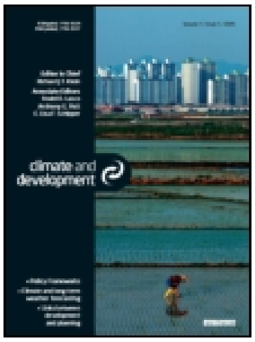

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RESEARCH ARTICLE

Is rainfall really changing? Farmers' perceptions, meteorological data, and policy implications

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Understanding farmers' perceptions of how rainfall fluctuates and changes is crucial in anticipating the impacts of changing climate patterns, as only when a problem is perceived will appropriate steps be taken to adapt to it. This article seeks to: (1) identify southern African farmers' perceptions of rainfall, rainfall variations, and changes; (2) examine the nature of meteorological evidence for the perceived rainfall variability and change; (3) document farmers' responses to rainfall variability; and (4) discuss why discrepancies may occur between farmers' perceptions and meteorological observations of rainfall. Semi-structured interviews were used to identify farmers' perceptions of rainfall changes in Botswana and Malawi. Resulting perceptions were examined in conjunction with meteorological data to assess perceived and actual rainfall with regards to: *what* was changing (onset, duration or cessation), and *how* it was changing (amount, frequency, intensity or inter-annual variability). Most farmers perceived that the rains used to start earlier and end later. Meteorological data provided no evidence to support farmer perceptions of rainfall starting as early as September (south Malawi) or October (Botswana); however, a high inter-annual variability in the timing of the onset was observed alongside an increasing number of dry days and declining amounts of rainfall at the onset and cessation of precipitation. While some rainfall patterns are associated with El Niño-Southern Oscillation (ENSO) fluctuations and larger-scale changes, one explanation for the differences between farmer perceptions and meteorological evidence is that rainfall changes can be easily confused with changes in farming system sensitivity. Our findings suggest that scientists, policymakers, and developers of climate adaptation projects need to be more in tune with farmers' and extension workers' understandings of how weather is changing in order to improve adaptation policy formulation and implementation.

Keywords: climate change adaptation; erratic rainfall; Africa; farmers' perceptions; agriculture; access drought; maize

1. Introduction

Southern African farmers are well positioned to reflect on changes in rainfall patterns. More than 95% of sub-Saharan African agriculture is rainfed, and so the impacts of rainfall changes are felt particularly by those who directly depend on reliable weather patterns to secure a livelihood (Stringer, Mkwambisi, Dougill, & Dyer, 2010; Tadross et al., 2009). Impacts on crop losses are particularly acute where unreliable rainfall combines with institutional constraints that limit access to inputs such as fertilisers and water (Osbahr, Dorward, Stern, & Cooper, 2011; Rockström et al., 2010). Research using meteorological observations is commonplace within the scientific literature. However, this body of empirical information remains largely separate from farmers' perceptions, resulting in a lack of common understanding within and between different groups as to *what* aspect of climate (exposure) is changing, and *how* it is changing. This leads to a situation in which: (1) researchers analyse climate data at different timescales than those important for farmers' decision making and crop growth (Ovuka & Lindqvist, 2000); (2) researchers focus on meteorological droughts while farmers refer to agronomic droughts (Slegers, 2008); and (3) researchers use complex mathematical rules while farmers use simple practical approximations of available soil moisture to characterise onsets and cessations of rainfall (Mugalavai, Kipkorir, Raes, & Rao, 2008). Despite these differences, demand is rising from both donor and local communities for climate policies that better acknowledge local contexts (Jennings & Magrath, 2009; Twomlow et al., 2008), particularly as development agencies add climate change adaptation to their project portfolios (McGray, Hammill, & Bradley, 2007).

One area where there is a growing need to align farmers' perceptions and meteorological observations relates to the broad perception in the academic literature

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that southern Africa is experiencing unpredictable and ‘more erratic rainfall’ patterns (Jennings & Magrath, 2009, p. 5; Twomlow et al., 2008, pp. 780–781). Evidence from across Africa links changing climatic patterns, in particular changing rainfall, with plummeting agricultural production (Boko et al., 2007; Kandji, Verchot, & Mackesen, 2006). For example, crop failures occurred in Botswana due to droughts in the 1980s (Parida & Moalafhi, 2008; Ringrose, Chanda, Nkambwe, & Sefe, 1996). In Malawi, rainfall-related risks for agriculture include crops drying before maturity and damage due to floods and water shortages (Mkwambisi, Gomani, & Kambani, 2010). These sorts of conditions led to food shortages in the 1990s and early 2000s. Similarly, in Swaziland, changing rainfall patterns contributed to the reduced ability of farmers to control the parasitic weed *Striga asiatica*, with knock-on implications for maize production (Stringer, Twyman, & Thomas, 2007).

These examples highlight the impact that changing, unpredictable, erratic or variable rainfall can have on food security. Nevertheless, many reports rarely specify whether it is the spatial or temporal dimension of rainfall variability that is important (see e.g. FEWSNET, 2011). Attempts to quantify the unpredictability typically refer to onset, amount or frequency of rainfall (Osbahr et al., 2011), using methods such as coefficient of variation (Parida & Moalafhi, 2008), trend analyses of dry spells or the difference between minimum and maximum rainfall (Osbahr et al., 2011), or associating erratic rainfall with periodic atmospheric phenomena such as El Niño (Tadross et al., 2009). Quantitatively, however, there is a big difference between uncertain, unpredictable, variable, or out-of-season rain. Often ‘more erratic rainfall’ seems a convenient but vague way of describing various combinations of changing weather patterns that can potentially result in inappropriate farmer responses.

One way to unpack how rainfall is perceived to be changing is by using local or indigenous knowledge. Marin (2010) argues that indigenous knowledge complements the analysis of climate change by providing data from a different spatial scale. In particular, appreciating how changes are perceived at the local level is crucial to anticipating the impacts of climate variability and/or change, as only farmers who perceive a problem will implement strategies to adapt or respond to it. For example, crop model simulations have shown that ‘false onsets’ (a dry spell after the initial rains) may be due to failure to distinguish local rainfall from large-scale onset. In years with such false onsets, farmers could obtain higher yields by postponing planting if they had access to the necessary information explaining this to them (Marteau et al., 2011). Patt and Gwata (2002) show that farmers who receive training and are able to question meteorological experts and interrogate forecasts, interpret and respond more successfully to meteorological information than those who simply receive weather forecasts through one-way communications. However, in the absence of such information, even within the same location, different groups may perceive the same rainfall changes differently. This can be as a result of differences in age, past experience, personal motives, interests, attitudes, current situations and the complexity of the overall situation (Marin, 2010), and suggests a need for further research to develop shared interpretations of weather characteristics (e.g. Newsham & Thomas, 2011; Patt, Suarez, & Gwata, 2005; Roncoli et al., 2009).

In this article we begin to build this bridge between meteorological observations and farmers’ perceptions of rainfall. We assess farmers’ perceptions of changing rainfall patterns in two countries in southern Africa where increasingly ‘erratic’ rainfall is predicted to have a significant socio-economic impact (Boko et al., 2007). This article therefore:

1. Compares farmers’ perceptions of rainfall, rainfall variations, and changes. Specifically, it asks: is rainfall changing? What parts of the rainy season are changing? How are they changing? When were the changes noticed?
2. Uses meteorological data to examine the nature of meteorological evidence for the farmers’ perceived rainfall variability and change. It uses conventional climate statistical methods as well as farmers’ characterisations to address the same questions as considered in objective one.
3. Documents farmers’ responses to variable rainfall.
4. Uses the literature to discuss, and account for, why discrepancies may occur between farmers’ perceptions and meteorological observations of rainfall. We consider local contexts in which it is difficult to differentiate yield impacts due to changes in weather (i.e. perceptions of rainfall changes) from the yield impacts resulting from changes in the farming system (i.e. confounding factors).

