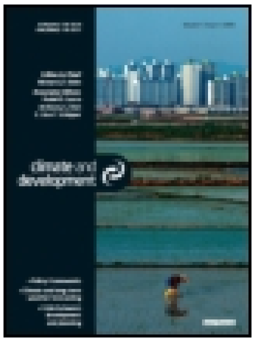
Supporting climate change adaptation using historical climate analysis



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Supporting climate change adaptation using historical climate analysis

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ABSTRACT

Climate change and variability presents a challenge for rural communities in developing countries. Bridging organizations help align stakeholder and local perspectives and mediate communication that shapes adaptation responses. We argue that a first step for adaptation projects is to determine the nature of the climate norms and how climate is changing. This paper explores the degree to which development organizations in Kenya, Uganda and Tanzania used analysis of local historical climate information in project aims, planning and design. This included 67 participants, managing 102 community-level climate-related agricultural projects, and three NGO case studies. Most focused on low-regret options. The majority of projects enhanced awareness of climate change and variability, but only 7% had used historical climate information during planning. Instead, projects relied on general knowledge or farmers' perceptions, which sometimes differ from analyzed historical climate information, potentially leading reinforcement of perceptions. It is vital that bridging organizations and policy makers value analyzed historical climate information when determining climate norms (including variability) and identify what data shows regarding how climate is changing. This is essential for planning with stakeholders the suitability of alternative crops and cultivars and ensuring other relevant environmental factors influencing agricultural production are considered.

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Adaptation; planning; perceptions; historical climate information; organizations

1. Introduction

Farmers' perceptions of climate change and variability constitute a growing research theme within the body of agricultural adaptation literature (Muita, van Ogtrop, Ampt, & Vervoort, 2016). In particular, an increasing number of studies have sought to compare farmers' perceptions of changes and trends in climate with meteorological analyses of local historical climate data (Marchildon, Wheaton, Fletcher, & Vanstone, 2016; Meze-Hausken, 2004; Osbahr, Dorward, Stern, & Cooper, 2011; Oyerinde et al., 2015; Rao, Ndegwa, Kizito, & Oyoo, 2011; Simelton et al., 2013; Sutcliffe, Dougill, & Quinn, 2016). The complex and divergent findings of these studies make it hard to draw any firm conclusions about the overall reliability of perceptions versus meteorological analyses. Whilst a number show that farmers are able to fairly accurately identify climatic events and trends (especially with regard to temperature) (Cobbinah & Anane, 2015; Marchildon et al., 2016; Shrestha & Nepal, 2016), many (particularly those studies conducted in locations characterized by high natural variability of rainfall such as sub-Saharan Africa) have revealed contradictions between local perceptions and meteorological analyses of changes to rainfall (Cooper et al., 2008; Meze-Hausken, 2004; Muita et al., 2016; Osbahr et al., 2011; Simelton et al., 2013; Sutcliffe et al., 2016). However, few, if any papers, have given specific attention to the over-arching question of the role of bridging organizations in helping align top-down and local perspectives on climate variability and change. This paper seeks to address this gap by exploring how climate information is accessed and used in the design and planning of projects by organizations whose role it is to bridge the divide between the decision-making of agriculturists at the local scale, and the science-driven adaptation goals that occupy global international development players.

Temperature and precipitation are the climate characteristics that receive the most attention in analyses of historical, and scenarios of future, climate change. In both cases, due to its much lower day to day variability, far greater clarity and certainty exists regarding past and likely future trends in global mean and regional temperatures (IPCC, 2014). To date, determining what has been happening, and what will happen, to rainfall has presented more of a problem because of its much higher natural variability and the potential masking effects of cyclical oscillations (such as El Niño). Identifying a climate change signal within rainfall patterns against this background noise has been problematic for researchers, and whilst predictions show that major impacts on rainfall can be expected as climate change progresses (Trenberth, 2011), identification of ongoing changes has been achieved only recently, and most reliably at the global scale (Marvel & Bonfils, 2013; Rao et al., 2011). The direct impacts of climate change on precipitation being experienced at the regional scale are considered by climatologists likely to remain obscure and uncertain for years to come (Sarojini, Stott, & Black, 2016).

Nevertheless, precipitation, specifically, seasonal rainfall, is the climate characteristic with which adaptation policy-makers and agricultural producers are the most preoccupied (Marchildon et al., 2016). Broadly speaking, in the East African context,

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with which this paper is concerned, the perceptions literature reveals that many farmers perceive the growing season to be shortening, rains and rainy season onset to be becoming more erratic, rainfall to be becoming increasingly intense, and dry spells during the growing season to be worsening (Muita et al., 2016; Simelton et al., 2013). These widely accepted local beliefs about changes to seasonal rainfall are echoed within agricultural development narratives and appear in some publications, where the negative impacts of erratic rainfall on agricultural producers in the global south have been attributed to climate change, despite the difficulty for climate scientists in identifying patterns of change within the high variability that already exists between seasons. These perceptions and their diffusion via related narratives have major implications for local agricultural decision-making, including whether and which adaptation strategies to employ, and how far to invest in agricultural innovations (Muita et al., 2016).

Many attempts have been made to explain why local perceptions of rainfall change and meteorological analyses may differ in some locations. Explanations have focussed on the subjectivity of human memory, including 'borrowed memory'[1] or that perceptions of changes in rainfall are often not based on any measurements of it but rather on observations of indirect impacts, such as agricultural yields or food scarcity, which are a product of multiple, confounding factors (e.g. declining soil fertility, population pressure, reduced access to fertilizers, wider economic events), rather than climate alone (Osbahr et al., 2011; Simelton et al., 2013).

Whilst there may be shortcomings within human capacity to interpret longer term trends and changes in rainfall based on experience alone (Meze-Hausken, 2004; Rao et al., 2011), or conversely, within the capacity of meteorological analyses to reflect human experiences of climate at the local scale (Marchildon et al., 2016; Muita et al., 2016; Savo et al., 2016), narratives about climate change are global, in terms of their reach and influence. The term 'climate change' has been described as having become a 'household jargon' after 'a globalized effective communication has succeeded in selling the term to farmers' (Yaro, 2013, p. 1259). It should be noted that climatic narratives are likely to influence the way people present their perceptions of local change to researchers (Mertz, Mbow, Reenberg, & Diouf, 2009), and that 'expatriate narratives' can turn 'scientific truths of global climate change into myths about environmental change at the local level' (Osbahr et al., 2011, p. 309). This is not to suggest that climate change is not occurring or that the impacts are not being experienced, but that the consequences of multiple narratives may lead to local climatic experiences being misinterpreted and other environmental drivers, often interrelated to climate factors, being overlooked.

