton 2008) and to acknowledge that climate variability is just one of the several challenges for smallholder farmers. Smallholders may have the knowledge but not the means to carry out certain adaptation measures. Several earlier studies have called for a better understanding of adaptation awareness and barriers to uptake of adaptation measures among smallholders, especially related to climate (Cavanagh et al. 2017; Deressa et al. 2008; Kalungu and Harris 2013).

Women and men on smallholder farms in sub-Saharan Africa have different roles and different agendas on the farm. Men are more focused on commercial purposes and goals, while women are concerned about subsistence goals to maintain a supply of food, fodder and firewood (Chikoko 2002; Kiptot and Franzel 2011). Men are also generally responsible for property and decision-making and have more time and opportunities to be part of the public sphere (e.g. attending meetings or trainings), when women, on the other hand, are expected to take reproductive responsibility and carry out most of the daily farm work, and are thereby more or less isolated in the domestic sphere (Laszlo Ambjörnsson 2011). Earlier research has documented the imbalances in responsibilities and rights between women and men, although research on agricultural and ecological sustainability rarely takes gender into account (Öborn et al. 2017; Ogunlela and Mukhtar 2009; Rocheleau 1991; Twyman, Muriel, and García 2015).

The overall aim of this study was to identify smallholders' awareness of adaptation and coping measures to rainfall variability, in order to sustain food security and livelihoods, in two contrasting areas in Western Kenya. Specific objectives were to:

(1) Identify smallholders' awareness of adaptation and coping measures to rainfall variability, and examine similarities and differences between women and men farmers' views and between two geographical areas.
(2) Evaluate how access to regular advisory services can affect smallholders' awareness of adaptation and coping measures to rainfall variability.
(3) Identify sources of where farmers learnt the measures from, and recognize factors limiting the use of the measures.

Area background

Study areas

The study was carried out in three (Muhoroni, Nyando and Nyakach) of the seven sub-counties in Kisumu County (Kisumu) and in all five sub-counties in Trans Nzoia County (Trans Nzoia) in Western Kenya (Figure 1) with bimodal rainfall patterns. These two counties have contrasting agricultural conditions in terms of altitude, climate, soils and topography (Online resource 1; Figure 2a,b). Trans Nzoia ('the bread-basket of Kenya') has a cool (mean annual minimum and maximum temperatures of 12°C and 26°C, respectively), wet (mean annual rainfall 1267 mm) climate, due to high altitude (~1800–2000 m above sea level (asl)) and proximity to Mt. Elgon and the Cherangani hills. The cool temperatures allow farmers to harvest just one maize crop that grows during both the long and short rains (Odhiambo et al. 2015). Kisumu, located by the shores of

Figure 1. Map of Kenya (Africa map from Wikimedia commons CC-BY-SA-3.0) showing the two contrasting counties where the study was carried out.

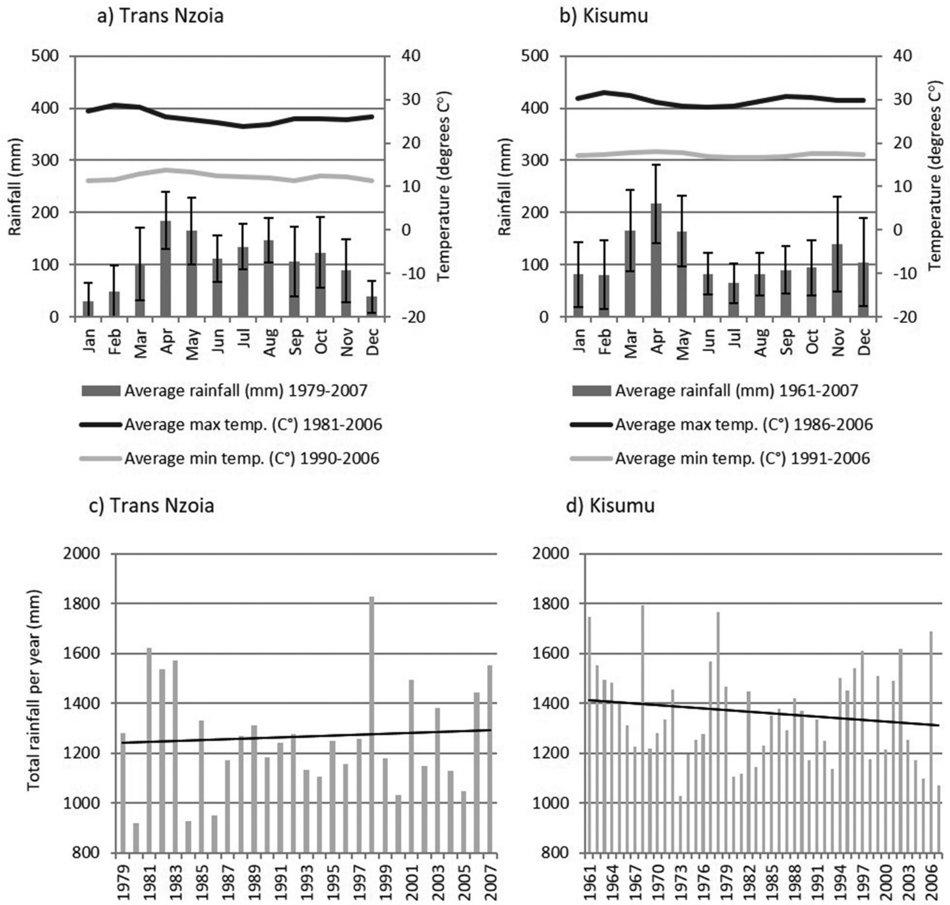

Figure 2. Mean monthly rainfall (± standard deviation) and mean monthly minimum and maximum daily temperatures in periods for which data were available (1961–2007 for Kisumu and 1979–2007 for Trans Nzoia regarding rainfall; 1991–2006 for Kisumu regarding maximum and minimum air temperatures; and 1981–2006 and 1990–2006 for Trans Nzoia regarding maximum and minimum air temperatures) at (a) Kisumu and (b) Trans Nzoia meteorological stations in Kenya. (c) Total annual rainfall 1979–2007 for Trans Nzoia and (d) 1961–2007 for Kisumu (including trendlines).

Lake Victoria, has similar mean annual rainfall (1362 mm), but lower altitude (~1100 m asl) and warmer annual mean minimum and maximum temperatures (17°C and 30°C, respectively). Due to the higher temperatures, farmers in Kisumu can harvest in two maize cropping seasons per year if the rains are favorable (Odhiambo et al. 2015). The inter-annual variability in rainfall is great in both counties, with total annual precipitation ranging between 919 and 1829 mm in Trans Nzoia and 1029 and 1791 mm in Kisumu over a 28- and 44-year period, respectively (Figure 2c,d). In terms of soils, Kisumu is dominated by Vertisols and Planosols that are prone to flooding and overall more challenging for farmers to manage than the Ferralsols in Trans Nzoia (Government 1985).