Use of farmers’ perceptions in combination with meteorological data bridges qualitative and quantitative approaches, and informs debates on the need for more inclusive adaptation and development policies.

2. Study areas

Primary data collection was undertaken in eastern Botswana and southern and central Malawi between 2009 and 2010. These areas are rainfed semi-arid/arid agro-environments in countries that have suffered from droughts that caused differing degrees of agricultural and human distress at least since the 1970s. Both countries have uni-modal rainfall distributions with a peak in January or February. The main growing season is November to May/June

(Botswana) and December to June (Malawi) with maize and sorghum being the key crops. Basic summary statistics for average annual and seasonal rainfall in the field sites are given in Table 1. Locations of interviewed villages and key meteorological stations are given in Figure 1.

Despite Botswana's relative wealth and social welfare system, its urban and rural areas remain divided in terms of the institutional support they receive. Significant concerns over rural poverty and land degradation remain (e.g. Reed, Dougill, & Taylor, 2007; Sporton & Thomas, 2002). Although staple food cultivation is mainly for household consumption, wealth is largely associated with cattle herd size. Maize production has remained relatively stable overall since the 1980s, although with high variation between years (Chipanshi, Chanda, & Totolo, 2003; see also Supplementary Figure 1). After severe droughts in the 1980s, the government introduced various drought-relief programmes, including subsidies for small stock and livestock. Some policies are controversial, particularly those that favour large cattle ranges such as subsidised waterholes, as these can lead to overstocking (Belbase & Morgan, 1994; Reed, Fraser, & Dougill, 2006; Sallu, Twyman, & Stringer, 2010). Malawi's Structural Adjustment Programmes (1981–98) resulted in well-studied 1990s and 2001/02-famines. For example, the 2001/02 famine originated from a decline in maize harvest that resulted in domestic food price inflation that the government failed to buffer (Devereux, 2009; Snapp, Blackie, Gilbert, Bezner-Kerr, & Kanyama-Phiri, 2010). Nationwide seed and fertiliser subsidies (1997–2000; 2006 to ongoing in 2011) targeting poor households have boosted national maize production. Although farmers switched from local to composite seed varieties and increased their use of fertiliser, yields remained flat (see Supplementary Figures 1 and 2), hence all additional harvests were a result of increasing the cultivated area. Staple food cultivation and temporary job migration remain key for household food security, while cash crops (cotton, tobacco) are associated with improved livelihoods. HIV, and its demographic impacts, is a challenge for rural development; reducing the agricultural labour force in both Malawi and Botswana (Devereux, 2009; Snapp et al., 2010).

3. Methods

3.1. *Data collection on perceptions of rainfall change and meteorological records*

Farmers' perceptions of rainfall were gathered during village level fieldwork between 2009 and 2011. Regions selected for data collection cover different agroenvironments within each country, but are drought affected and produce similar crops (maize, sorghum). Specific villages that could meet these criteria were selected after consultation with local partners.

Fieldwork consisted of focus group meetings and semi-structured interviews in two villages in Botswana and two villages in Malawi (see Table 1 and Figure 1). A total of 13 men and 19 women ($n=32$) were interviewed in Malawi, and 12 men and 19 women ($n=31$) were interviewed in Botswana. The age ranges of respondents varied from early 20s to 70+. In Malawi (see column for Malawi II in Table 1), data were collected from focus group discussions in an additional 14 villages across the country ($n=4-20$ per group, in total about 230 people). Focus groups lasted 60–180 min, while individual interviews lasted 20–60 min. Both the interviews and focus groups were conducted in the local language and translated into English with the help of Malawian and Botswanan research assistants.

Focus group members were selected by village leaders based on a number of characteristics including length of experience and involvement in agriculture and extent of knowledge about the village. The gender distribution of participants reflected the relatively high number of female-headed households. The purpose of each focus group was to generate information about the village, including past and current agricultural practices with a general farming and rainfall calendar; and to identify qualitative criteria for local wealth distribution, which were used by the village leaders to stratify households into different categories for in-depth interviews. For all villages, this resulted in three relative wealth categories: poor, middle, and better-off. The criteria developed during the focus groups included housing type and construction materials, assets ranging from clothing to agricultural tools, access to and use of land for agriculture, incomes from outside agriculture, ability to pay school fees, and number of food-secure months. Indicators were, therefore, relatively straightforward to cross-check during interviews.

In-depth semi-structured interviews were conducted with adult household members from each wealth group, as recommended by the village leader and the focus group participants. Questions were open-ended and if farmers raised climate, drought, or rainfall as key topics, follow-up questions were asked. Preliminary findings were anonymised and reported back at a village meeting, which allowed for questions and clarifications from both sides.

Although the intention during the interviews was to start talking about the general challenges farmers face and then lead the discussion towards their perceptions of changing weather, in particular rainfall, farmers may have felt obliged to say that they had perceived changes when in fact they had not (Maddison, 2007). An attempt to avoid this was made by using semi-structured open-ended questions, but consequently perceptions are not easily quantifiable. Furthermore, rainfall in arid and semi-arid areas is very local by nature. Local spatial dynamics will not be elaborated in this article as current meteorological

Table 1. Village level information and summary statistics for total annual and seasonal rainfall.

	Botswana	Malawi	
Fieldwork carried out	2010	2009 (Malawi I)	2010 (Malawi II)
Where	Two villages (Mogobane and Lethlakeng), east region	Two villages (Novu and Kamwendo), south and central regions	Fourteen villages across the country
Climate system[1]	Arid; Uni-modal rainfall with peak in January–February, smaller amount in June (khogo la moko)	Semi-arid in the lower Shire Valley (south), to sub-humid on the plateaux and the highlands in the Rift Valley Escarpments. Uni-modal rainfall with peak in January	
Landscape	Sandvelt (Mogobane), Hard velt (Letlhakeng)	Lower (Novu) and middle (Kamwendo) Shire Valley, Rift Valley	Kasungu Lilongwe Plain (Lilongwe, Chisazima/Kasungu, Khanganya/ Dedza, Ntchisi), lower Shire Valley (Chikwawa), middle Shire Valley (Chilimba/Zomba)
Focus groups and household (HH) interviews	Two focus groups (n=12) HH interviews (n=31)	Two focus groups (n=12) HH interviews (n=32) Interviews with extension and NGO staff (n=12)	Two focus groups in nine districts (n=11–15 people/group, total n~230)
Wealth ranking (%) (better-off/middle/ poor)	20/40/40	25/25/50	Not applied to focus groups
Main agricultural production	Maize, sorghum, groundnut, livestock	Maize, beans, millet, cotton, tobacco, sweet potato	Maize + various food crops
Main meteorological station(s)	Letlhakeng (1068 masl; Lat: 24.1 S; Lon: 25.4 E) $<$10 km to Letlhakeng village Gaborone (983 masl; Lat 24.4 S; Lon: 25.6 E) ca. 50 km N of Mogobane village	Bvumbwe (1146 masl; Lat: 15.9 S; Lon: 35.0 E) ca. 30 km E of Kamwendo village Dedza (1759 masl: Lat: 14.4 S; Lon: 34.3 E) ca. 180 km W of Novu village	Chitedze (1149 masl; Lat: 14.0 S; Lon: 33.6 E) ca. 20 km E of Lilongwe, 90 km S of Ntchisi, 120 km S of Kasungu Dedza (1759 masl; Lat: 14.4 S; Lon: 34.3 E) 10 km E of Zomba Chileka (767 masl; Lat: 15.7 S; Lon: 35.0 E) ca. 50 km NW of Chikwawa, Bvumbwe (1146 masl, Lat: 15.9 S; Lon: 35.0 E) ca. 20 km E of Chikwawa
	Daily precipitation 1995–2008	Daily precipitation 1961–2009	Daily precipitation 1961–2009
Annual mean rainfall (min; median; max) (mm)	Letlhakeng 405 (239; 337; 742)	Bvumbwe 1150 (735; 1128; 1910)	Chileka 870 (478; 850; 1338)
Growing season rainfall, min-max range (mm), period	200–800 (September– May)	650–1100 (October–March)	450–1180 (October–March)
Trend annual total rainfall (mm/year)[2]	−6.0 (R^2<0.02)	(R^2<0.01)	(R^2<0.01)
Coefficient of variation (%)	40	23	24
Trend inter-annual variability (mm/ year)	6.0 (R^2=0.01)	0.5 (R^2<0.001)	1.0 (R^2<0.001)
Structural adjustment programmes	No	1981–98	
Famine/drought history	1982–87, 1992	1990s, 2001/02	