Meanwhile, the movement to make development activities more participatory (Briggs & Sharp, 2004) has rightfully increased the attention paid to indigenous and traditional ecological knowledge (Guthiga & Newsham, 2011; Mapfumo, Mtambanengwe, & Chikowo, 2015; Orlove, Roncoli, Kabugo, & Majugu, 2010; Savo et al., 2016), and many climate vulnerability analyses base themselves around local understandings and experiences using participatory techniques (Dazé, Ambrose, & Erhart, 2009; Ibrahim & Ward, 2012; Oxfam Australia, 2012). Whilst this is entirely appropriate, there is a danger that the interplay between top-down narratives on 'global climate change' and bottom-up narratives about experienced climate variability and impacts may, without careful efforts, hybridize to produce inaccurate understandings about the underlying causes of the effects being experienced and whether or not they are a manifestation of trends that will lead into the future. As such, whilst participatory approaches and the incorporation of local knowledge are essential to effective adaptation planning (Villanueva, 2011), warnings have been made against over-reliance on farmer perceptions as the sole basis for development interventions (Rao et al., 2011), and failure to effectively integrate local knowledge with broader scientific measurements of environmental and climate change can result in problems, if, for example, rainfall is blamed for increasing local vulnerability, when alternative factors (such as soil degradation, economic conditions, labour shortages or changes to crop germplasm) are the root cause.

As such, this article argues that for any coping or adaptation project a first step should be to determine the nature of the climate norms within the project area in order to ascertain the efficacy of current coping strategies. To this end, carrying out historical climate analysis offers many benefits, by encouraging critical dialogue amongst supporting organizations and local agricultural actors about local climate features and global climate change, and providing input to enable the best strategic farming decisions, given current and potential future climate characteristics. However, the degree to which development organizations working on climate-related projects are selecting, or able to, incorporate analyzed historical information is at present unclear.

By 'historical climate analysis' we mean using a range of analytical techniques for understanding and describing the prevailing climatic characteristics within a region, usually using daily climate records that equal or exceed thirty years (the minimum timespan over which climatologists consider a measurement of climate can be obtained). Many local weather stations in countries that are likely to be adversely affected by climate change have collected daily rainfall and temperature data for decades, but rarely has this data been exploited to offer practical advice on agricultural decision-making to local farmers, except by, in relatively few cases, providing annual rainfall totals and monthly averages. Figure 1 illustrates this current challenge of seasonal variability and can be used to highlight the value of understanding characteristics of the local climate. Similar time-series graphs can be produced for the length of season, dates of starts and ends of season, temperatures, and incidences of extreme events (including dry spells and heavy rainfall). A starting point is to consider how the climate is changing locally, in what ways does this agrees or disagrees with local perceptions, and if there are differences what are possible reasons. These have clear implications when deciding on appropriate adaptation strategies in particular locations. In many cases, dealing with seasonal variability can be a greater challenge than slow climate change trends in the short-term. Once figures have been obtained, records can be examined to see if seasonal precipitation patterns are trending in any identifiable way, or whether the degree of variability being experienced has been typical for the area since recordings began. Analytical findings can be used as the basis for design and

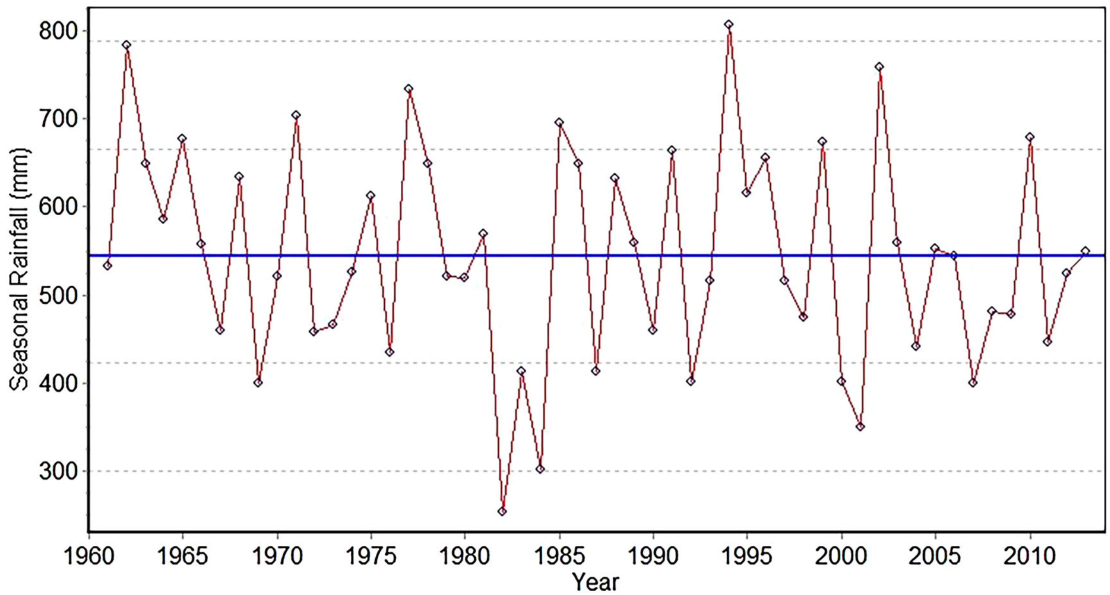

Figure 1. Example of graph showing historical seasonal rainfall totals: March – May total seasonal rainfall, Kisumu, Kenya.
Source: Data from Kenya Meteorological Department.

planning by support organizations, as well as participatory activities with farmers that aim to enhance agricultural decision-making and planning for the future.

This paper reports the results of a research project that explored access to, and use of, climate data and information within development projects seeking to address the impacts of climate change and variability for local communities and agriculturalists in East Africa. The central question for this paper is: To what extent do organizations leading development projects that seek to address the impacts of climate change and variability utilize local historical meteorological data to determine project design?

There are a suite of sub-questions: (i) In the process of planning and designing projects, what sources of climate information do organization staff refer to in order to obtain information about the impacts of climate change and variability in project locations? (ii) What climate impacts are projects seeking to address? (iii) How do project aims address these climate impacts? (vi) How open are organizations to incorporating the analysis of local historical climate data as a component stage in their project planning and design, and how do they think it would help?

2. Method

In order to better understand how organizations are obtaining and using climate information, and how such organizations perceive the potential utility of historical climate analysis, a semi-structured questionnaire was composed and fielded with development organizations running climate-oriented projects in Kenya, Tanzania and Uganda. This resulted in the project activity covering a wide variety of agroecosystems and farming types. Organizations were selected purposively to create a sample that was populated by a range of organization types, and participants were identified using links to existing networks and snowballing. For Tanzania and Kenya, participants completed their questionnaires whilst attending workshops (in January and May 2013 respectively) about organizational learning and climate change. In Uganda, participants were contacted by one of the researchers and either completed their questionnaires via a face-to-face discussion or over the telephone. The criteria for invited participants were that they must be involved in the design, management and delivery of projects focussing on climate change and variability. Participating organizations comprised national and international NGOs, local and central government agencies and universities and research institutes. A total of 67 participants from the three countries contributed data about one or two of their organization's main climate-orientated projects. All participants were representatives from the organizations. In addition 5 NGOs who had a particular mandate to promote climate change adaptation projects were selected for follow up interviews to explore their responses and issues in more detail. Intended project beneficiaries from the organization's initiatives were predominantly smallholder farmers (50% of the projects), or villagers within communities local to the project (45% of the projects), although a number of other beneficiaries were named, with 12% of projects including policy makers as intended project beneficiaries. The breakdown of project and participant numbers by country can be found in Table 1.