There are also socio-economic differences between the counties, with mainly one tribe (Luos) in Kisumu and a mix of tribes in Trans Nzoia. Men in the Luo community are traditionally fishermen, although very few pursue this occupation today (Hansen et al. 2011). They inherit their land, where mainly women are engaged in subsistence farming of maize, sorghum, sugarcane, etc. (Bernier et al. 2013; Ocholla-Ayayo 1976). Kisumu town offers job opportunities in the area. The land in Trans Nzoia, on the other hand, is desirable for farming (Otieno, Jayne, and Muyanga 2015), so people from different tribes moved in after colonial large-scale farmers left after independence in 1963. The characteristics of the two areas, with potentially different levels of interest and tradition in agriculture and different preconditions through soils and temperatures, permit interesting comparisons in terms of awareness and limitations of adaptation and coping measures, as agriculture is the main livelihood activity and income source.

Agricultural advisory services in the study areas

Government advisory workers organized within four disciplines (livestock, forestry, agriculture and environment) were present in both areas before or during the study period, together with staff from another government advisory program, the National Agricultural and Livestock Extension Programme (NALEP) (Cuellar et al. 2006). In the Kisumu sub-counties studied, there were 12 government staff (including NALEP staff) in total during the period 2000–2010, while Trans Nzoia had a total of 27 staff in that period (Nyariwo Wilson, personal communication 2014).

A nonprofit and non-government organization (NGO) called Vi Agroforestry also had field advisors in the two counties during the same period. These field advisors offered capacity development in agroforestry and other sustainable management practices, with tree planting by farmers as the core activity (Wekesa and Jönsson 2014). The Kisumu area had five such advisors in total in 2013, but between 2002 and 2010 there were 77. In Trans Nzoia, there were 100–250 advisors between 1990 and 2004, but the scheme was then phased out and it had no advisors by 2013 (Nyariwo Wilson, personal communication 2014). Other NGOs were present in both areas during the study period in 2010, but they were working primarily with HIV/Aids. Both government and NGO advisory services accessed groups rather than individuals, in order to reach more households.

Materials and methods

Selection of participants and set-up of farmer group interviews

The farmer group interviews had the purpose of (i) detecting rainfall-related challenges perceived by farmers, (ii) identifying different adaptation and coping measures that farmers were aware of, (iii) asking farmers to score the effectiveness of measures which they had experience of, on a scale from 0 to 5 (Table 1), (iv) understanding learning sources of measures that farmers had experience from, and (v) recognizing limiting factors when farmers did not practice the measures. The group interviews had a factorial design including the two counties, male and female respondent groups and groups with or without regular access to advisory services. The study had two replicates of each of the eight factorial combinations and thereby 16 groups in total. Advisory service access was divided between farmers who had had regular access to advisory services through the NGO (Vi Agroforestry) during the period 2000–2010, and farmers who had only had occasional contact with agricultural advisors from the government (hereafter called trained and non-trained farmers, respectively). Village elders, local resource persons and field staff from the NGO assisted in informing and calling farmers (almost all were members of formal groups/associations). The participation criteria were that individuals should: (1) represent farm size ≤2.5 ha; (2) obtain the majority (>50%) of their income from the farm; and (3) represent a mix of farms on both flat and sloping land. A short individual questionnaire (Online resource 2) was used to gather some background information on farm size, level of education and extent of market orientation, etc. (Table 2), and to ensure that farmers fulfilled the criteria for participation. After being introduced to the purpose of the study, all participants gave their informed consent for participation. Each group interview had between six and 12 participants (Kumar 1987; McLafferty 2004), who among themselves appointed a secretary to write down all challenges, measures, scores, limiting factors and learning sources on a flip chart for everybody to see, which makes the process more transparent and allows participants to take charge of the discussion to a greater degree (Hay 2010). The farmer group interviews were held in Luo in Kisumu and in Swahili in Trans Nzoia. Questions were standardized across all group interviews and saturation of measures (Hay 2010) was achieved in both counties. A female and male translator was used for women's and men's

Table 1. Full definition of the different scores that could be given to adaptation and coping measures.

Score	Definition of score
0	This measure has **no positive effect** to adapt to or cope with rainfall variability
1	This measure has a **small positive effect**, but alone is **never enough** to adapt to or cope with rainfall variability
2	This measure has a **visible positive effect**, but alone is **rarely enough** to adapt to or cope with rainfall variability
3	This measure has a **visible positive effect** that alone is **sometimes is enough** to adapt to or cope with rainfall variability
4	This measure has a **strong positive effect** and alone can **often be enough** to adapt to or cope with rainfall variability
5	This measure is **enough** alone to adapt to or cope with rainfall variability

Table 2. Background information for all individual participants in the farmer group interviews carried out in Kisumu and Trans Nzoia Counties.

Details of participants	Kisumu (n = 67)	Trans Nzoia (n = 61)	Women (n = 70)	Men (n = 58)	Trained (n = 59)	Non-trained (n = 69)	All (n = 128)
Average age of participants (yrs) (range within brackets)	44 (20–74)	43 (23–84)	40 (20–60)	48 (22–84)	47 (20–84)	40 (22–68)	43 (20–84)
Average family size (no. of persons) (range within brackets)	7 (1–15)	7 (2–17)	7 (1–15)	6 (1–17)	7 (1–17)	7 (1–15)	7 (1–17)
% participants with 0.2 hectares (ha) or less land	21	20	23	17	12	28	20
% participants with more than 0.2 but less than 2 ha of land	78	72	76	74	85	67	75
% participants with 2–2.5 ha of land	1	8	1	9	3	6	5
% participants with no formal education	6	5	9	2	3	7	5
% participants with primary school education	60	61	67	52	56	64	60
% participants with secondary school or higher education	34	34	24	47	41	29	34
% participants with crop products for both consumption and selling	51	82	59	76	64	68	66
% participants with animal products for both consumption and selling	49	66	53	76	59	67	63
% participants with tree products for both consumption and selling	54	64	50	72	63	58	60

groups, respectively. Women were targeted as women farmers, and not necessarily as female heads of households.

