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Contextual analysis of dynamic drought perception among small farmers in Jamaica

Douglas W. Gamble[1,*], Dorlan Burrell[2], Jeff Popke[3], Scott Curtis[3]

[1]Department of Earth and Ocean Sciences, UNC Wilmington, Wilmington, NC 28405, USA
[2]Land Administration and Management Division, Ministry of Economic Growth and Job Creation, Kingston 5, Jamaica
[3]Department of Geography, Planning, and Environment, East Carolina University, Greenville, NC 27858, USA

ABSTRACT: The purpose of this research is to identify the environmental variables, seasonal patterns, and geographical characteristics that correlate with the positive identification of drought by farmers in St. Elizabeth, Jamaica. To do so, we collected agrometeorological data on 15 farms and tracked the farm operators' perception of drought over a 2 yr period. Generally, low rain, low soil moisture, and high winds are most directly associated with perceived drought, and these core physical parameters lead drought perception by a short-term, 2 wk window. Drought is also more frequently identified at lower elevations. Seasonally, drought is perceived more than twice as often as non-drought during winter (December, January, February), spring (March, April, May), and summer (June, July, August), whereas non-drought conditions are perceived close to twice as often as drought conditions in fall (September, October, November). If the current season is drier than the same season 1 yr prior, it is more likely to be perceived as a drought. These findings suggest that mitigation planning should be sensitive to variable topography and microclimates within the Caribbean, and the ways in which these variations can impact perception of drought. Further, year-to-year meteorological variability may be a key factor in farmer perception of drought, and thus any monitoring or forecasting efforts that attempt to link current to previous years' moisture conditions may be well received by farmers.

KEY WORDS: Climate change · Natural hazards · Agriculture · Caribbean

1. INTRODUCTION

The small island states of the Caribbean are particularly susceptible to the disruptive impacts of natural hazards (López-Marrero & Wisner 2012). This is illustrated most dramatically by the sudden shocks created by hurricanes and earthquakes, and for this reason these hazards have received significant attention by the research and emergency management communities. Although its impacts are often subtler, drought is also a significant slow onset hazard for the Caribbean, one with potentially serious negative consequences for the region's households and economies (Watts 1995, Cashman et al. 2010, Gamble 2014). Indeed, the region has suffered a number of drought events over the past 2 decades, and is projected to experience drier conditions under future climate change scenarios (Taylor et al. 2012). Drought, then, has the potential to create significant disruptions to Caribbean society over the coming years. This is perhaps especially true when it comes to agriculture. Farmers across the region are largely dependent upon rain-fed production, and have developed planting calendars and cultivation methods in accordance with the bi-modal pattern of rainfall that characterizes the basin's climatology (Barker 2012). Significant deviations from expected rainfall patterns can therefore result in crop losses and disruption of livelihood activities, with negative implications for household incomes, community resilience, and national food and nutrition security (FAO 2016).

*Corresponding author: gambled@uncw.edu

In assessing the potential impacts of drought, the perspective and agency of agricultural producers is an important consideration. Farmers are not passive victims in response to the vagaries of climate; they often have a keen sense of their local environment, and actively and creatively deploy coping strategies or measures of adaptation in response to their perception of changing conditions. For this reason, it is widely recognized that drought should be understood as more than simply a deficit from expected rainfall; rather, it is 'a complex and multi-dimensional phenomenon' (Dagel 1997, p. 200) that encompasses not only hydrometeorological phenomena but also aspects of agricultural practice and perception.