Country samples presented varying representations of the different organization types involved, as displayed in Table 2.

For each of the projects being reported on, participants were asked to provide information about project aims, duration, scale of delivery and beneficiary type. Participants also

Table 1. Sample sizes for participants and projects in the three countries.

Country	Number of participants	Number of projects
Kenya	21	35
Tanzania	32	47
Uganda	14	20
Total	67	102

characterized the perceptions about regional climate characteristics that had guided the project design, and identified the sources of this knowledge. Participants were presented with examples of analyzed historical climate information for one or more sites in respective countries (graphs of thirty or more years of data up to the present and showing seasonal rainfall totals, dates of rainy season onset and termination, season lengths, occurrence of extreme events, and mean annual minimum and maximum temperatures),[2] and were asked to consider whether incorporating a greater level of historical climate analysis at the project outset would have changed the project design. They were also asked about how open their organization would be to including such analysis in future, when designing projects.

Most of the data from participants were collected in an open-ended format, and coded later on during analysis by one of the researchers. Data from the completed questionnaires were processed and analyzed using Excel and SPSS. Ethical clearance for this research was obtained following University of Reading Ethical Procedures.

3. Results

3.1. What sources of climate information do organization staff refer to in order to inform project design and gain understanding of key climate features in project locations?

Overall, very few of the projects had referred to any historical climate information (only 7 projects, or 6.8% of the sample). The remaining sources of climate information used by the projects fell into five categories: farmer perceptions, research, meteorological data or bulletins (e.g. short term and seasonal forecasts which do not contain historical data), general accepted knowledge and media reports. Farmer perceptions constituted the dominant climate information source used, having been referred to by 78.9% of projects. Following this, just over a third of projects were reported to have referred to accepted general knowledge, with a similar proportion having referred to some form of meteorological data or bulletins (37.8% and 36.7% respectively).[3] The analysis also showed that 48.9% of the projects were purely based on some combination of farmer perceptions, general accepted knowledge and media reports ($n = 90$), without making reference to any research or meteorological data of any kind.

A high proportion of projects had used only one source of information about climate to inform project design (41.1%, $n = 90$), and most frequently that single source was farmer perceptions, with those projects consulting farmer perceptions as their only source of climate information constituting over a quarter (27.8%) of the total sample. Following farmer perceptions, 7.8% of projects using only one source relied upon accepted general knowledge, 4.4% relied on research and 1.1% relied on meteorological data or bulletins (see Table 3 below).

For many of the projects more than one information source had been referred to, with the mean number of sources used standing at 1.8 (SD = .81). The number of information sources referred to varied between different organization types, with NGO projects being based on a significantly higher mean of 2.2 climate information sources (SD = .85), than the projects of research centres and universities, which had a mean of 1.6 (SD = .66) and government projects, with a of mean of 1.36 (SD = .57). A planned contrast established the statistical significance of the higher mean value for the NGOs: $t(85) = 4.560$, $p = .000$. Using multiple sources suggested the opportunity for cross-checking information in some organizations. We consider international and national NGOs together as in practice as we found there not to be a clear distinction in their design and implementation of projects. In practice, national NGO offices, even where working as part of an INGO, voiced a high degree of autonomy for the design and implementation of climate change adaptation projects.

Reliance on particular sources for climate information also varied depending on organization type. There were significant differences between organization types in terms of their levels of sole reliance on farmer perception and accepted general knowledge. A chi-square test revealed that a significantly higher proportion of those projects relying solely upon farmer perceptions came from research centres or universities (47.8%) compared with the other two organization types where only 15.0% and 28.0% of NGO and government projects respectively relied solely on farmer perceptions, χ^2 $(2, N = 88) = 7.943$, $p = .019$ (the business category was excluded from this part of the analysis because it only contained a single case). A Fisher's Exact Test showed a significantly higher proportion of projects relying solely on general accepted knowledge belonged to government organizations compared with those from the remaining organization types (24.0% versus 1.6% respectively, $p = 0.02$, FET).

3.2. What climate impacts are projects seeking to address?

Research participants identified a range of impacts attributable to climate change and variability that they considered to be affecting their project areas, and which their projects were

Table 2. Representation of organization types within country samples.

	Type of Organization				
Country	International or National NGO	Local or Central Government or Ministry	Research Centre or University	Other (business)	Total (% of total)
Kenya	25	2	7	1	35
(% within country)	(71.4%)	(5.7%)	(20.0%)	(2.9%)	(100%)
Tanzania	10	17	20	0	47
(% within country)	(21.3%)	(36.2%)	(42.6%)	(0.0%)	(100%)
Uganda	9	10	1	0	20
(% within country)	(45.0%)	(50.0%)	(5.0%)	(0.0%)	(100%)
Total	44	29	28	1	102
(% of total)	(43.1%)	(28.4%)	(27.5%)	(1.0%)	(100%)

Table 3. Climate information sources referred to by staff during project planning.

SOURCE OF INFORMATION ABOUT CLIMATE IMPACTS AFFECTING PROJECT	NUMBER OF CLIMATE INFORMATION SOURCES REFERRED TO: 1 information source		2 information sources		3 information sources		4 information sources			
	Response count	% of responses	Response count	% of responses	Response count	% of responses	Response count	% of responses	Total responses	% of total projects
Farmer perceptions	25	27.8	30	33.3	13	14.4	3	3.3	71	78.9
Research	4	4.4	8	8.9	2	2.2	1	1.1	15	16.7
Met data or bulletins	1	1.1	17	18.9	12	13.3	3	3.3	33	36.7
Accepted general knowledge	7	7.8	12	13.3	12	13.3	3	3.3	34	37.8
Media reports	0	0.0	7	7.8	0	0	2	2.2	9	10.0
Total number of responses in this category	37	41.1	74	82.2	39	43.2	12	13.2	162	180.1
Total	37	41.1	37	41.1	13	14.4	3	3.3	90	100

seeking to address. The frequencies with which the different impacts were identified are listed in Table 4 below. Since many participants identified more than one climate impact, the number of responses exceeds the number of project cases.

It is evident that the majority of project staff considered it important to focus on rainfall, with staff from a total of 60.0% of the projects identifying problems with rainfall as a climate impact in their project areas. By comparison, only 24.2% reported that temperatures in the project area were increasing.

Despite the different patterns in the use of information sources that the organizations displayed, there were few significant associations between the type of information source relied upon and the impacts identified within the project areas. An association was evident between reliance on farmer perception as an information source and the belief that the occurrence of extreme events, such as droughts and floods, was increasing within the project area ($p = .032$, FET), with 27.5% of those that referred to farmer perception indicating an increase in extreme events, compared to only 5.3% of those that did not rely upon farmer perception ($N = 88$). A weak association was also identified between projects relying solely on farmer perceptions and the belief that rainy season length in the project area was decreasing (with 20.8% of those that relied purely on farmer perception indicating that rainy season length was decreasing compared to 7.8% of the rest of the sample), but this was only significant at the 10% level ($p = .094$, FET).