The interviews lasted 1–3 hours and were carried out for 2 months in 2010 using a semi-structured interview guide that had been tested on two test farmer groups (Online resource 3) (Hay 2010). All group interviews were audio-recorded and measures were written down by the group secretary on flipcharts. The researcher was listening and taking notes. No transcription or coding was used. During interviews, adaptation measures were referred to as 'measures one plans for', whereas coping measures were referred to as 'measures one may be forced to take'. During data analysis of the interview records, all measures were divided into 11 categories according to their nature and aim, and to the scale at which they are decided upon/practiced (field, farm or landscape).

Statistical analysis

Generalized linear mixed-effect models were fitted to test effects of different factors on: (i) the number of measures identified, (ii) the average score allocated to the measures, and (iii) the number of times different learning sources were mentioned. All analyses were conducted in R 3.4.2, using the glmer function in the lme4 package for tests on the number of measures and the lme function in the nlme package for tests on average score (The R Foundation for Statistical Computing Platform 2017). A first test for farmer groups included the following fixed factors: sex, area (Kisumu vs Trans Nzoia), regular access to training or not, type of measure (adaptation or coping) and the following interactions: type of measure x sex, type of measure x area, type of measure x training. Since each farmer group recorded coping and adaptation measures separately, farmer group was included as a random factor. A separate test was conducted for the scale at which a measure was deployed (field, farm or landscape). For tests of the number of times different learning sources were mentioned by farmer groups, the following fixed factors were used: sex, area, regular access to training or not, and interactions between area x training, area x sex, and trained x sex. Separate tests were conducted for the following learning sources: Elders, Ministry of Agriculture, neighbors and friends, Vi Agroforestry, other sources and common sense (in cases of no external source). For tests on the number of measures, a Poisson error distribution was assumed. However, as over-dispersion was detected, an observation level vector was also added to the random model (Bolker et al. 2009). For tests on average score, a Gaussian error structure was assumed. For each response variable, a model simplification procedure was used to select the model that best explained the variation in the data, by comparing all possible models with the Akaike Information Criterion adjusted for small sample size (AICc). The modavg function in the AICcmodavg package was then used to average all models with ΔAIC <2.0 compared with the best fitting model (lowest AICc value).

Results

Farmers' perceptions of rainfall challenges and awareness of adaptation and coping measures

From the participant background information, it was clear that 94% had some formal education, farm size was small (20% of farmers had less than 0.2 ha) and one-third of the farmers were unable to sell any crop products (Table 2). All farmer groups perceived increasing challenges related to water availability for farming. Too little rain with occasional drought, too much rain with occasional flooding, hailstorms and unpredictable rainfall were the main challenges mentioned in the two areas. Farmers from Kisumu reported that during parts of the year (April–May), heavy rain often led to floods (Table 3). In other parts of the year, those farmers reported a shortage of rain (increasingly erratic) with occasional severe droughts (e.g. from January–March). The farmer groups in Trans Nzoia mentioned increasingly unpredictable seasons, with delayed but more rain during recent years, combined with cold, windy weather with occasional hailstorms.

The 16 farmer groups mentioned between 12 and 40 different adaptation and coping measures each, and a total of 79 different measures were identified (Table 4). Division of these measures into 11 categories depending on their nature and aim revealed that the majority fell within five categories: erosion control, crop production, livestock production, irrigation, and tree production. The other six categories were: off-farm, food and cooking, external, vegetable growing, opportunistic, and other measures. Significantly more (a total of 68) measures (model-averaged estimate: 0.76, 95% CI: 0.5, 1.02) were considered to be adaptation measures than coping measures (11) and the adaptation measures were given significantly higher scores (farmer groups model-averaged estimate: 1.09, 95% CI: 0.66, 1.51) (Figure 3a,b). In all, 33 measures were decided upon and practiced at field level (e.g., ditches, mulching, trees to prevent wind and erosion). Another 25 measures were defined as being decided upon and practiced at farm/household level (e.g. roof catchment, changing eating habits or planting fodder crops). The remaining 21 measures were landscape measures that needed decisions/actions both from the farm and outside the farm (e.g. saving money through a group, selling timber or off-farm income sources).

Many farmers considered coping measures (e.g. selling an animal, tree or sand) to be negative, but necessary for survival (Table 3). Coping measures such as selling labor, eating fewer meals per day and queuing for food aid were considered to undermine farm development, since they caused a decrease in labor for the farm, while many adaptation measures were labor-intensive. On average per farmer group, farmers mentioned similar numbers of measures at farm (9), field (8) and landscape level (7) (Figure 3a). The scores allocated to the effectiveness of the different measures were similar for all farmers, with

Table 3. Citations (translated to English) from the group interviews with farmers from Kisumu (KI) and Trans Nzoia (TN).

Topic	Person	Comment
Rainfall challenges	Non-trained man KI	'Previously we experienced big floods every 10th year (1961–1963, 1971–1972 and 1984), whereas now the floods are more frequent but small floods for a shorter time. Rain used to be constant and reliable nearly every day during the rainy season. Since the beginning of the 80 s, the rain is not reliable and not well distributed. Rain can now come too much in a shorter period and then after that, drought for a longer period.'
Unpredictable rainfall	Trained man in TN	'Before the 60 s and 70 s we knew when rains were coming, but now no-one knows – we cannot predict when or how much rain will come'
Too much rain, wind and hailstorms	Trained man TN	'Too much rain and hailstorms is another problem. Fertilizer can be washed away and extreme cold during that time affects the crops. We have been going back to our old traditional crops that are grown underground like arrowroot, cassava, sweet potatoes and groundnuts, as they are not so much affected by extreme weathers or hailstorms. Use of trees in cropland (agroforestry) also helps when the wind is too strong so that crops are not affected much. It also helps to do dairy farming, as the livestock are not as affected by the weather as crops'
Too much rain	Non-trained men TN	'We concentrate more on livestock during too much rain, since there is not much one can do about the crops. Firewood is a problem during too much rain as we cannot always buy charcoal so sometimes we have food, but we can't eat it raw'
Sell animal as coping measure	Trained woman KI	'How can you sit and watch your livestock die? You just bring it to the market'
Relief food as coping measure	Non-trained men KI	'It has no positive effects', 'the distribution system is corrupt and very selective' and 'even if you get, it will never be enough'
When challenge is too much	Trained woman TN	'We are being forced to be idle'
Drought	Trained woman KI	'When drought is here there is nothing you can do on the farm' and continued talking about different off-farm businesses they carry out instead.
Land for agriculture	Trained man KI	'The subdivision of land has reached a point of no return'
Relevance of fish farming	Trained woman TN	'Fish farming has been promoted by government, but you need much land to put aside some for a fish pond and the pond needs an inlet and an outlet to keep water clean so in these areas where water is stagnant for a long time I don't think fish can do well. Also, some neighbors who tried got problems with the fish pond flooding and fish died or escaped'
Relevance of greenhouse	Trained man TN	'We don't have money to build greenhouses that could protect the crops during both too much and unpredictable rainfall, but they still would be too small to plant maize'
Trees' effect on rain	Trained man TN	'When colonial people were here trees were everywhere and rains were easy to predict, but now trees are cut, and rains are not reliable'
Plant vegetables in a sack	Trained woman in KI	'I always have vegetables and it needs little water'
Less meals per day	Non-trained woman KI	'We work like elephants and eat like hares, get weak and lose weight'
Plant trees and Napier grass on contours	Non-trained woman TN	'It helps a lot since water-flow stops at trees and grass holds the soil'
Leasing land	Non-trained woman TN	'It is often far from your home so people may steal crops and livestock'