[1]FAO country profile, e.g. http://www.fao.org/ag/AGP/agpc/doc/Counprof/Botswana/Botswana.htm.
[2]Trend refers to the annual total rainfall for the period available for respective meteorological station (see row above for 'Main meteorological station').

observations are too sparse for meaningful analysis (Batisani & Yarnal, 2010). Instead, we compare meteorological trends with farmers' perceptions, in line with the objectives of the article, and assume that verification across both methods provides stronger evidence for the type of change. Lastly, it is important to be aware of language barriers and semantics, as many nuances may have been lost in translation (both between sociolects and ethnic languages).

Rainfall data were collected for available periods from National Meteorological Bureaux in the respective countries (Table 1, Figure 1) and were quality checked by the respective distributors, and for obvious non-physical and missing values (less than 8% of any data set) by the

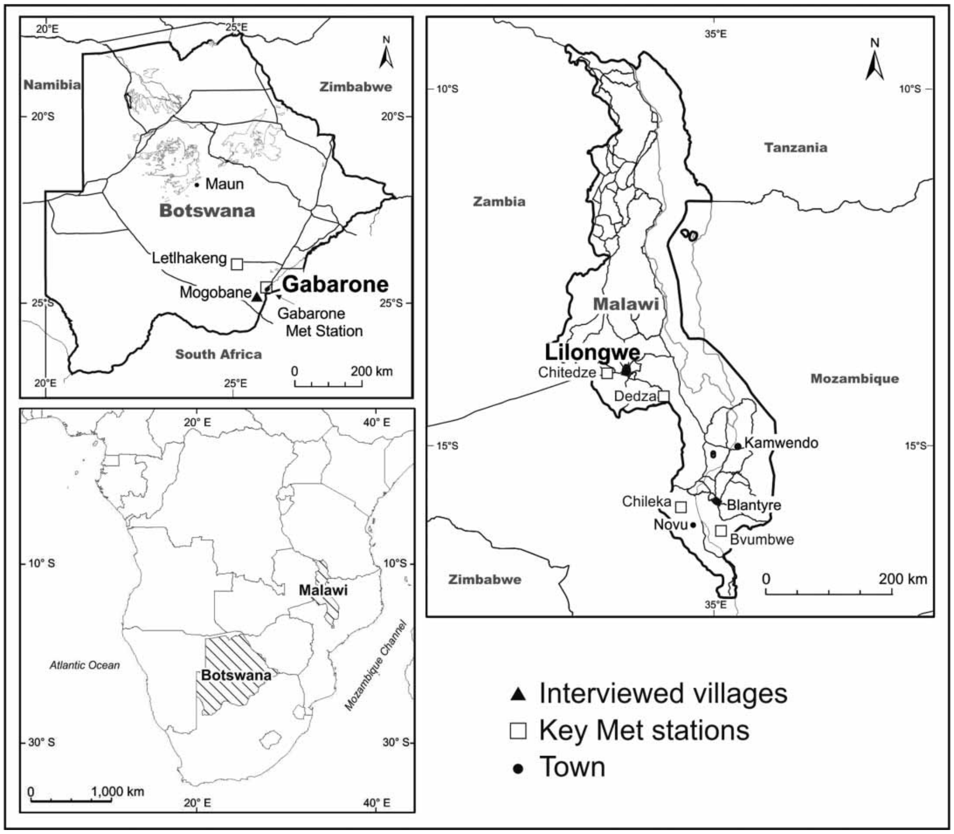

Figure 1. Southern Africa with Botswana and Malawi, and the villages for interviews (black dots) and key meteorological stations (white squares). More details are found in Table 1.

authors. Missing values were not extrapolated. The bi-monthly multivariate El Nino-Southern Oscillation (ENSO) index (MEI) was downloaded from NOAA (2011). MEI ranks from 1–8 to denote weak to strong La Niña conditions; 44–61 denote weak to strong El Niño conditions (Wolter & Timlin, 2011).

3.2. *Data analysis*

To ensure consistency, we developed a simple framework for organising and contrasting both the qualitative farmer perceptions data and the quantitative meteorological data. The framework is designed as a flowchart matrix that reads from left to right (Figure 2), where each column adds detail to our comparison of the meteorological data and the perceptions of how rainfall patterns may be changing. In this way, farmers' perceptions can be merged (Objective 1 of this study) and contrasted with corresponding conventional climate statistics as well as informing local definitions of e.g. onset (Objective 2 of this study), at each of the three levels.

After having characterised the typical rainfall season, the first level (left column) establishes whether a change in rainfall characteristics is perceived; this includes perceptions relating broadly to any type of changes in rainfall. At each level the number of respondents saying they had not perceived any changes is noted as well.

The second level (middle column) identifies what period is changing, sorting perceptions related to the onset, duration or cessation of the rainy (or dry) season. Changes in onset and/or cessation of rainfall may influence its duration. The literature offers several definitions of onset and cessation, depending on local agronomic contexts. To visualise the perceived onset with meteorological data, we asked how farmers knew when it was time to plant or that the rainy season had started. This resulted in three simple definitions of onset: (i) the month the rainfall starts after the dry season (i.e. a meteorological definition); (ii) the time at which the soil horizon is moist to the depth of the lower arm's length (i.e. an agronomic definition based on when farmers started planting in Botswana that discounts small <10 mm/day rainfall as lost to evaporation, and is identified in the meteorological data as 2 and 3 days with daily rainfall >10 mm, P_{20} and P_{30}); and (iii) the definition of 40 mm in 4 days (P_{40}) from Tadross et al. (2009).