3.3. How do project aims seek to address these climate impacts?

Respondents were encouraged to give open-ended descriptions of their projects' aims and actions, and a wide variety of aims were identified. These are listed in order of frequency in Table 5 below. For many projects, several aims were listed, and hence the number of responses exceeds the number of projects. Notably, projects tended to be short-term in nature, with a mean duration of 3.6 years (SD = 4.36), although five projects were described as ongoing or continuous in nature, and two were described as having a duration of 30 years.

The analysis sought to determine how project aims related to the climate information sources that the project staff had referred to. For those few projects that had accessed or referred to analyzed historical climate information ($n = 7$), a weak significant relationship was observed with the aim of increasing awareness and communications about climate variability and change. A total of 57% of those projects that had access or used analyzed historical climate information aimed to 'increase awareness and communications about climate variability and change', compared with only 23% of those that had not ($p = .064$, FET). However, the vast majority (85%) of projects pursuing this aim had not referred to or used any analysis of historical climate information ($n = 26$). This could be leading to a cycle of reinforcement whereby the project communications reinforce widely-held perceptions, and these perceptions then inform the project aims. Likewise, whilst there could be high potential value in conducting analyzed historical climate information for many of the other project aims listed (for instance to assist in determining the suitability of alternative crops and cultivars to be promoted), this type of analysis was only very rarely

Table 4. Perceptions held by project staff about how climate variability and change were affecting project areas.

	Responses		
Project staff beliefs about climate variability and change affecting project areas	*N*	%	Percent of Projects (%)
Rainfall events are more unevenly distributed through the season	35	25.7	36.8
Increase in temperature	23	16.9	24.2
Increase in occurrence of extreme events (floods and droughts)	21	15.4	22.1
Rainfall amount is decreasing	18	13.2	18.9
Rainy season length is decreasing	11	8.1	11.6
We have limited information	6	4.4	6.3
Other[a]	22	16.1	23.4

[a]Climate impacts in the 'Other' category all contained 5 or fewer responses and consisted of: Successive crop failure, New pests and diseases, Forest Resource depletion (5 responses each), Loss of vegetation (4 responses), Soil moisture decreasing, Loss of livelihoods, Melting of glaciers (1 response each).

incorporated in a minority of projects, as shown in the fourth column of Table 5.

Amongst the project aims that were most frequently mentioned it is notable that, whilst some are climate-sensitive, many projects had adopted aims that were rather more general in their outlook and whose potential success was less dependent on accurate climate knowledge and understanding. Increasing water efficiency, tree-planting and environmental conservation stand out as aims that constitute general environment-development objectives, but which also have value in terms of mitigating and reducing vulnerability to climate change. As such, these constitute low-regret options that might appear particularly attractive where access to location specific, scientifically-verified climate information has not been achieved. More climate-specific project aims that were mentioned by many projects included increasing awareness and communications about climate variability and change, general adaptation, and the promotion of alternative crops or cultivars.

The most common aim was to increase awareness and communications about climate variability and change. Of the 25 projects that included this aim, 60% consulted research or meteorological data or bulletins (e.g. short term and seasonal forecasts which do not contain historical data) as a source of information about climate change and variability in their project location. The remaining 40% based their knowledge purely on some combination of farmer perceptions, accepted general knowledge and the media.

Similarly for the other common climate-sensitive aims, many projects made no reference to any scientific sources of climate information. For general adaptation ($n = 16$), just over two thirds (69%) consulted research, meteorological data or bulletins, and for promotion of alternative crops or cultivars ($n = 14$), 64% consulted the former more scientific sources, whilst 36% relied purely on farmer perceptions, accepted general knowledge and the media.

However, for the less climate-sensitive project aims, a much higher proportion of projects relied solely on combinations of farmer perceptions, accepted general knowledge and media, with these information sources constituting the only climate information accessed by 72% of tree-planting projects, 67% of increased water efficiency projects and 53% of environmental conservation projects.

The analysis also looked for relationships between the types of climate impacts perceived to be affecting project areas and the aims chosen. Significant associations were identified between a number of climate perceptions and aims. The perception that rainy season lengths were decreasing was positively associated with the aim of general adaptation (with 45.5% of those projects where staff considered rainy season lengths to be decreasing including this aim, compared with only 14.3% of those that did not hold this perception, $p = .024$, FET). Significant positive associations were also identified between the perception that rainfall amounts were decreasing and the aim of tree planting (with 44.4% of those that considered rainfall

Table 5. Frequencies of project aims and actions and their associated use of analyzed historical climate information.

PROJECT AIMS AND ACTIONS	*N*	Percentage of responses (%)	Percentage of projects (%)	Number of projects with this aim that used analyzed historical climate information
Increase awareness and communications about climate variability and change	26	14.1	25.5	4
Increase water efficiency	23	12.5	22.5	1
General adaptation	20	10.9	19.6	0
Tree-planting	20	10.9	19.6	1
Environmental conservation	18	9.8	17.6	0
Promote alternative crops or cultivars	15	8.2	14.7	0
Climate change mitigation	8	4.3	7.8	0
Environmental monitoring	8	4.3	7.8	2
Increase market participation	7	3.8	6.9	0
Breed climate tolerant crops	7	3.8	6.9	0
Boost agricultural productivity	5	2.7	4.9	0
Support farmer innovations on climate	4	2.2	3.9	1
Climate change advocacy	4	2.2	3.9	0
REDD	4	2.2	3.9	0
Promote energy efficient cooking stoves	4	2.2	3.9	0
Community based adaptation	4	2.2	3.9	1
Seasonal weather forecasts	3	1.6	2.9	1
Conservation Agriculture	2	1.1	2.0	0
Climate Smart Agriculture	1	0.5	1.0	0
Payment for Ecosystem Services	1	0.5	1.0	0

totals to be decreasing including this aim, compared with only 14.3% of those that didn't hold this perception, $p = .008$, FET), and with the aim of environmental conservation (where 38.9% with this climate perception included this aim, compared to only 13% who didn't hold this climate perception, $P = .017$, FET). Finally, there was also a significant positive association between the perception that rainfall was unevenly distributed, and the aim of promoting the uptake of alternative crops or cultivars (with 28.6% of projects whose staff held this perception choosing to promote alternative cultivars or crops, versus only 8.3% of those that did not, $P = .017$, FET).

Further discussions with one case study organization X revealed that decisions to pursue and abandon climate-related objectives had been made on the basis of perceptions that were not corroborated by meteorological analysis. As such, one participant described how, in a relatively large project designed to identify, then support and promote innovations developed by farmers, project staff had rejected (through unconscious bias) those innovations that did not address the widely accepted narrative of rainfall amounts and timings having changed. As a result of this, potentially beneficial innovations were not investigated further or promoted by the organization.

3.4. How open are organizations to incorporating the analysis of local historical climate data as a component stage in their project planning and design, and how do they think it would help?