Table 4. Adaptation (A) and coping measures (C) identified by farmer groups organized into 11 categories depending on the nature and aim of the measure, and to one of the three different spatial scales, field (FI), farm (FA) or landscape (LA), depending on which level they were decided upon and practiced. Measures mentioned in Kisumu = KI and Trans Nzoia = TN. The number (n) of scorings can be larger than the number of groups since measures were grouped, e.g., there are several types of ditches. Mean and standard deviation (±SD) of scores are shown for single measures where applicable. Farmer groups only scored measures that they had experience from.

Type of measure	Name of measure	A	C	FI	FA	LA	KI	TN	n	Mean score	±SD	Explanation and reason to use measure
Erosion control	Plough/plant along contours								3	5	0	Across slope to improve water infiltration
	Plant without plowing								1	1	-	No tillage to improve water infiltration
	Raised beds								1	5	-	To prevent flooding of crops
	Double digging								1	2	-	To get better root conditions to survive drought
	Dig terraces								2	3	1.4	To promote water infiltration
	Dig ditches								20	2.6	1.4	To promote water infiltration and prevent flooding
	Dig cutoff drain								2	2.5	2.1	Drain ditches to prevent flooding
	Soil in sacks								4	2.5	0.6	Building ridges to prevent flooding
	Grass strips								3	2.6	2.1	Across slope to improve water infiltration
	Stone lines								1	1	-	Across slope to improve water infiltration
	Add mulch								5	2.6	0.9	To promote water infiltration
	Add manure								4	2.75	2.0	To promote water infiltration
	Add compost								1	2	-	To promote water infiltration
	Early plowing								2	1	0	To utilize a shorter rainy season
	Early planting								4	4.25	1.0	To utilize a shorter rainy season
	Dry planting								1	3	-	Plant before rain to utilize a shorter rainy season
	Use greenhouse								10	3.7	1.4	To not depend on rainfall
	TOTAL	17	0	13	4	0	12	14	65			
Crop production	Water-tolerant crops								12	3.4	0.9	E.g., rice, banana, yams, vegetables, sweet potato, cassava
	Drought resistant crops								8	3.75	0.7	E.g., cassava, sweet potato, sorghum, millet, cow/pigeon pea, local vegetables
	Plant under-ground crops								2	5	0	Not affected by hailstorms, e.g., cassava, yams, sweet potato, groundnuts
	Plant traditional crops								2	4.5	0.7	Better adapted to this area, e.g., watermelon, butternut, pumpkin, millet, cow pea
	Plant perennial crops								1	5	-	Can withstand more rainfall variability, e.g., sugarcane, banana, coffee, tea, macadamia
	New/short-term crop varieties								7	2.9	1.2	To be sure to harvest
	Crops in nursery								1	3	-	For survival, then transplant
	Bananas in ditches								1	3	-	To collect water for better performance

(*Continued*)

Table 4. (Continued).

Type of measure	Name of measure	A	C	FI	FA	LA	KI	TN	n	Mean score	±SD	Explanation and reason to use measure
	Plant cover crops								1	4	-	To promote water infiltration, e.g., sweet potatoes, desmodium
	Early harvesting								1	3	-	To get something at least
	Chemical on leaves to reduce moisture								2	3	1.4	Did not know name
	TOTAL	9	2	11	0	0	8	9	38			
Livestock production	Build raised cattle shed								1	5	-	To protect hooves from water when flooding
	Plant fodder								5	4.4	0.5	To not depend on rainfall
	Zero grazing system								1	5	-	To control grazing and improve fodder efficiency
	Dry/store fodder								1	5	-	To not depend on rainfall
	Focus on livestock								10	3.4	1.5	If crops failed, pay more attention to livestock
	Rotational grazing								1	3	-	Graze one area at the time to make grass last
	Beekeeping								4	4	1.4	To not depend on rainfall
	Establish fish pond								6	2.8	1.7	To not depend on rainfall
	Take livestock to greener pasture								3	1.7	1.2	Walk with livestock to other area to graze
	Sell livestock								12	2	0.9	To get money to survive
	TOTAL	9	1	0	8	2	4	9	44			
Irrigation	Pump irrigation								7	3.6	1.9	For crops to survive when drought
	Gravity irrigation								1	5	-	For crops to survive when drought
	Drip irrigation								3	3.7	1.2	For crops to survive when drought
	Hand irrigation								2	3	1.4	For crops to survive when drought
	Dig a water pan								8	2.9	1.5	Small pond to store water
	Roof catchment								8	2.9	1.2	To utilize water better
	Dig a well								2	4.5	0.7	To get water when drought
	Micro-catchments on farm								1	3	-	For improved water infiltration
	Timely watering								1	1	-	Morning and evening to utilize water better
	TOTAL	9	0	5	4	0	8	8	33			
Tree production	Plant trees for erosion control								14	3.4	1.4	To improve water infiltration
	Plant trees for soil fertility								6	3.3	1.3	To improve water infiltration
	Plant trees as windbreak								1	5	-	To prevent strong wind destroying crops
	Plant trees to absorb water								4	3.25	0.5	To prevent flood
	Sell timber								8	1.9	1.0	To get money
	Sell firewood or charcoal								13	2.4	1.3	To get money
	Sell fodder from trees								1	1	-	To get money
	Sell fruit from trees								1	4	-	To get money

(*Continued*)

Table 4. (Continued).