At the third level (right column), we analysed in more detail how any of the three periods at the second level are changing, i.e. changes in amount of rainfall, frequency

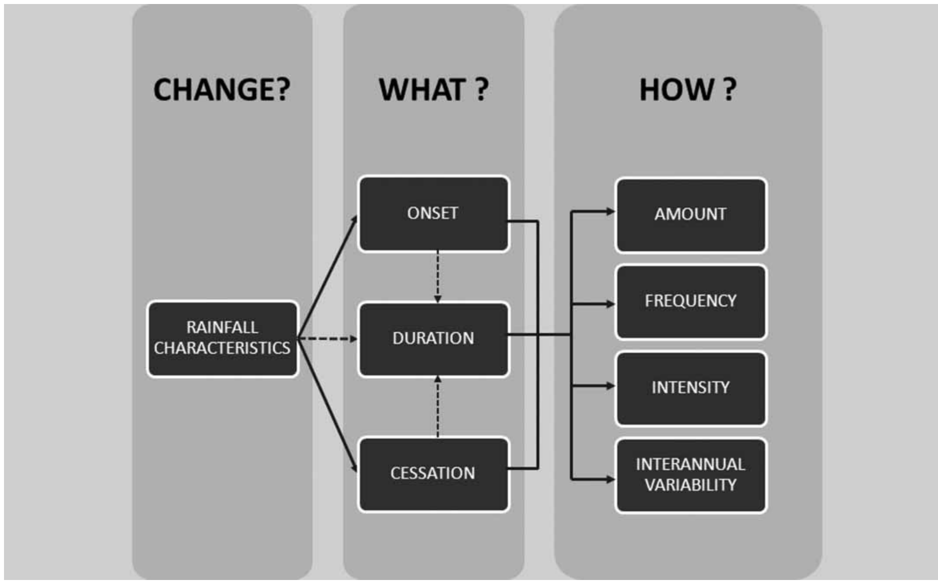

Figure 2. Analytical flowchart matrix for organising and categorising quotes on changes in rainfall. The first level (left) collates quotes stating the ways in which rainfall is (or is not) changing, the second level categorises what part of the rainy seasons the quotes and narratives relate to, and the third level (right) aims to specify in detail how this is perceived to change. Note that changes in the onset or cessation may overlap with perceptions of the duration. Corresponding analyses of meteorological data are contrasted with the perceived changes at each level.

(unit time between wet or dry spells), or intensity (amount per unit time) or whether it is possible to detect inter-annual variability or timing when there is no trend.

The key standard meteorological data analyses include difference between means (*T*-test), linear trend, moving average, coefficient of variation, and the statistical significance level was set to $p<0.05$. More details on the methodology and comparisons in four African countries, see Simelton et al. (2011).

4. Results

Section 4.1 explores farmers' perceptions of rainfall following the framework (Table 1). Section 4.2 contrasts rainfall observations with farmers' perceived changes. Section 4.3 accounts for farmers' responses to rainfall variations.

4.1. *Farmers' perceptions of rainfall*

4.1.1. *Is rainfall changing?*

Table 2 gives selected quotes of how farmers' perceptions of rainfall fitted into the framework of Figure 2. Statements referring to insufficient rainfall and droughts were identified as the most limiting factors for agriculture production across income groups in both countries. This was rated among the top three challenges for a good harvest by 50% of respondents belonging to high and low wealth groups and 100% of middle income groups in Malawi, and by 100% across all wealth groups in Botswana. The question was open ended and gave no alternatives for participants to select. Approximately 90% of farmers interviewed aged between 40 and 70 years ($n\sim95$), i.e. those with sufficiently long experience, in both Botswana and Malawi, said they had observed changes in rainfall during their lifetimes.

4.1.2. *What period is changing – and how?*

The perceived changes can largely be related to the onset of the rainy season, the duration of the rainy season or the cessation, as well as the timing.

4.1.2.1. *Onset*. A general perception of the onset in both countries was that it came 'later than before', with farmers describing: 'In the past rain started in July to drive dust away, end of September rains for planting came and ran into October, then the rains came at Christmas' (female, Botswana) and suggesting: 'in the past it was normal to plant in October, now rains are very late, in December' (female, Botswana). Moreover, there was the notion of onsets becoming more unpredictable: 'It is difficult to know if the rainy season started or if it is just a sprinkle' (focus group, Malawi). One farmer said: 'in the past there was a specific season but rains can come any time now' (female, Botswana). Focus group discussions in Malawi indicated general agreement that rains, in particular the onsets, had become progressively more difficult to predict from the 1990s and 2000s. Farmers explained that 'rain may fall early [in October] so people plant, followed by repetitive dry spells where crops wilt and wet spells where farmers replant' (focus group, Malawi), and with continuous dry spells until January 'maize starts flowering too young and then dries in the field' (female, Malawi). Similarly in Botswana: 'the rains came, we planted but then the rain stopped and the plants died' (male, Botswana).

Table 2. Examples of quotes of perceived changes in rainfall from Kamwendo (K), Khanganya (Kh) Chilimba (C), Chisazima (Cz), and Novu (N) villages in Malawi and Mogobane (M) and Letlhakeng (L) villages in Botswana. Similar quotes have been merged.

	Amount	Frequency	Intensity	Inter-annual variability
Erratic rainfall	Rains come on one side of the farm and not the other (C, N) Disturbed rainfall (K). In the past rainfall was reliable (M, L) The pattern is very different than in the past, more unreliable (M)			
Onset	Rains used to start in October, now they come in November, December or not at all (M, L) Onset is much later (N) It used to rain in September, now it comes in December, January or not at all (K) Nowadays the first rains are used for planting unlike in the past, where we could have September rains [... and] October rains [... that] were not for planting. In the past real rains started in December, that's when we planted our crops (Kh)	Onsets are more unpredictable with dry spells after planting (K, N, C) It used to rain for 3 days, then dry for a couple of days, then rain 3 days. Now it comes anytime any day (M, L) In the past it rained for a week, held for a week. (M)	It is difficult to know when the rainy season starts or if it is just a sprinkle (K, N) Rain may fall early, in October, so people plant. But then it dries up and crops wilt. Rain may then come too heavily in November and stop again (C, K) Rains are also heavier and later so not useful for agriculture (M) Later rains nowadays, and the rains are little, light, random and not reliable (Cz)	I knew when the rains were going to start (in the past) now I do not know (M) 2008 was a poor harvest, because the rains came late and were heavy (K)
Duration	Insufficient rainfall is the biggest challenge (N) Before it used to rain from planting until crops were ripe (M)	There are fewer rainy days now (Malawi, Botswana) In 2000 and 2005 it rained for 2 weeks in January/ February (M) Short periods of rainfall now (Cz)	Before there were small light rains 'dikedikedikedik', now there are heavy rains 'poom, poofff' (M) Much more concentrated in heavy down pours (M) Too much rain, started late, heavy and stopped early (K) Too much rain killed off the crops (N) Flooding and droughts started at the same time, in 1992 if not before (N)	We used to have abundant rains in the 1970/80s and early 1990s but since 2000, we had some changes in rainfall (C) Rains are more irregular than 15 years ago (M) Rainfall season is much shorter now (M) Since 2000 has got worse (N) Since 2004 until now the weather has been bad (N) Rains started to change since 1982, things have changed dramatically (M) Rainfall season is much shorter now. Last good rains were in 2005/2006 (M)
Cessation	The rainy season finishes 1–2 months earlier now (Botswana; Malawi Table 3) Recently the rains are not as they were a few years ago. They are coming late and going quickly (C) ...and finishes earlier (N)	*Khogo la moko* comes in June used to come in July (L, M) Used to get a fair amount of rainfall, it stopped in April, May. Now, erratic rains they stop in April, May (Kh)		Rainfall is different, in the past there was rain in late June/July, now it never rains at that time (L)

(*Continued*)

Table 2. Continued.

	Amount	Frequency	Intensity	Inter-annual variability
Confounded perceptions	When I was younger, we could transplant rice right through until April as there was enough rain. But since 1991, if you transplant later than January, there will be no harvest. There is less rain than there used to be. My parents used to harvest more (C)	People cutting trees causes problems of erosion and flooding, farming too close to the river too (K)	People in my village started using hybrid seeds since the agricultural extension workers recommended it due to unpredictable rains (C) No water gathers it just floats off the soil surface and one cannot see afterwards that there has been a rain (M)	During the Kamuzu Banda era (1966–94) rains fell from November to May, in the Muluzi era (1994–2004) from October to February or December to April. Both Muluzi and Bingu (2004-present) periods gave bad rains. The best rains fell in the Kamuzu Banda era (N) Early maturing fruit means rains will come early (Malawi)

Source: Authors' fieldwork in Malawi and Botswana.