Respondents were asked to consider a hypothetical situation wherein analyzed historical climate information had been used at the project outset and had revealed a clear increase in temperature, but no clear trend or change for rainfall despite continuous high variability (for East African examples of this scenario see Osbahr et al., 2011; Rao et al., 2011). Respondents were then asked to indicate whether this would have changed the original design of their project. For the majority of projects (63.7%), participants indicated that the original intentions would not have changed. There were no significant associations between specific project aims and the likelihood of project staff indicating that incorporating analyzed historical climate information would have resulted in a change to the aims pursued, although staff indicated that aims would have changed for a comparatively higher proportion of projects promoting alternative crops and cultivars (see Table 6).

Where respondents indicated that their projects would have changed had analyzed historical climate information been incorporated, they mainly detailed changes to the timing of project activities and the promotion of specific crop, cultivar and livestock varieties. Additionally, some suggested the information would increase their confidence in leading climate-focussed projects and could be used to enhance participatory action research with project beneficiaries.

Participants were then asked how they thought incorporating analyzed historical climate information could help with the planning of future projects. Just under half (49.5%) considered it would aid decisions on which interventions to make, 37.6% thought it would help focus responses to the climate risks being faced, and 28% felt it would help them to better schedule project activities. Overall, the vast majority of participants (91.7%) considered that access to historical climate analysis would be either useful or very useful for their organization (after choosing from a range of 1–5 where 1 = not useful and 5 = very useful).

Table 6. Percentages of projects that would have changed their project aims had analyzed historical climate information been used (six commonest aims).

PROJECT AIMS AND ACTIONS	*N*	Percentage that would have changed project aims if analyzed historical climate information had been used	Percentage that felt analyzed historical climate information would be helpful with future project planning
Increase awareness and communications about climate variability and change	26	27.3	91.7
Increase water efficiency	23	33.3	85.7
General adaptation	20	31.3	84.2
Tree planting	20	31.6	61.1
Environmental conservation	18	33.3	73.3
Promote alternative crops or cultivars	15	53.8	0.0

The ability of organizations to take up this kind of analysis was also explored by the survey, with participants asked to describe how open they thought their organization would be to incorporating analyzed historical climate information (even if that analysis revealed continuous variability with no distinct change in terms of rainfall). For the majority of the projects (78.1%), respondents indicated that organization staff would be open or very open to using analyzed historical climate information, with a very small number (2.1%) of projects described as not open, and 19.8% expressing uncertainty about how such information would be received. When the scenario of continuous variability of rainfall with no significant change was considered, respondents for the most part indicated no change in terms of their organization's probable willingness to accept the information, although 14.6% indicated they felt their organization's openness would decline in this scenario. Follow up discussion with organization Y, who had presented examples of analyzed historical climate information to field staff, reported that other staff members had questioned the validity of the results shown in the analyzed historical climate information because it challenged widely accepted perceptions about reducing rainfall amounts and changing patterns. Furthermore, several respondents at the workshops spoke of difficulties regarding access to climate data and a lack of the analytical skills required for using it. One commented that,

> I think there would be a lot of scepticism, given the general belief that things have been changing. It would require a lot of explanation of the long-term nature of climatic pattern changes to convince the audience that total amounts of rainfall are still the same as historical figures

and another suggested that some development agencies would prefer to use the 'accepted general knowledge that there is climate change, which seems to resonate well with donors'. Overall, there were no significant differences between organizational types with regard to their openness to analyzed historical climate information.

Despite the widely perceived potential benefits of incorporating historical climate analysis, problems with its uptake were quite widely perceived, with respondents indicating for nearly half (46.3%) of the projects that they expected there would be some difficulties. Respondents suggested that it would take time to build the capacity for using and interpreting analyzed historical climate information amongst staff and project beneficiaries, with some indicating they expected there would be confusion or uncertainty amongst farmers over which information sources to place their trust in. One of the case study organizations provided an example of the problems that may be encountered with assimilating information from analyzed historical climate information into project planning. In the case of organization Z, historical climate information derived from analysis of climate data from the nearest meteorological station was used during the project planning and proposal stages. These showed that temperature had increased but that rainfall amounts and timings have remained highly variable with no evidence of statistically significant trends. However, in this project planning phase the results were misinterpreted, or assumed to support the already held perception that rainfall has been reducing.

4. Discussion

The findings of this research have revealed that, even for development projects geared towards addressing climate variability and change, analyzed historical climate information using local meteorological data is scarcely employed. The small percentage of those projects that did use or conduct analysis of historical data were mostly run by or closely linked to meteorological services, indicating that access to data and analytical skills are key factors determining decisions about whether to include this kind of analysis in project planning. Failing to include analyzed historical climate information in projects that aim to introduce climate-focussed development interventions places a question mark over the suitability of the interventions being introduced. It is especially important that projects seeking to encourage farmers to change crops or cultivars, determine which species of tree they should be planting, invest in infrastructure, or simply to schedule activities appropriately, inform themselves accurately about current climate norms in the area before the finer details of project objectives are determined. It is also important that perceptions about current climate trends, which might influence the selection of certain interventions, are scrutinized via the analysis of area-specific data. Thus if there is data about the length of season and water availability, it is possible to explore and discuss the options for crop variety choices for different locations, an approach that would be helpful for those planning innovation projects.

Of the climate information sources that were widely relied upon, farmer perceptions was by far the most common. Multiple studies have now been conducted exploring how well perceptions of climate match meteorological analyses, and many have revealed the two do not always align closely (P. J. M. Cooper et al., 2008; Dhanya & Ramachandran, 2015; Muita et al., 2016; Simelton et al., 2013; Sutcliffe et al., 2016). This means that relying purely on farmer perceptions as the only source of climate information used to support decisions about project interventions risks missing insights that can come from the historical data. Authors exploring why human perceptions and scientific measures of climatic conditions, trends and threats may differ, have proposed a number of possible explanations. Humans tend to perceive their environment from a utilitarian standpoint (Meze-Hausken, 2004; Osbahr et al., 2011), meaning that environmental features are not perceived separately from their value relative to human concerns, and in particular, livelihood impacts. As such, droughts of meteorological significance which do not affect regional food security or production may not register in collective memories, but perceived climate impacts associated with livelihood crises are much more likely to, even if the associated signal in the climate record is weak or absent (because non-meteorological factors are to blame). Memories are selective and can distort historical events by adding weight to recent occurrences as well as those associated with significant social events such as political strife (Glantz & Katz, 1977; Osbahr et al., 2011). Negative climatic events are allocated higher significance in memories such that they may be perceived to occur more frequently than they appear in meteorological records (Rao et al., 2011), and changes to rainfall may only be perceived if they occur during periods of heightened agricultural sensitivity within the growing season (Ovuka & Lindqvist, 2000).

Whilst failing to explore the perspectives of the local population about their perceptions of local climate impacts and trends appears to have been less of a problem within the sample (with nearly 80% of projects obtaining climate information from local farmers), it is also a step in the process of project planning that should not be missed out. Experiential processing of events is considered to have a greater cognitive significance than analytical processing and is more likely to motivate action as a response (Marx et al., 2007). This means adaptation responses are more likely to be based on perceptions of experienced changes rather than received reports based on the analysis of climate data (Patt & Schroter, 2008). As such, understanding both the meteorological evidence for local climate impacts and trends, and local perceptions of what is happening, and engaging in participatory discussions with project beneficiaries to explore both, is essential preparation for introducing interventions that effectively respond to current and future climate risks whilst also offering the best chance of being successfully adopted.