Type of measure	Name of measure	A	C	FI	FA	LA	KI	TN	n	Mean score	±SD	Explanation and reason to use measure
	TOTAL	8	0	4	0	4	3	8	48			
Off-farm	Make and sell baskets, ropes, pots								8	2.4	1.1	To not depend on rainfall
	Make and sell bricks								6	2.8	1.2	To not depend on rainfall
	Keep a shop								7	2.4	1.1	Craftsman, hairdresser, bicycle taxi, shoe polisher
	Go fishing in lake/river								5	3	2	To not depend on rainfall
	Sell labor								13	1.4	0.7	To not depend on rainfall
	Mine and sell stones								4	1.75	1.0	To not depend on rainfall
	Trading								13	2.2	1.2	Buy and sell goods to not depend on rainfall
	TOTAL	4	3	0	0	7	7	4	56			
Food and cooking	Use raised energy-saving stoves								1	5	-	To use less firewood and avoid flooding
	Preserve food								12	4.4	0.7	E.g., with solar dryer to always have food
	Less meals per day								16	1.3	0.7	From three meals to two to make food last
	Change eating habits								6	1.5	0.8	Eat less preferred food to make food last
	TOTAL	2	2	0	4	0	3	4	35			
External	Government dikes								4	4.25	1.5	To prevent flooding
	Relief food								6	1.7	0.5	To survive
	Migration								11	1.2	0.8	To survive
	Help from relatives								1	1	-	To survive
	TOTAL	1	3	0	1	3	4	3	22			
Vegetable growing	Kitchen garden								4	3.75	1.0	Possible to irrigate and have emergency food
	Grow vegetables in a sack								3	3.7	2.3	Possible to irrigate and have emergency food
	Grow tomatoes off-season								1	5	-	To get better price and not depend on rainfall
	TOTAL	3	0	0	3	0	3	0	8			
Opportunistic	Harvest and sell sand								2	2	1.4	Sand comes with water during flooding
	Sell fish from flooded area								1	3	-	Try to fish from flooded area to get money/food
	Sell river water								2	1.5	0.7	To get money
	TOTAL	3	0	0	0	3	3	0	5			
Other	Lease land								2	2	1.4	Plant crops in another place to spread risks
	Saving/loaning/marketing through group								2	2	0	To be able to invest or save for future
	Plant other area								6	2.8	1.7	Swampy, sloping, drier depending on challenge to at least get some harvest
	TOTAL	3	0	0	1	2	3	1	8			
	Grand total	**68**	**11**	**33**	**25**	**21**	**58**	**60**	**364**			

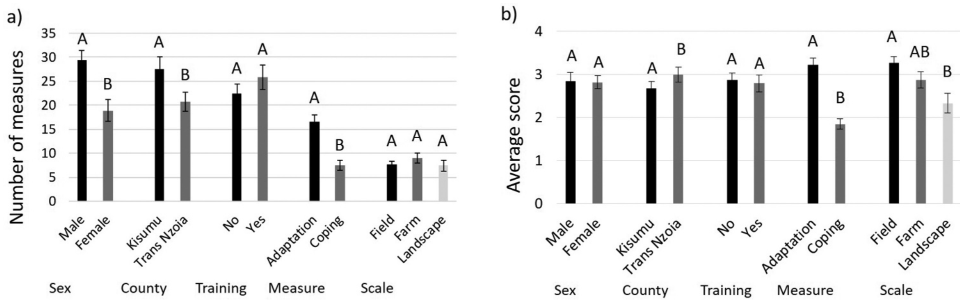

Figure 3. Statistical data on (a) average number of measures (with standard errors) mentioned per farmer group for male and female groups, for groups from Kisumu and Trans Nzoia, for trained and non-trained groups, for measures divided between adaptation and coping measures, and for measures divided between field, farm and landscape-level measures; and (b) average score (Table 1) for the same categories of sex, county, training, measure and scale (with standard errors).

field measures being scored on average highest and landscape measures (mostly coping measures) being scored significantly lower (farmer group estimate: 0.9032, $P < .00$) (Figure 3b). Some farmers complained about the relevance of measures promoted by the government, using deployment of greenhouses as an example since a greenhouse is expensive and only covers a small plot of land, and is therefore insufficient/too risky to rely on (Table 3).

Comparison of the study areas

Similar measures were identified in the two contrasting counties, even though farmers in Kisumu (with higher temperatures, flat topography and soils with slow infiltration) mentioned more extreme rainfall-related challenges and gave significantly lower scores than Trans Nzoia farmers (model-averaged estimate: −0.44, 95% CI: −0.78, −0.11) (Figure 3b). Kisumu farmer groups were aware of significantly more measures (model-averaged estimate: 0.28, 95% CI: 0.08, 0.48), especially on landscape scale, than the farmer groups in Trans Nzoia (Figure 3a). Most of the 21 measures that were only mentioned in Trans Nzoia were related to livestock keeping and tree production, while Kisumu farmers had 19 unique measures mostly relating to opportunistic, off-farm and vegetable growing measures (Table 4). In Kisumu, both men and women mentioned different off-farm opportunities, while in Trans Nzoia it was mainly men. Women in Trans Nzoia even explained that they were “forced to be idle” when rainfall challenges were too great (Table 3). Seventy-one percent of Trans Nzoia farmers had crop, animal or tree products for sale (surplus after consumption requirements), compared with only 51% in Kisumu and the NGO (Vi Agroforestry) was mentioned more than twice as many times as a learning source for a measure in Trans Nzoia (20%) than in Kisumu (8%) (Figure 4). The greatest source of learning measures in Kisumu was elders

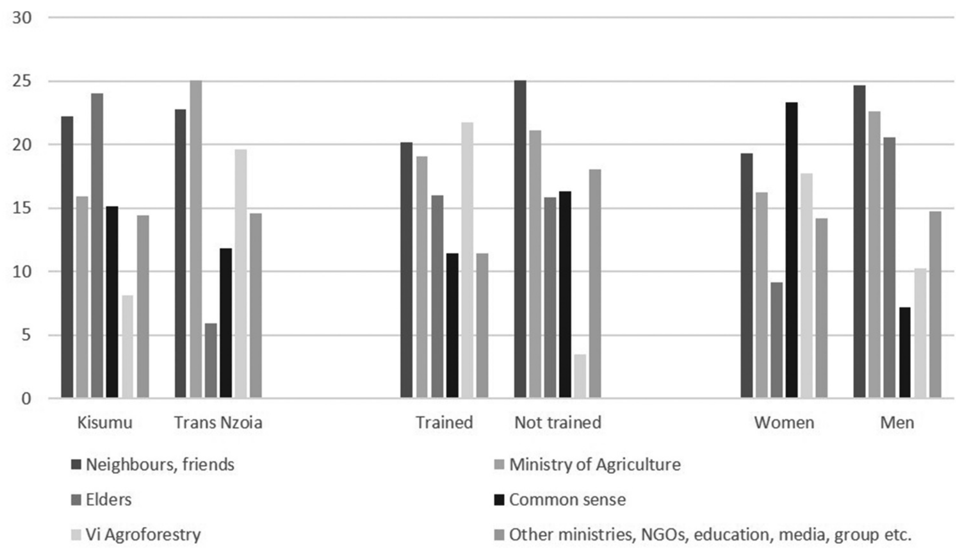

Figure 4. Sources of knowledge for learning about measures (% of all sources) for: men and women, for farmers who were trained and non-trained (regular advisory services or not) and for the two counties.