4.1.2.2. *Duration*. Farmers in both countries said that 'the rainfall season is much shorter now' (female, Botswana), which could indicate later onset, earlier cessation or both; or shifts within the duration of the season, e.g. 'Rain has shifted from November to January, less rainfall and stops earlier even if it starts at the right time' (male, Malawi). Although many farmers did not mention rainfall amounts (~1/3) or specifically said it had not changed (<1/3), >1/3 perceived there was less rain now: 'July rain has gone. January rain has gone' (female, Botswana). Farmers commonly suggested changes in the frequency and/or intensity of rainfall: 'Now [there is] much heavier rain over seven days, then rains for three days then stops completely. In the past they were reliable [...], starting on time, raining for long enough; rain for seven days, one month break then rain again, then a break, then 3–4 days of rain then a break. [...]' (female, Botswana).

4.1.2.3. *Cessation*. The focus groups across Malawi (Malawi II) agreed that rainfall ends up to 2 months earlier than 'before', particularly in the central (Table 3) and northern regions. In Botswana, there is normally light rainfall after the main rainy seasons [around days 125–160). This is referred to as *khogo la moko*, the rain that cleans up the harvest dust, see Figure 3]. Farmers said this rainfall 'behaved differently after 2004'. One farmer said that 'In the past there was rain in late June, July. Now it never rains [at] that time' (male, Botswana).

4.1.3. *When did the changes happen?*

The timing of the perceived changes in rainfall onset, duration, or cessation were either seen as (i) starting from one particular year, typically between 1999 and 2010: 'I experienced droughts every year since 2000' (female, Malawi), or, (ii) gradually occurring over a periods of 5–10 years in the 1980s or 1990s: 'in late 1990s we were food secure to June/July' (male, Malawi). A few of the older interviewees in both countries perceived changes as early as the late 1960s and 1970s, reflecting the span of living memory and possibly nostalgia (e.g. a former village leader in Botswana stated that rainfall was more predictable before the mid-1960s, before independence and when village leaders had more power. Respondents in Malawi related good rains to the more popular presidental periods; see Table 2).

4.2. *Meteorological evidence for rainfall variability and changes*

4.2.1. *Is rainfall changing?*

The annual and growing season rainfall trends are given in Table 1. Accumulated rainfall over longer periods generally show no significant trends due to high inter-annual variability, while at monthly scale there are a few significant trends (see Duration below). The rest of this section outlines the changes discernible from the meteorological data, comparing this with the changes perceived by farmers.

4.2.2. *What period is changing – how and when?*

4.2.2.1. *Onset*. The high inter-annual variability makes it difficult to convincingly evaluate how predictable or regular rainfall was in the past. Figure 2 shows inter-annual variability in the timing of, and the duration between, the first 10-mm rainfall in the first day (P_{10}), the second day (P_{20}) and third day (P_{30}). The largest difference in the P_{30}-onset between any two years was 44 days in Bvumbwe, Malawi, 78 days for Letlhakeng, Botswana, and 64 for Gaborone, Botswana, illustrating the challenges for agricultural preparedness. In Bvumbwe, Malawi, the 1980s and 1990s decadal average duration between P_{10} and P_{20} was 18 and 17 days, respectively, and 26 days between P_{10} and P_{30}. In the 2000s this increased to 26 days

Table 3 Central and South Malawi: Farmers' perceptions of the onset and cessation (duration) of rainy season between 'now' and 'before' with black for great unity among focus groups and grey for differences between groups. Note that in the south farmers perceive rainfall to end earlier, it was not clarified whether early April refers to 'now' or 'before' and has been marked 'X'. The perceptions are contrasted with meteorological observations, i.e. the change in the average number of dry days per month (DD) and monthly rainfall (P) for the periods 1961/62–1988/89 and 1989/90–2007/08. Significant trends in number of dry days per decade are shown (d/10yr).

Location	Period	S	O	N	D	J	F	M	A	M
Central										
Dedza	'before' 'now'									
Dedza Met station	% Change	DD ± 0% $P < 5$ mm	DD +4% $P < 11$ mm	DD +8% P +3%	DD+27%; +1.3d/10y P −21%	DD−10% P +8%	DD+20%; +1.2d/10y P −9%	DD +4% P +6%	DD+15%; +0.9d/10yr P −33%	DD+7% $P < 12$ mm
Kasungu Lilongwe Ntchisi	'before' 'now' 'before' 'now'									
Chitedze Met station	% Change	DD ± 0% $P < 5$ mm	DD +1% P −21%	DD+8% P −31%	DD+19% P−17%	DD ± 0% P + 12%	DD+5% P−4%	DD+8% P −11%	DD+12% +1d/10yr P −62%	DD −2% $P < 16$ mm
South										
Chikwawa	'before' 'now'								X X	
Bvumbwe Met station	% Change	DD −2% $P < 11$ mm	DD+7% P −80%	DD+6% P −5%	DD+11% P+2%	DD −8% P+22%	DD+19% P+5%	DD+14% P −12%	DD+13% P −48%	DD+6% $P < 25$ mm
Chileka Met station	% Change	DD ± 0% $P < 5$ mm	DD+5% P −48%	DD+4% P −9%	DD+9% P −13%	DD ± 0% P+18%	DD+17% P −6%	DD+10% P −29%	DD+9% P −20%	DD+4% $P < 10$ mm

% Change between mean for 1961/62–1988/89 and 1989/90–2007/08; DD = dry days; P = monthly precipitation; d/10yr = decadal trend in DD (1961–2008)

Source: Authors' fieldwork in 2009 and focus group discussions in 2010; Malawi Meteorological bureau.

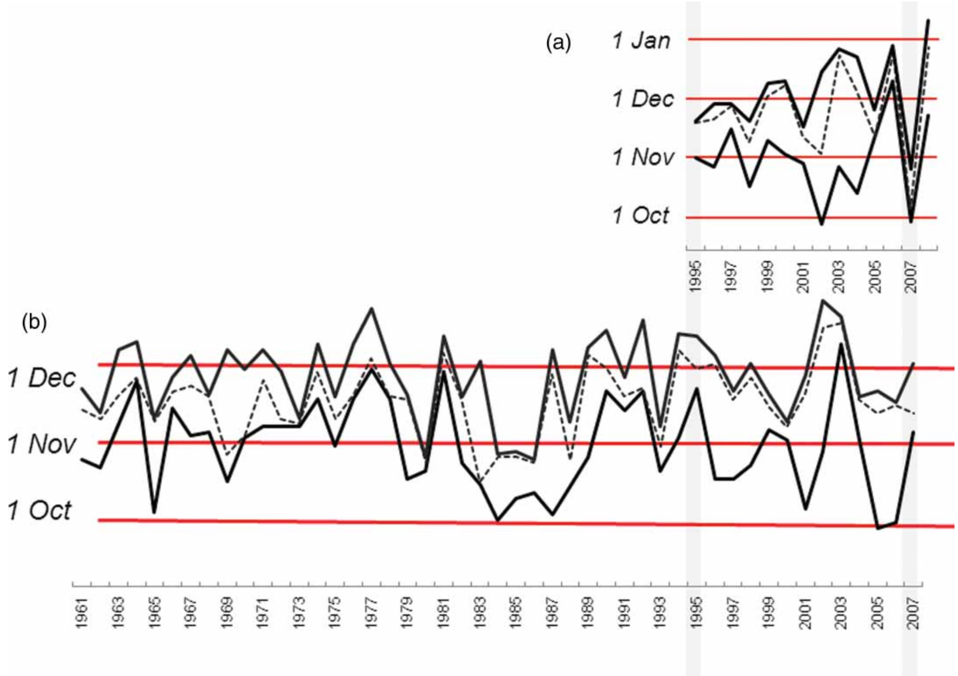

Figure 3. Interannual variability in the agronomic onset of rain in Malawi and Botswana, defined as 3 days with >10 mm each. The first (lower black line), second (hatched line) and third (upper black line) day with at least 10 mm in 1 day, where three sets of 10 mm rain (and potential showers in between) are assumed to indicate the onset of the rainy season in (a) Letlhakeng, Botswana (upper right) and (b) Bvumbwe, Malawi (bottom).

between P_{10} and P_{20} and 32 days between P_{10} and P_{30}. Only the Botswana data show statistically significant increases in the average inter-annual variability of the first two rainfalls, P_{10} and P_{20}, between 1995–2001 and 2002–2008 ($p<0.05$). In Letlhakeng, in the 1990s and 2000s the period between P_{10} and P_{20} increased from 20 to 29 days, and between P_{10} and P_{30} from 26 to 43 days. The Gaborone meteorological data for the same two periods showed a consistently delayed average onset of 2 weeks (17, 14, and 13 days for P_{10}, P_{20}, and P_{30}).