Considering the dominance of reliance on farmer perceptions as a climate information source displayed by the projects, the findings display two particularly notable features. Firstly, a much higher proportion of project staff identified rainfall impacts as a concern, compared to the proportion identifying temperature (60% compared to 24.2%). This reflects research reported elsewhere, where larger proportions of participants have expressed concerns about changes to rainfall than about temperatures (Cobbinah & Anane, 2015; Rao et al., 2011). High levels of concern with rainfall are not surprising; agricultural calendars revolve around the coming of the rains and rainfall tends to be more noticeable, constituting a definite, bounded event whereas temperature is experienced as a continuous environmental feature. Nonetheless, the comparatively smaller proportion of projects for which increasing temperatures were identified as an impact in their area is concerning. Clearly, rainfall and temperature are closely linked in complicated ways, and it may be difficult (and undesirable) to try to pinpoint development interventions that are limited to responding purely to one or the other. However, interventions should certainly be seeking to shape themselves around the likelihood that they will need to operate effectively under higher temperatures (P. Cooper & Cappiello, 2012). This is a critical consideration in the breeding and promotion of alternative crops and tree species (Challinor, Koehler, Ramirez-Villegas, Whitfield, & Das, 2016), and also in terms of decisions about infrastructure investment. The second finding to note is the existence of statistical associations between project reliance on farmer perception and the belief that extreme events are increasing and rainy seasons are getting shorter. As previously discussed, human perceptions of past climate events are subject to bias, and the existence of these associations in the data suggest there is a risk that bias in farmer perceptions of climate might be influencing the way project objectives are determined. For example, if project objectives are selected with the belief that seasons are shortening, when in fact this is a misconception for some locations, they may go on to promote the cultivation of less than optimal cultivars or crops, which could reduce opportunities for building greater resilience over time (Sutcliffe et al., 2016).

The results reveal that most project aims were selected without access to analyzed historical climate information, and only a few had consulted other data sources (i.e. research, meteorological data or forecast bulletins). This pattern was representative for both NGO and government-research organizations and their range of projects. It is legitimate therefore to ask whether steps need to be taken to ensure that climate-oriented development projects have access to this information, for all organizational types. In addition, the significant relationships observed between climate perceptions and some of the more climate-sensitive aims chosen (such as the associations between perceptions that seasons were shortening and rainfall becoming less predictable and the aims of general adaptation and promotion of new crops and cultivars), indicate that some projects are shaping climate-sensitive objectives around perceived climate impacts and trends without seeking to corroborate these perceptions with evidence based on meteorological data.

In most cases, however, confidence in the reliability of the climate information sources consulted did appear to have influenced the selection of project objectives, such that, overall, there was a greater likelihood that projects pursuing more climate-sensitive aims would have accessed scientifically-based climate information sources, whilst those that had not accessed such sources were more likely to have selected general environment-development aims that might be considered as lower-regret options (Wilby & Dessai, 2010). This finding indicates that project staff are seeking to respond logically to the information they have at hand, particularly where confidence in the climate information they have been able to obtain is not high. It also suggests that, if project staff can access and use analyzed historical climate information in future projects, they may well be empowered to include more climate-sensitive aims in their projects, which might yield greater benefits in terms of reducing vulnerability and increasing resilience.

Whilst nearly all project staff welcomed the concept of analyzed historical climate information and perceived clear benefits to incorporating it during project planning, there were indications that barriers may need to be overcome to facilitate its uptake. Participants indicated that they faced difficulties accessing the necessary data, lacked the technical skills for analysing it, and worried that considerable time and effort would be required to carefully communicate the findings to local populations without creating confusion or undermining community trust in external information sources. Both coverage and accessibility of meteorological data remain a problem for many areas in Africa, with payment for data often required by meteorological services (Africa Climate Policy Centre, 2011). Academic authors have thus bemoaned the limited use of climate information within development and adaptation initiatives and noted that 'potentially useful climate information often goes unused' (Abid, Schilling, Scheffran, & Zulfiqar, 2016; Lemos, Kirchhoff, & Ramprasad, 2012; Slingo, Challinor, Hoskins, & Wheeler, 2005; Vermeulen et al., 2013). Even where suitable data is accessible and analysis has been undertaken, its uptake by agricultural decision-makers may be limited because it fits poorly with previously held knowledge, or there is too little interaction between potential users of the information and its producers (Lemos et al., 2012).

One approach which seeks to overcome these barriers in how climate information is used to aid development and adaptation at the grassroots is PICSA[4] (Dorward, Clarkson, & Stern, 2015). The PICSA approach (Participatory Integrated Climate Services for Agriculture), developed at the University of Reading, with the support of CCAFS[5] and other funders, aims to assist climate coping and adaptation by smallholder farmers by bringing together: enhanced analyzed historical climate information (presented as simple graphs) which is explored and discussed jointly with farmers, use of participatory decision making and planning tools about production risks and opportunities, and forecasts. PICSA aims to support farmers in their decision-making and innovation to meet their own individual objectives and for their specific farm and social context and involves farmers undertaking a series of participatory activities to facilitate, identify and plan locally appropriate crop, livestock and other livelihood options (Dorward et al., 2015). PICSA has to date been used in approximately 20 countries and in several regions (Africa, Asia, Latin America, Caribbean) with encouraging results e.g. in Northern Ghana more than 90%of farmers that had used PICSA had made changes to their practices as a direct result (Clarkson, Dorward, Torgbor, Osbahr, & Kankam-Boadu, 2019) and in Rwanda approximately 110,000 farmers have used the approach so far. Our experience is that the challenges associated with the lack of use of historical climate information by organizations designing and implementing climate related agricultural development interventions has not been limited to the countries focused on in this paper, and these challenges exist in other regions within and outside Africa. The limited use of historical data may be due to a lack of awareness of its value (for design and implementation), the limited availability of analyzed historical data, and perhaps a perception that much historical information is of limited use due to missing data within data sets and errors in recording and transcription. In recent years there have been a growing number of examples where historical data from multiple locations in countries have been systematically and rigorously checked, cleaned, analyzed and presented in easy to interpret graphical products. From these examples there is emerging best practice which includes: ownership of and responsibility for data remaining with national meteorological services (NMS); capacity development within NMS in approaches and programmes that support data rescue and management, quality control, and analysis and presentation of historical information (e.g. using CLIMSOFT and RINSTAT); NMS staff providing historical climate information products rather than data (thereby avoiding sensitivities about access to data); NMS staff being actively involved in successful climate services initiatives and therefore realizing the practical value of historical information along with other products. There remains however an urgent need for NMS to devote adequate resources to these activities and for more NMS to recognize the value of historical information. The research presented here reveals that approaches like PICSA are urgently needed to ensure that insights from meteorological analysis of historical data can be effectively explored together with local experiences and perceptions of the climate impacts being experienced, in order to enhance abilities to select development options that support current agricultural livelihood decisions and open up pathways towards effective adaptation As the reach and power of narratives about the impacts about climate change continues to increase, the use of analyzed historical climate information in participatory development activities opens up opportunities for effective cross-scale engagement between global organizations driving funding agendas and those on the ground who are dealing first hand with the negative livelihood impacts of a changing climate.