(24%), a source used significantly more there (model-averaged estimate: 1.58, 95% CI: 0.92, 2.23) than in Trans Nzoia, where only 6% of farmers mentioned elders as a learning source (Figure 4).

Role of gender

Only 24% of the women surveyed had secondary education, compared with 47% of the men (Table 2). Men also learnt significantly more from external learning sources like the Ministry of Agriculture (model-averaged estimate: 0.72, 95% CI: 0.03, 1.41) and elders (model-averaged estimate: 1.16, 95% CI: 0.55, 1.77), compared to women (Figure 4), who relied significantly more on common sense (model-averaged estimate: 0.78, 95% CI: 0.27–1.3). Men identified significantly more measures (29 per group) than women (19 per group) (model-averaged estimate: 0.41, 95% CI: 0.18, 0.65) (Figure 3a). However, they scored the measures similarly (Figure 3b). Women identified mainly field and farm measures (74%), while men were aware of mostly farm and landscape measures (73%). The top three limiting factors to implement a measure were money, knowledge and labor for men, but money, labor and material/tools for women (Figure 5). Moreover, 9% of the men lived on a farm with 2 ha or more land, compared with only 1% of women, and 75% of the men had surplus crop/animal/tree products for sale, compared with just 54% of women.

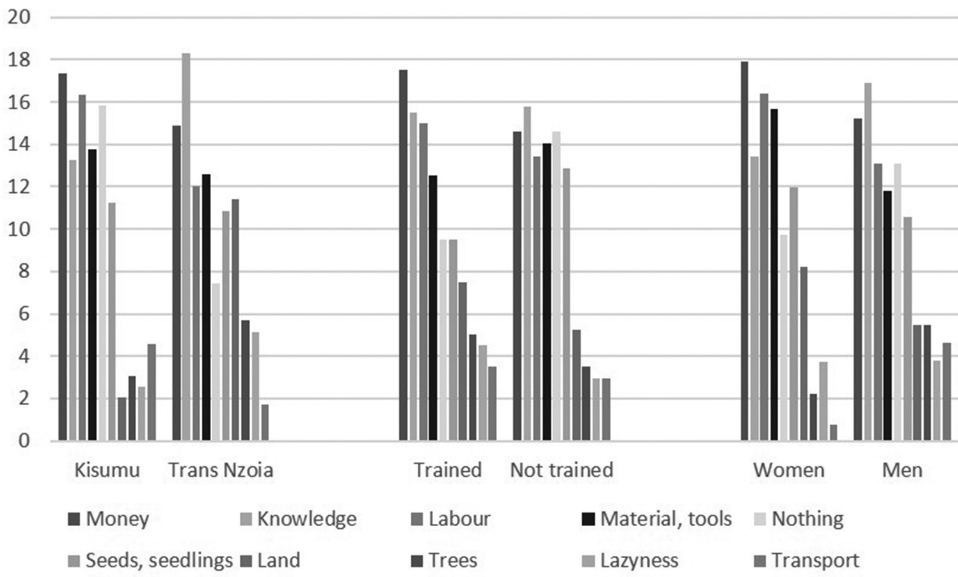

Figure 5. Identified limiting factors preventing farmers from using measures (% of all factors) for: men and women, for farmers who were trained and non-trained (regular advisory services or not) and for the two counties.

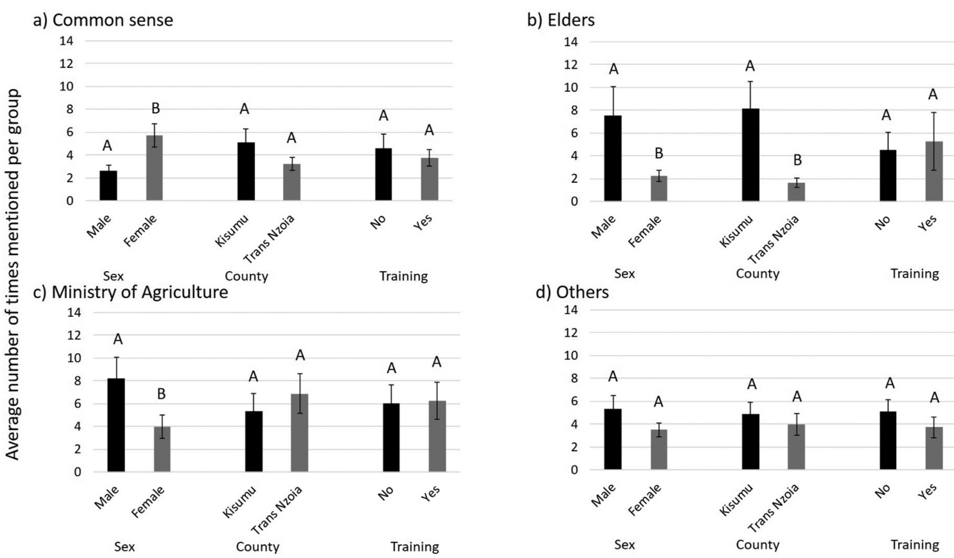

Figure 6. Average number of times a learning source was mentioned per farmer group (with standard errors), comparing men and women, the two counties and trained and non-trained farmers (regular advisory services or not) for: a) common sense (no external learning source), b) elders and relatives, c) Ministry of Agriculture and d) other learning sources (other ministries, other NGOs, education, media or their own farmer group). The remaining learning sources mentioned (neighbors and friends, Vi Agroforestry) were not included, as neighbors and friends did not improve the model fit and Vi Agroforestry was a selection criterion.

Role of access to regular advisory services

Access to regular advisory services did not have a significant effect on the number of adaptation and coping measures farmers were aware of, or the average score of measures (Figure 3a,b). However, there was a tendency for the trained farmer groups to mention more measures with high scores than non-trained farmers, a variable which improved model fit, but was not significant. For example, trained farmers were aware of, on average, four measures relating to trees and three relating to livestock (compared with two and two, respectively, for non-trained groups). Non-trained farmers were aware of more external measures (i.e. measures with external assistance, e.g. relief food), which were scored lower (1.9) than tree (2.7) and animal (3.0) measures in all group interviews. Among trained farmers, 41% had secondary education or higher, compared with only 29% among the non-trained farmers. Trained farmers learnt about 22% of the measures from the NGO, while non-trained farmers instead learned about them from the Ministry of Agriculture, neighbors and common sense (Figure 4b).