In terms of rainfall frequency, the number of dry days in the onset period from September to December increased significantly between the 1990s and 2000s in Chitedze (by 8 and 19% in November and December), and Dedza (by 27% in December) in Malawi (Table 3), and Gaborone and Letlhakeng in Botswana (by 37 and 15%, respectively, in December). Despite an increasing number of dry days and declining rainfall at the normal time for the onset, there is no meteorological data supporting perceptions that rains used to start as early as September (e.g. south Malawi) or that rains started regularly in October (Letlhakeng), or had reached P_{20} by October (Gaborone). This lack of meteorological evidence is also clear from Figure 3.

4.2.2.2. *Duration*. The farmer perceptions regarding changes in rainfall amounts and when these occurred were far from clear cut. Firstly, due to the high inter-annual variability, analyses of total seasonal rainfall did not support perceptions that there is less rain ‘now’ compared to a previous period (Table 1), except for a few individual months (Table 3). Furthermore, in central Malawi on an annual scale, the significant decreases in monthly rainfall in December, February, and April are balanced to some extent with increases in January (Table 3). Secondly, although in this study only one farmer said ‘rainfall comes in cycles’ (male, Botswana), certain periodicity was observed when comparing meteorological data across decades. In particular, in Botswana rainfall corresponded with ENSO-cycles. Growing season rainfall (September to May) for five meteorological stations in Botswana was higher during La Niña and lower during El Niño conditions (this can be expressed as a linear function of growing season rainfall and the $\text{MEI}=681-7.2$ mm; $R^2=0.39$).

In southern Malawi rainfall intensity (amount of rainfall per rainy day) became more variable from 1996/97 and rainfall intensity increased significantly in January, in this case reflecting a significant increase in monthly rainfall by 80 mm ($p<0.05$) rather than changes in the number of wet days (frequency). Patterns for January are country-wide, but not statistically significant (Table 3). In Botswana the inter-annual variability in intensity increased from 2004 particularly in February and March; in Gaborone the intensity significantly increased in January while it reduced in March between the 1990s and 2000s ($p<0.01$).

4.2.2.3. *Cessation*. Meteorological data show an increasing number of dry days and a notable decrease in the amounts of rainfall in March and April, towards the end of the rainy season, in Malawi over the past two decades (Table 3). In Botswana the timing of the cessation varies considerably between years. Perhaps more illustrative is the *khogo la moko rainfall,* which farmers expect as a light rain in July. Figure 3 shows rain in June between 2004 and 2008 and with very high intensity in 2009.

4.2.3. *When did the changes happen?*

There is some meteorological evidence from Malawi to support a combination of events leading to changing rainfall patterns in the 1980s and 1990s (before and after 1989), including the timing of onsets, average rainfall amounts, and frequency at onset and cessation (Figure 3 and Table 3). The short data series for Botswana indicates a shift in the inter-annual variability in the timing of onset and in January rainfall between the 1990s and the 2000s.

4.3. *Farmers' responses to variable rainfall*

Farmers' perceptions of rainfall and response strategies fall in two categories. First, farmers' perceptions of rainfall changes and responses correspond with impacts of rainfall changes. They said in focus groups and interviews that the unpredictable onsets and increasing dry periods between each rainfall sometimes resulted in planting too early and plants drying out before the next rain (false onsets). This iterative replanting caused farmers to deplete their seed stocks during failed planting attempts. If dry spells continued until January many Malawian farmers considered it 'too late to plant [staple] crops' and shifted to legumes, sweet potatoes and pumpkin. Another direct consequence of the perceived unpredictable onsets was that extension workers and FAO officials in Malawi found it increasingly difficult to give advice, as information provided to farmers had followed the lines of 'when the rain starts this is what you do…'. Furthermore, Botswana farmers said the changes in the *khogo la moko* rainfall (Figure 4) caused a rise in demand for water for cattle at boreholes and that their gardens dried too early. They also showed us peach trees with dry leaves falling off and flowering ahead of time.

Second, farmers' perceptions of rainfall and responses appear confounded by non-climatic impacts such as management impacts on agriculture (see last section in Table 2). Some comments refer to whether use of traditional or hybrid maize varieties is a suitable coping strategy in the event of drought. Notably, at the national level, maize yields in Malawi tended to track rainfall up to the early 1990s. Then, with the provision of nationwide hybrid maize seeds and fertiliser subsidies in the 1990s, inter-annual variability of yields multiplies while rainfall variability remains the same (Figure 5). This increased fluctuation highlights that hybrid species may produce higher yields than traditional cultivars, but that they have a lower tolerance of weather extremes. This may be particularly true for farmers who only have limited access to fertiliser and irrigation. In southern Malawi, even though Kamwendo village is situated within 5 km of the Mwanza River, interviewees said that the water was not used for irrigation due to a lack of pumping equipment. According to a member of the irrigation scheme in Novu village only those who could afford to pay membership fees received water. Notably, in neither of these villages were farmers aware of simple and inexpensive methods to improve soil water retention, such as mulching.

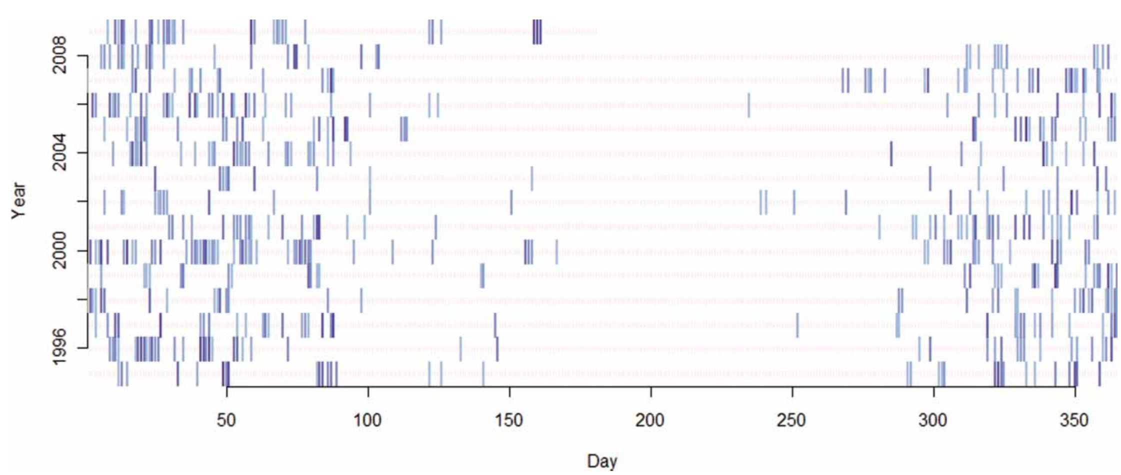

Figure 4. Distribution of daily rainfall, Letlhakeng, Botswana for 1995–2009. The *x*-axis shows the day number 1–365 (i.e. 1 January–31 December), the *y*-axis the years and the shade illustrates daily rainfall intensity (white = < 1 mm/day, lightest grey 1–4 mm/day, lighter grey=5–9 mm/day, darker grey 10–19 mm/day, darkest grey > 19 mm/day). Note the inter-annual variations in the so-called Khogo la moko rainfall, which local farmers expect after some dry spell around day 120–170, i.e. early May to mid-June (colour online).