5. Conclusions

Development organizations remain crucial brokers between top-down and local perspectives on climate variability and change, and their interpretation of different information and communication messages ultimately shape the effectiveness of adaptation response. It is vital that this role is understood given the current debate comparing farmers' perceptions of changes and trends in climate with meteorological analyses of local historical climate data. The analysis in this study reveals how climate information is accessed and used in the design and planning of projects by organizations in East Africa whose role it is to bridge the divide between the decision-making of agriculturists at the local scale, and the science-driven adaptation goals that occupy global international development players.

We found only 7% had used any historical climate information in their planning phase, and whilst some had referred to short-term forecast information, the majority had relied on general knowledge or farmers' perceptions to shape the innovations or design of projects. This has the potential to lead to a cycle of reinforcement whereby project communications reinforce widely-held perceptions, and these perceptions then inform project aims. As such, projects tended to focus on low-regret options that were attractive where access to location specific, scientifically-verified climate information had not been achieved. Ensuring access to analyzed historical climate information and other forms of climate information is important but only part of the challenge. This paper has argued that for any coping or adaptation project a first step should be to determine the nature of the climate norms within the project area in order to ascertain the efficacy of current coping strategies and to explore the range of appropriate options best suited to that location. This is also important to avoid an underestimation of other environmental factors, such as decreasing soil fertility, and ensure more specific support is provided which will avoid maladaptive pathways. A greater awareness of these implications remains vital, not least for government organizations, which were shown by the study to rely heavily on general knowledge, but have a role in promoting debate at the policy level. In addition, the successes that has been achieved by some National Meteorological Services (using tools such as CLIMSOFT and RINSTAT), need to be built on regarding the introduction of effective data rescue, quality control and management of historical data, and effective production of historical information for practical use. We recommend that policy makers and national strategies encourage National Meteorological Services to undertake these activities to provide analyzed historical information for all meteorological stations in the form of graphs and tables for main characteristics including: total seasonal rainfall, start and end dates of seasons, season lengths, numbers of rain days per season, occurrence of extreme events, and characteristic of temperature for all years for which data is obtainable. We further recommend national and local organizations to utilize these products in both planning and implementation and request further products where they need them to explore particular aspects of climate.

There is high potential value in increasing awareness of current demonstration initiatives that adopt the use of analyzed historical climate information for the design and planning of adaptation projects, thereby allowing options and resulting trade-offs to be discussed by the different stakeholders as part of the process. For example, this approach is particularly useful for projects that seek to identify suitability of alternative crops and cultivars to be promoted, in addition to the wider value in terms of understanding the extent to which climate is changing, the implications for seasonal variability, and how this relates to local perceptions. Bridging institutions and organizations involved in policy development, planning and implementation, must construct effective climate compatible development strategies by mediating between the experiences of rural communities, narratives of global development and the findings of scientific research. Facilitating greater understanding of local climate impacts by using analyzed historical climate data in participatory planning activities is one way to broker climate-focused development objectives that effectively integrate local and scientific knowledge.

Notes

1. Known phenomena identified within cognitive psychology (e.g. Brown, Croft Caderao, Fields, & Marsh, 2015) where people often retell their experiences to intentionally include some modifications based on information from others.

2. Sites were selected for having good quality data that had been checked and then analyzed using INSTAT and being in areas where smallholder agriculture is important e.g. Dodoma in Tanzania and Mbarara in Uganda.
3. These percentages include those that relied upon only a single source as well as those that relied upon several different sources.
4. https://research.reading.ac.uk/picsa/.
5. CCAFS – CGIAR Research Program on Climate Change, Agriculture and Food Security.

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References

Abid, M., Schilling, J., Scheffran, J., & Zulfiqar, F. (2016). Climate change vulnerability, adaptation and risk perceptions at farm level in Punjab, Pakistan. *Science of The Total Environment*, *547*, 447–460. doi:10.1016/j.scitotenv.2015.11.125

Africa Climate Policy Centre. (2011). *Assessment of Africa' s climatic records and recording networks including strategic for rescuing of climatic data, Working paper 3, African Climate Policy*. Retrieved from http://www.uncclearn.org/sites/default/files/inventory/uneca05.pdf

Briggs, J., & Sharp, J. (2004). Indigenous knowledges and development: A postcolonial caution. *Third World Quarterly*, *25*(4), 661–676. doi:10.1080/01436590410001678915

Brown, A. S., Croft Caderao, K., Fields, L. M., & Marsh, E. J. (2015). Borrowing personal memories. *Applied Cognitive Psychology*, *29*(3), 471–477.

Challinor, A. J., Koehler, A.-K., Ramirez-Villegas, J., Whitfield, S., & Das, B. (2016). Current warming will reduce yields unless maize breeding and seed systems adapt immediately. *Nature Climate Change*, *6*(10), 954–958. doi:10.1038/nclimate3061

Clarkson, G., Dorward, P., Torgbor, F., Osbahr, H., & Kankam-Boadu, I. (2019). An investigation of the effects of PICSA on smallholder farmers' decision-making and livelihoods when implemented at large scale – the case of Northern Ghana. *Climate Services*, *14*, 1–14. In Press.

Cobbinah, P. B., & Anane, G. K. (2015). Climate change adaptation in rural Ghana: Indigenous perceptions and strategies. *Climate and Development*, 8(May), 169–178. doi:10.1080/17565529.2015.1034228

Cooper, P., & Cappiello, S. F. (2012). *Case studies: The large-scale implementation of adaptation and mitigation actions in the agriculture and food sector. Draft for discussion*. Nairobi: CGIAR Research Program on Climate Change, Agriculture and Food Security.

Cooper, P. J. M., Dimes, J., Rao, K. P. C., Shapiro, B., Shiferaw, B., & Twomlow, S. (2008). Coping better with current climatic variability in the rain-fed farming systems of sub-Saharan Africa: An essential first step in adapting to future climate change? *Agriculture Ecosystems & Environment*, *126*(1–2), 24–35. doi:10.1016/j.agee.2008.01.007

Dazé, A., Ambrose, K., & Erhart, C. (2009). *Climate vulnerability and capacity analysis handbook*. London: CARE.

Dhanya, P., & Ramachandran, A. (2015). Farmers' perceptions of climate change and the proposed agriculture adaptation strategies in a semi arid region of south India. *Journal of Integrative Environmental Sciences*, *8168*(September), 1–18. doi:10.1080/1943815X.2015.1062031

Dorward, P., Clarkson, G., & Stern, D. (2015). *Participatory integrated climate services for agriculture (PICSA): Field manual*. Reading: University of Reading and CGIAR.

Glantz, M. H., & Katz, R. W. (1977). When is a drought a drought? *Nature*, *267*, 192–193.