Discussion

Inter-annual rainfall variability, changed rainfall patterns or changed land use?

Both female and male farmers taking part in this study reported experiencing challenges related to rainfall variability, as seen among other East African farmers (Adimo et al., 2012; Wetende, Olago, and Ogara 2018). However, several studies in Kenya have also indicated perceived changes in climate, and especially rainfall, among smallholders while the climate data cannot support their perceptions (Bryan et al. 2013; Rao et al. 2011). It can be difficult for farmers to understand the reasons for the increasing challenges, but their experiences are most likely due to a combination of several factors. Perceived changes in rainfall patterns could be directly linked to changes in rainfall amount, intensity and/or interval, but could also be linked to land-use changes (e.g. cultivation of deforested land prone to soil erosion, especially on hill slopes), causing less infiltration, less groundwater recharge and more surface run-off, and thereby temporary floods downslope (Meze-Hausken 2004; Öborn et al. 2015). Moreover, the farmers have become more vulnerable due to factors such as increased population density with agricultural land expansion or smaller farm size as a result (Kebede et al. 2019). Also, a practice of ‘growing what you eat’, even if cropping is then sometimes pushed beyond suitable areas, with every farmer growing maize instead of traditional, more drought-tolerant crops like sorghum and cassava, could also potentially explain stress perceived as rainfall-related challenges (Deressa, Hassan, and Ringler 2011). Large inter-annual variation (Figure 2c,d) also plays a great role for smallholders in terms of being food secure or not

(Generoso 2015). The large number of adaptation and coping measures mentioned, spanning over eleven different categories and three scales, showed that farmers had a great experience in rainfall variability and its consequences just like was found by Ngugi (2002) and Agesa et al. (2019). The scoring of measures also indicated that no single measure alone can make a household resilient. Rather, the more active choices a farmer can make, the more resilient they become. For example, a combination of food and cash crops can spread the risks. Previous studies have shown the importance of market access (Frelat et al. 2016) and microfinance services (Abate et al. 2016) for smallholders to save and invest in their agriculture and be able to make a profit when trading. Thus, agricultural advisors should be able to facilitate links to these services. Field measures were scored highest and considered to be most effective, probably because the effect was more direct and easy to notice. Some new, innovative adaptation measures were also mentioned (like drip irrigation and greenhouse use), but these need large initial investments.

Farmers clearly explained the drawbacks of the coping measures, giving them significantly lower scores than adaptation measures (Bryan, Theis, and Choufani 2017). A few adaptation measures represented traditional but nowadays rarely used agricultural practices (e.g. preserving food and using drought-resistant, traditional, perennial and root and tuber crops) that have high potential to be successful and sustainable in different combinations (Altieri and Nicholls 2017; Below et al. 2012). The three most limiting factors for implementing adaptation measures according to farmers – money, knowledge and labor – were required in nearly all measures. Access to money and labor sometimes go together, since many farmers have to look for off-farm jobs to sustain themselves, and thereby lose labor for their own farm.

Similar measures in contrasting counties

More extreme rainfall-related challenges like droughts and floods were mentioned, together with a higher number of measures, by farmers in Kisumu, which could be expected owing to that county's higher temperatures and less permeable soils. However, most of the identified adaptation and coping measures were similar between the two counties and reflect findings in other parts of the world (Below et al. 2012; Challinor et al. 2007; Gbegbelegbe et al. 2017; Nguyen et al. 2013). Farmers perceived that better management, e.g. using mulch, having more tolerant/resistant crop types or using different water-saving techniques, sometimes in combination with off-farm businesses, could reduce their vulnerability. Most of the measures mentioned were common agricultural practices designed to improve productivity in general, but which in combination could improve farmers' adaptive capacity (Bedeke et al. 2019; Vermeulen et al. 2012). Vegetable growing, opportunistic and off-farm measures were more commonly mentioned in Kisumu, also by women. This difference is most likely because Kisumu farmers were unable to rely on the farm alone for subsistence (Laszlo Ambjörnsson 2011) and because nearby Lake Victoria and Kisumu town generate more off-farm opportunities. Women in particular, but also men, in Trans Nzoia are thus more vulnerable to extreme weather, since they often lack an off-farm income opportunity (Table 3), which is a common practice for reducing vulnerability (IPCC 2014). In the long term, however, off-farm activities may lead to lost time and labor for their own farms, thereby undermining farmers' future capacity to adapt their own farming to new challenges. Off-farm work also means that farmers actually move away from farming as a way of living, as has happened in Kisumu (sometimes with few viable alternatives of getting food and income), and become dependent on the job market and buying food from other producers, which is being vulnerable in a different way (Challinor et al. 2007).

The NGO, with focus on trees and agroforestry, had been active for longer in Trans Nzoia than in Kisumu, which could be a reason for tree measures being more commonly mentioned in Trans Nzoia. One could expect more adaptation measures in Trans Nzoia, since its farmers were more dedicated to farming and had actively chosen to buy land in a highly productive area (Dulal et al. 2010) relatively recently (after independence 1962). However here, the opposite pattern was found, with more measures identified in Kisumu than in Trans Nzoia (27 and 21, respectively, on average per group), possibly due to a higher need and more severe challenges with rainfall variability in Kisumu (more floods and droughts). Farmers in Kisumu also gave significantly lower scores to the measures (mean 2.7) than farmers in Trans Nzoia (mean 3.0), indicating either that the measures were not working effectively or that a combination of more measures was needed in order to adapt to the more extreme challenges. The two farming counties clearly had different objectives and preconditions for farming. Trans Nzoia farmers had less severe challenges, scored their adaptation measures higher (i.e. rated them more effective) and had more products for sale (crop, animal and tree products). The objective of farmers in Trans Nzoia was really to sustain the family, while in Kisumu the farm was sometimes more of a security behind other income-generating activities. It was more common in Kisumu to learn adaptation and coping measures from elders, while in Trans Nzoia a higher percentage of farmers learnt from the NGO (Figure 4b). There could be at least two reasons for this difference: the NGO had worked longer in Trans Nzoia than in Kisumu, and farmers in Trans Nzoia had migrated from other areas and therefore had fewer elders around to learn from.