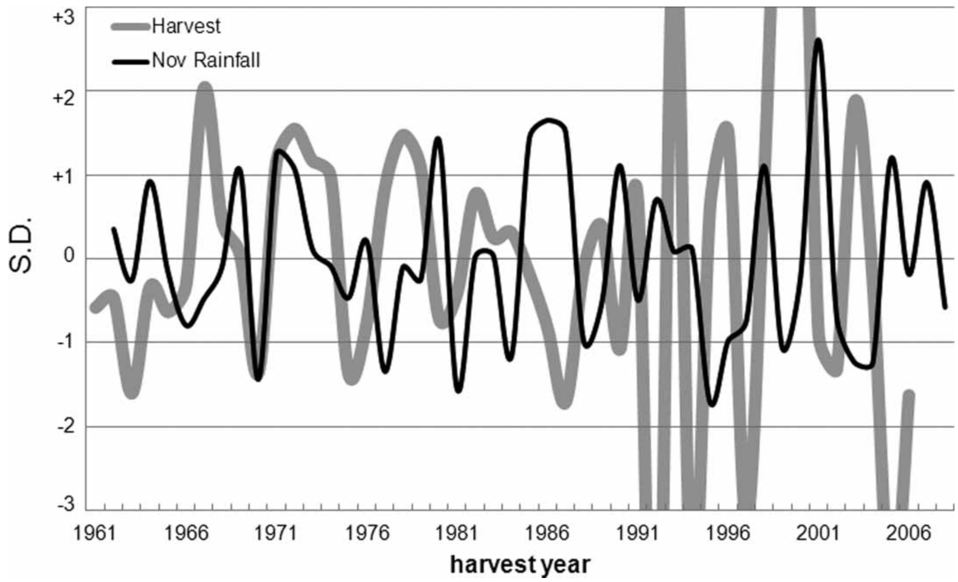

Figure 5. Inter-annual variability in rainfall and maize harvest, Malawi. Standardised rainfall for the key onset month of November (as an average rainfall of nine meteorological stations across Malawi correlated significantly with standardised national-level harvest (cf. Supplementary Figures 1 and 2).
Source: Malawi Meteorological Bureau, Ministry of Agriculture and Irrigation, Ministry of Agriculture and Food Security.

In Botswana, in contrast to Malawi, the poorest farmers decided not to plant at all when they expected poor rainfall, based on expectations that their input (time and/or capital) would not be worth the outcome (harvest and/or profit), particularly as annual rainfall was already at the lower limit for successful cultivation. Here, the poorest households expected to receive drought relief, while the wealthier households invested in livestock for economic safeguarding (see also Sallu et al., 2010). Furthermore, a policy on free ploughing of 5 ha led to queues for draught power in both Botswana study villages. Hence, access to equipment and its timing determined planting, not farmer decision making.

5. Discussion

5.1. *Consensus between farmers' perceptions and meteorological observations*

The most common farmer statement that 'rains are more unpredictable', in particular with regard to their onset, is reflected in the high inter-annual variability in the meteorological data, but is not confirmed as an increasing trend or change. This study shows that qualitative and quantitative systematic specification of how and when rains are unpredictable provides insights as to how farming systems are exposed to climatic impacts.

With regard to onsets, generalised perceptions such as 'it is difficult to know when the rainy season starts' were reflected in the meteorological data in terms of the inter-annual variability of onsets and extended periods between the first rains and the required accumulated amount (30–40 mm) for planting. A study from southern Botswana with a longer data set clearly shows a delay in the onset from mid-September in the 1960s to between the third decadal in October to the first decadal of December during the period from mid-1980s to mid-2000s (Adelabu, Areola, & Sebego, 2011).

With regard to the duration of the rainy season, the statement 'there is more rain when it rains' was observed as increased rainfall intensity in Malawi and Botswana, during the rainy season, especially in January. However, this can be contrasted with the disagreement among farmers as to whether 'there is less rain now' and the limited meteorological evidence for declining rainfall amounts. In terms of cessation, one common perception that 'the rainy season ends earlier now' could be observed as increasing frequency of dry days in March and April, especially in Malawi. Using longer time series than available in this study, Batisani and Yarnal (2010) reported an increase in the number of dry days between 1975 and 2005 across Botswana. The meteorological data for Malawi suggest a combination of shifts in rainfall frequency and intensity around 1990s. Other studies support similar conclusions for Botswana (Parida & Moalafhi, 2008). Furthermore, Adelabu et al. (2011) used estimates based on rainfall and temperature to show the length of southern Botswana's growing season declined in two steps between 1961 and 2005.

Variability in rainfall patterns is partly linked with large-scale climatic phenomena. For example, in the 1950–60s, Botswana and Malawi droughts were associated with regional ocean–atmosphere anomalies over the south-west Indian Ocean, while droughts in the 1970–80s were largely associated with ENSO and gave more variable rainfall in January–March and more intense droughts (Richard, Fauchereau, Poccard, Rouault, & Trzaska, 2001). The present study shows that anomalies for December, January, and February in Letlhakeng, Botswana were negative during the El Niño phase up to the 2000s. This is supported by other studies for southern Africa that linked onsets (December, January, February rainfall) with ENSO (Tadross et al., 2009). The correspondence of rainfall with ENSO found in this study contrasts with other findings from Botswana. For example, Parida and Moalafhi (2008) demonstrated a general increase in annual rainfall during 1961–81 and a decrease during 1982–2003. Further, Batisani and Yarnal (2010) found that annual rainfall for seven or eight meteorological stations in Botswana declined by less than 2.5 mm/year between 1975 and 2005. The lack of trends found in the present study is probably because the data set limits analyses prior to 1995. Furthermore, across eastern Africa earlier cessations have been associated with warming of the Indian Ocean (Funk et al., 2008). Due to the geographical locations of our study countries, it is possible that the Indian Ocean has a stronger influence on cessation in Malawi than in Botswana.

While forecasts of El Niño phases show mid-season rainfall is likely to be lower than in other years, farmers in this study, similar to findings from West Africa (Ingram, Roncoli, & Kirshen, 2002), perceive the timing of rainfall onset and cessation distribution to be more critical than total rainfall amounts when it comes to decision making. Erratic onsets reduced farmers' capacities to respond as previous experiences were no longer valid. Forecast uptake depends on farmers' income levels, degree of risk aversion as well as its perceived trustworthiness (Millner & Washington, 2011; Osbahr et al., 2011). Hence, forecasts accounting for ENSO phases as one factor among many variables influencing weather (Kandji et al., 2006), together with improved accuracy in predicting the timing of rainfall, could help extension workers, and so farmers, to better adjust their crop selection and management strategies.

5.2. *Discrepancies between farmers' perception of rainfall and meteorological data*

Farmers' perceptions of rainfall change and meteorological data were sometimes at odds. For example, there is no meteorological evidence that rainfall used to start as early as September (south Malawi) or that 20 mm had regularly accumulated by October (Botswana). One cause of inconsistency is that farmers may tend to state a more recent timing for changes than the meteorological data show. This matches Marx et al.'s (2007) research showing that while memories of extreme weather events are vivid if they coincide with other memorable events (the *availability heuristic*), decisions tend to be based on recently experienced events and therefore over-estimate the likelihood of the same event happening again (the *recency heuristic*).