Guthiga, P., & Newsham, A. (2011). Meteorologists meeting rainmakers: Indigenous knowledge and climate policy processes in Kenya. *Ids*

Bulletin-Institute of Development Studies, *42*(3), 104–109. doi:10.1111/j.1759-5436.2011.00228.x
Ibrahim, M., & Ward, N. (2012). *From vulnerability to resilience: A handbook for programming design based on field experience in Nepal*. Rugby: Practical Action.
IPCC. (2014). Climate change 2014 synthesis report summary chapter for policymakers. *Ipcc*, 31. doi:10.1017/CBO9781107415324
Lemos, M. C., Kirchhoff, C. J., & Ramprasad, V. (2012). Narrowing the climate information usability gap. *Nature Climate Change*, *2*(11), 789–794. doi:10.1038/nclimate1614
Mapfumo, P., Mtambanengwe, F., & Chikowo, R. (2015). Building on indigenous knowledge to strengthen the capacity of smallholder farming communities to adapt to climate change and variability in Southern Africa. *Climate and Development*, *5529*(October), 1–11. doi:10.1080/17565529.2014.998604
Marchildon, G. P., Wheaton, E., Fletcher, A. J., & Vanstone, J. (2016). Extreme drought and excessive moisture conditions in two Canadian watersheds: Comparing the perception of farmers and ranchers with the scientific record. *Natural Hazards*, *82*(1), 245–266. doi:10.1007/s11069-016-2190-7
Marvel, K., & Bonfils, C. (2013). Identifying external influences on global precipitation. *Proceedings of the National Academy of Sciences of the United States of America*, *110*(48), 19301–19306. doi:10.1073/pnas.1314382110
Marx, S. M., Weber, E. U., Orlove, B. S., Leiserowitz, A., Krantz, D. H., Roncoli, C., & Phillips, J. (2007). Communication and mental processes: Experiential and analytic processing of uncertain climate information. *Global Environmental Change*, *17*(1), 47–58.
Mertz, O., Mbow, C., Reenberg, A., & Diouf, A. (2009) Farmers' perceptions of climate change and agricultural adaptation strategies in rural Sahel. *Environmental Management*, *43*(5), 804–816.
Meze-Hausken, E. (2004). Contrasting climate variability and meteorological drought with perceived drought and climate change in northern Ethiopia. *Climate Research*, *27*(1), 19–31. doi:10.3354/cr027019
Muita, R. R., van Ogtrop, F., Ampt, P., & Vervoort, R. W. (2016). Managing the water cycle in Kenyan small-scale maize farming systems: Part 1. Farmer perceptions of drought and climate variability. *Wiley Interdisciplinary Reviews: Water*, *3*, 105–125. doi:10.1002/wat2.1118
Orlove, B., Roncoli, C., Kabugo, M., & Majugu, A. (2010). Indigenous climate knowledge in southern Uganda: The multiple components of a dynamic regional system. *Climatic Change*, *100*(2, Sp. Iss. SI), 243–265. doi:10.1007/s10584-009-9586-2
Osbahr, H., Dorward, P., Stern, R., & Cooper, S. (2011). Supporting agricultural innovation in Uganda to respond to climate risk: Linking climate change and variability with farmer perceptions. *Experimental Agriculture*, *47*(2), 293–316. doi:10.1017/s0014479710000785
Ovuka, M., & Lindqvist, S. (2000). Rainfall variability in Murang'a District, Kenya: Meteorological data and farmers' perception. *Geografiska Annaler: Series A, Physical Geography*, *82*(1), 107–119.
Oxfam Australia. (2012). Integrated disaster risk reduction and climate change: participatory capacity and vulnerability analysis toolkit, 1–33.
Oyerinde, G. T., Hountondji, F. C. C., Wisser, D., Diekkruger, B., Lawin, A. E., Odofin, A. J., & Afouda, A. (2015). Hydro-climatic changes in the Niger basin and consistency of local perceptions. *Regional Environmental Change*, *15*(8), 1627–1637. doi:10.1007/s10113-014-0716-7
Patt, A. G., & Schröter, D. (2008). Perceptions of climate risk in Mozambique: Implications for the success of adaptation strategies. *Global Environmental Change*, *18*(3), 458–467.
Rao, K. P. C., Ndegwa, W. G., Kizito, K., & Oyoo, A. (2011). Climate variability and change: Farmer perceptions and understanding of intra-seasonal variability in rainfall and associated risk in semi-arid Kenya. *Experimental Agriculture*, *47*(2), 267–291. doi:10.1017/s0014479710000918
Sarojini, B. B., Stott, P. A., & Black, E. (2016). Detection and attribution of human influence on regional precipitation. *Nature Climate Change*, *6*, 669–675. doi:10.1038/nclimate2976
Savo, V., Lepofsky, D., Benner, J. P., Kohfeld, K. E., Bailey, J., & Lertzman, K. (2016). Observations of climate change among subsistence-oriented communities around the world. *Nature Climate Change*, *6*(5), 462–473. doi:10.1038/nclimate2958
Shrestha, R. P., & Nepal, N. (2016). An assessment by subsistence farmers of the risks to food security attributable to climate change in Makwanpur, Nepal. *Food Security*, *8*, 415–425. doi:10.1007/s12571-016-0554-1
Simelton, E., Quinn, C. H., Batisani, N., Dougill, A. J., Dyer, J. C., Fraser, E. D. G., … Stringer, L. C. (2013). Is rainfall really changing? Farmers' perceptions, meteorological data, and policy implications. *Climate and Development*, *5*(2), 123–138. doi:10.1080/17565529.2012.751893
Slingo, J. M., Challinor, A. J., Hoskins, B. J., & Wheeler, T. R. (2005). Introduction: Food crops in a changing climate. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *360*(1463), 1983–1989. doi:10.1098/rstb.2005.1755
Sutcliffe, C., Dougill, A. J., & Quinn, C. H. (2016). Evidence and perceptions of rainfall change in Malawi: Do maize cultivar choices enhance climate change adaptation in sub-Saharan Africa? *Regional Environmental Change*, *16*(4), 1215–1224. doi:10.1007/s10113-015-0842-x
Trenberth, K. E. (2011). Changes in precipitation with climate change. *Climate Research*, *47*(1–2), 123–138. doi:10.3354/cr00953
Vermeulen, S. J., Challinor, A. J., Thornton, P. K., Campbell, B. M., Eriyagama, N., Vervoort, J. M., … Smith, D. R. (2013). Addressing uncertainty in adaptation planning for agriculture. *Proceedings of the National Academy of Sciences of the United States of America*, *110*(21), 8357–8362. doi:10.1073/pnas.1219441110
Villanueva, P. S. (2011). Learning to ADAPT: Monitoring and evaluation approaches in climate change adaptation and disaster risk reduction – Challenges, gaps and ways forward. *SCR Discussion Paper 9*, *9*, 1–49. Retrieved from http://mobile.opendocs.ids.ac.uk/opendocs/bitstream/handle/123456789/2509/Learning to ADAPT.pdf?sequence = 1
Wilby, R. L., & Dessai, S. (2010). Robust adaptation to climate change. *Weather*, *65*(7), 180–185. doi:10.1002/wea.543
Yaro, J. A. (2013). The perception of and adaptation to climate variability/change in Ghana by small-scale and commercial farmers. *Regional Environmental Change*, *13*(6), 1259–1272.