Men get the training and women do the farming

The reasons why women identified less adaptation and coping measures, just like in another Kenyan study (Kalungu and Leal Filho 2018), are probably multiple and complex, involving legal rights, traditions and cultural taboos, which commonly affect women negatively (Doss 2001). For example, women identified fewer tree production measures, but since trees are more permanent on the farm and planting/cutting needs a decision from the land owner (the man), women might feel demotivated to engage in tree-related measures (Kiptot and Franzel 2011). Women had less products for sale and listed fewer livestock-keeping measures, potentially since money and animals (except chickens) are mostly men's responsibility (Andersson and Gabrielsson 2012). In addition, women had smaller farms, less education and were less exposed to different external learning sources, which is similar to the situation in other sub-Saharan African countries (Doss and Morris 2000; Felix et al. 2010). This illustrates the vulnerable condition of female smallholders, not only bio-physically but also in relation to human and institutional capacity (Diiro et al. 2018; Dixon, Smith, and Guill 2003). It means that women have to rely more on 'common sense' to learn new measures, probably because they mostly do domestic work on the farm and in the household, and thereby rarely travel to trainings, meetings or advisory offices (Kiptot and Franzel 2011). However, the women in this study had learnt measures from the NGO to a larger extent than the men, which suggests its advisory services were efficiently aimed and actually reached women. Women did not feel as limited by knowledge as men, perhaps since women had a lot of experience of challenges in farming, and very limited experience of education and training. The fact that women commonly remain within the domestic sphere and carry out much of the actual farm work can explain why they identified fewer landscape-scale measures than men.

For women to improve their adaptive capacity, they need to get better access to education and training in general and advisory services in particular, but also access to land and capital, i.e. property and power (Diiro et al. 2018; Doss and Morris 2000; Gabrielsson and Ramasar 2013). These system changes take time, but one important start could be policies and laws. Here, the Kenya Vision 2030 has a great role to play and could set the standard. Kenya Vision 2030 states that women and men should be treated equally and that women should have increased participation in economic, social and political decisions (Kenya 2007). It also highlights the importance of raising public gender awareness (Mohamed et al. 2013). However, the examples given are to have more women in parliament and more money in the women's enterprise fund (Kenya 2007) which, while good initiatives, may not have much impact for smallholders in rural areas. The national climate change action plan (part of Kenya Vision 2030) mentions gender discrimination of women and describes women as a particularly vulnerable group in terms of climate change impacts and rainfall variability (Mohamed et al. 2013). This indicates that women need to be specially targeted with such examples as agricultural advisory services, education opportunities, land rights' information, and microfinance services, so that over time they are able to utilize a demand-driven service system on equal terms to other farmers.

Advisory services affect types of measures

The relationship between better adaptive capacity and smallholders having regular access to advisory services reported in other studies (Below et al. 2012; Deressa et al. 2009; Yang et al. 2017) was not supported by findings in this study. However, farmers accessing regular advisory services tended to be aware of more, and especially more effective, measures according to their own scoring, such as agroforestry, mulching and water harvesting (Figure 3a). These measures are triple-win measures that can potentially mitigate emissions, improve adaptation capacity and increase profitability (Bryan et al. 2013). Such measures are highly relevant, both according to Kenya's national strategy (Mohamed et al. 2013) and the worldwide focus on climate-smart agriculture (FAO 2015). However, according to Speranza et al. (2010), such practices are becoming less common for socio-economic or socio-political reasons, due to limited capital and labor or insecure land tenure, which together with knowledge were also among the most limiting factors in this study.

Farmers with regular advisory services tended to have higher educational background, and fewer had farm sizes below 0.2 ha, compared to farmers without regular advisory services, which could be why the former tended to know more measures. However, it could also mean that the more educated farmers were more actively seeking new knowledge, joining group training and adopting measures, which can relate to the challenge of reaching the poorest of the poor with information (Gwatkin, Wagstaff, and Yazbeck 2005; Karanja Ng'ang'a, Jalang'o, and Girvetz 2019; Lønborg and Rasmussen 2014). Also, the 'gap' identified (by farmers) between farmers and advisors needs to be reduced. One option could be to strengthen the horizontal sharing and learning of methods where farmers are leading the process through their own groups and associations (Rosset and Martínez-Torres 2012). Farmer-to-farmer learning networks have been successfully implemented elsewhere to overcome social barriers and to be able to scale up measures for an improved sustainability and resilience among smallholders (Rosset et al. 2011).

Conclusions

Smallholders in Western Kenya perceived and described increasing challenges relating to rainfall variability that made them feel vulnerable. While it was not possible to disentangle the causes of this increased vulnerability, the need for adaptation measures was obvious. Smallholders were knowledgeable and creative in terms of adaptation measures at field, farm and landscape scale that, in a sustainable way, could help them adapt to rainfall variability challenges. However, natural capital (rainfall) was not their only challenge, as human (labor), social (knowledge) and produced (money) capital were all limiting the farmers from adaptation work. When adaptation measures were not sufficient to manage a challenge, farmers knew different coping measures for survival, although coping measures often lead to negative consequences for farming.

Direct measures at the field level were considered most effective followed by measures at the farm/household level, while landscape-scale measures that involved another stakeholder than the farmer were rated lowest. Kisumu experienced more severe challenges and had greater awareness of both adaptation and coping measures, even though adaptation measures were scored less effective in Kisumu compared to in Trans Nzoia. Households in Kisumu often had off-farm income sources to reduce their dependence on farming, while farmers in Trans Nzoia mainly lived from farming.

Access to advisory services seemed important but was not a significant factor for adaptation measures. Women knew less measures than men and had least opportunities for training and education. This calls for more structural changes, as outlined in the national climate change action plan as part of Kenya Vision 2030. Further research is needed on the roles of women and men in smallholder farming and their access to and engagement in different advisory services approaches, and its connection to the actual use and effectiveness of different adaptation and coping measures on food security, livelihood and resilience.

Acknowledgments

This work was supported by the Swedish Ministry for Foreign Affairs as part of its special allocation on global food security, the Swedish Research Council Formas and Swedish International Development Cooperation Agency programme on 'Sustainable development in developing countries' (220-2009-2073) and the Swedish University of Agricultural Sciences (SLU). Farmers in Kisumu and Trans Nzoia counties are gratefully acknowledged for giving their time and sharing the experiences which formed the basis for this paper.

Disclosure statement and compliance with ethical standards

No potential conflict of interest was reported by the authors. All procedures performed in the study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments, or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Funding

This work was supported by the Swedish Ministry for Foreign Affairs; Styrelsen för Internationellt Utvecklingssamarbete [220-2009-2073]; Svenska Forskningsrådet Formas; Sveriges Lantbruksuniversitet.

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