Focus group meetings and interviews with qualitative questions further indicated that some perceptions of rainfall changes are not directly related to rainfall in meteorological terms (Table 2). Instead, perceptions may be confounded by factors including failures to distinguish between changes in the exposure to rainfall/weather and impacts of rainfall/weather (especially on harvests), and/or sensitivity of the farming system to rainfall/weather.

5.2.1. *Exposure versus impact*

Exposure to an extreme event can be confused with the impact of that event in numerous subtle ways. Given that farmers tend to base their adaptation strategies on recent years' weather and on extreme events rather than on the average climate (Marx et al., 2007), probing questions that ask about 'good versus bad' and 'now versus before' may be misleading if the intention is to investigate perceptions of rainfall change. Answers are likely to be associated with decision making and farming activity outcomes, whereby one year can be 'good' for somebody and 'bad' for another, irrespective of the weather. Sometimes planting at the first rain was successful; sometimes those who waited for the second shower had better yields. Particularly in semi-arid agro-environments, temperature change has direct, indirect, and aggregating effects on plant growth and soil moisture that may confound perceptions of rainfall (Marin, 2010). Some farmer groups in the present study mentioned 'stronger sunshine', others reported crops in sandy soils being 'roasted', reflecting the possible combination of changing evaporation rates as a result of less rain and increasing temperatures (agronomic onset). Although farmers often refer to agronomic rather than meteorological droughts (Slegers, 2008), our results show that farmers refer to both meteorological (rainfall) and agronomic (soil moisture) onsets. However, more clarity is needed to explain what underlies the disparities between perceptions and observations.

5.2.2. *Exposure versus farming system sensitivity*

The 1980s and 90s structural changes influenced the perceived ability to negotiate prices, resulting in lower incomes and increased food insecurity (Devereux, 2009; Snapp et al., 2010). Factors such as policies, institutional support, and poor health limit farmers' abilities to tend fields and respond in a timely manner to rainfall. These external changes may have affected Malawian farmers' perceptions that rainfall changed from the 1990s and onwards. We illustrated this by comparing the outcomes of Malawi's and Botswana's provision of institutional support on farming system sensitivity. However, our data suggest that many of the poorest households in the study areas did not receive these inputs, while richer households in the same villages did (Quinn, Simelton, Fraser, & Dougill, in press; Simelton et al., 2011). The data further show conflicting outputs of hybrid and traditional seeds in terms of suitability outside the normal weather ranges. Challenges with integrating national policies and local contexts are evident (Stringer et al., 2009), where some national policies to support agricultural inputs, intended to be pro-poor, instead resulted in a number of poor farmers who could not afford to adapt. The examples of Malawi and Botswana farmers' responses show that even if farmers knew when they should plant, policies can undermine farmers' capacity to fully utilize their experiences to take pro-active and reactive measures. For different reasons, it is likely that the sensitivity of the farming systems increased and this may have resulted in small rainfall perturbations being perceived as having a larger impact than they did in the past. Thus, under similar contexts, farmers may refer to an illusionary drought where: (i) external factors (e.g. subsidies, information, and extension) confound perceptions of exposure; and (ii) where climate impacts are inferred from resource dependency, i.e. reliance on a narrow range of resources, which adds stresses within livelihoods (Adger, 1999) or leads to maladaptation. Such illusionary, or 'access droughts' are sometimes mistaken for agronomic and meteorological droughts. Experiences with fertiliser and seed programmes in Malawi and drought relief programmes and draught power policies in Botswana illustrate the need for integrating development and adaptation policies.

5.3. *Implications for adaptation*

This study shows that for successful adaptation to changes in rainfall, the roles of farmers' perceptions and semantic challenges should not be underestimated. Response strategies are dynamic and largely depend on the resources farmers can access to enable them to respond to particular weather stresses; how immediate or severe the problem is perceived to be (Meze-Hausken, 2000); and the ease with which it is possible for farmers to turn one type of resource into another. In addition, experienced farmers are more likely to perceive climate changes and educated farmers are more likely to make at least one adaptation (Maddison, 2007).

One key factor that could potentially limit adaptation and confuses the communication of climate information is lack of words to express variability and changes in rainfall. During our fieldwork *yosadalilika* in Chichewa (spoken in Malawi) is synonymous with unpredictable rain, while *pula e e sa ikanyegeng* in Setswana (spoken in Botswana) refers to unreliable rain. Setswana does not yet have a word for climate change. In Chichewa the phrase for climate change, *kusintha kwa nyengo*, refers to both short- and long-term variability. Therefore, before establishing planned adaptation strategies, policy and project implementers need to ensure they are talking about the same weather, climate, change, and variability, as the farmers they intend to assist.

Four key lessons can be learned from the factors we identified as confounding perceptions of rainfall. First, references to 'now versus before' and listing 'good versus bad' years are precarious when the recent period is generally more vivid in memory. Second, with regard to adaptive capacity, it is important to separate re-active and pro-active behaviours; some people plant early, others late or not at all. These differences may influence the ways that farmers perceive rainfall. Third, it is essential to identify what external inputs (e.g. policies, subsidies) are provided that raise farmers' and scientists' expectations of yield (agricultural sensitivity) but bypass farmers' abilities to interpret and respond to weather stress. These need to be considered alongside those inputs that are provided, but not accessed by, all farmers, so plausibly preventing them from gaining experience of agricultural weather forecasting. When studying why some minor droughts result in major crop failures and some major droughts result in minor crop failures (e.g. Fraser, 2007), it is important that the contexts of exposure (perceived and observed), farm system sensitivity, and impacts are fully understood, so that the suggested adaptations address the appropriate changes. Fourth, the examples presented on seed distribution and draught power demonstrate areas in which development and adaptation policies could be better coordinated.

Our findings have three key implications for adaptation policy:

1. If scientists, policymakers, practitioners (e.g. development and extension workers), and farmers perceive different changes in weather and fail to distinguish between exposure (rainfall change), impact (yield change due to rainfall) or farming system sensitivity to rainfall (yield changes regardless of exposure), adaptation policies are unlikely to be successful.
2. For the agricultural sector to adapt to climate change, top-down climate exposure and impact scenarios need to be verified with farmers' and extension workers' understandings of how weather is changing.
3. Policymakers would be able to more clearly anticipate 'winners' and 'losers' linked to the development of new policies if they pursued stronger contacts with extension workers and diverse groups of farmers.

These recommendations require stakeholders (i) to agree on what aspects of climate and farming/livelihood systems seem to be changing and how, rather than viewing them in isolation, (ii) to estimate impacts of these and identify a number of adaptation options, and (iii) to prioritize measures that require relatively low effort but have high impact.

6. Conclusions

Qualitative studies of farmers' perceptions of rainfall add valuable information to conventional meteorological statistics on how rainfall is changing. Our analysis of data from two southern African countries suggests that the common statements 'more erratic/unpredictable rainfall' often refer to changes in the frequency of dry days at the onset and cessation, and in the intensity during the rainy season. Perceptions of rainfall are likely to be confounded unless scientists, practitioners, and farmers work together to distinguish between changes in the actual rainfall (exposure), in the impacts of rainfall, and in the farming system's sensitivity to rainfall. Failure to agree on what is changing and how it is changing has implications for farmers' capacities to adapt to climate variability and/or change. Adaptation studies can learn from the impacts of policies that run the risk of undermining farmers' capacities to fully utilize their experiences in agriculture and interpret weather patterns.

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