Studies that combine farmer perception of drought with hydrometeorological measurement are nevertheless rare. This is likely due in part to the challenges of employing a research design capable of combining the different epistemological perspectives of scientific measurement on the one hand, and farmer knowledge and experience on the other (Popke 2016). This paper represents a modest attempt to begin to redress this issue. It focuses on the farm-level hydrometeorological characteristics associated with perceived drought by a group of small farmers in Jamaica. Our analysis draws upon data collected as part of a larger research project aimed at understanding the impacts of climate change and market volatility on small-scale agriculture in the parish of St. Elizabeth, southwestern Jamaica. The project utilized a mixed-methods research design that combined qualitative interviews with the establishment of a mesonet for the collection of agrometeorological data. Previous research and our own pilot studies had suggested that drought is a key concern for farmers in St. Elizabeth, and we therefore sought to investigate the links between the perception of drought by farmers and the changing environmental conditions on their farms.

To do so, we collected agrometeorological data on 15 farms and tracked the farm operators' changing perceptions of drought over a 2 yr period. These data provide a unique opportunity to examine the relationships between drought perception and the farm-level hydrometeorological environment, as well as seasonal changes in growing conditions. Our primary aim in what follows, then, is to identify the environmental variables, seasonal patterns, and geographical characteristics that correlate with the positive identification of drought by farmers in St. Elizabeth. We believe this dynamic and multidimensional understanding of drought can offer valuable insight to policy makers and emergency management officials as the Caribbean faces the possibility of a future in which drought, and the need for farmers to respond to it, will become increasingly common (Taylor et. al. 2012, Curtis et al. 2014).

2. DROUGHT PERCEPTION IN CONTEXT

Scholars have long appreciated the role that perception plays in hazard response and mitigation (Burton & Kates 1964, Saarinen 1969, Kates 1971). This is particularly true of drought. In contrast to a rapid-onset disaster, such as a storm or seismic event, the effects of a drought accumulate slowly and are more ambiguous, and thus the onset and severity of a drought are subject to individual interpretation (Wilhite & Glantz 1985). As Heathcote (1969, p. 176) noted nearly 50 yr ago, 'drought means different things to different people.' In this vein, scholars have highlighted, for example, the importance of past experience, personal characteristics, and cultural attitudes in shaping the ways in which individuals and communities interpret and respond to any particular drought event (Saarinen 1966, Taylor et al. 1988, Diggs 1991).

The role of perception in the understanding and management of drought is particularly important in agricultural contexts. Farmers, ranchers, and pastoralists may be highly sensitive to rainfall deficits or other forms of environmental stress, but research suggests that agricultural producers often have a much broader and more complex definition of drought than mere moisture deficiency (Slegers 2008). For one thing, farmers tend to be less concerned with 'meteorological drought' than with 'agricultural drought,' that is, the impact that a rainfall deficit will have on farming activities and potential for success (Dagel 1997, Habiba et al. 2012, Simelton et al. 2013). This brings into play, among other considerations, the moisture needs of specific crops, the different needs of plants at different stages of growth, and the physical and biological characteristics of soils (Wilhite 2000). Second, and relatedly, farmers may be much more concerned with the timing of rainfall in the context of crop calendars and plant needs than the overall amount of a particular moisture deficit (Ovuka & Lindqvist 2000, Slegers 2008, Panda 2016).

This complexity means that perception of drought by farmers will be dependent upon the local context, and that the identification of drought may or may not closely correspond to particular environmental triggers. Indeed, researchers who have compared drought perception with the climate record have reached differing conclusions. Studies from Kenya (Ovuka & Lindqvist 2000), Burkina Faso (West et al. 2008), and Bangladesh (Habiba et al. 2012) found that farmer perception of drought closely corresponded to rainfall patterns evident in meteorological data. Other researchers, however, have found discrepancies between the perceptions of farmers and the climate record. Studies by Meze-Hausken (2004) in Ethiopia, Simelton et al. (2013) in southern Africa, and Panda (2016) in India all found that farmers' perceptions that rainfall patterns have changed were not corroborated by meteorological evidence. One possible reason for such discrepancies is that farmers are responding to changes in the sensitivity of the farming system or local environment, rather than changes in rainfall per se (Meze-Hausken 2004, Simelton et al. 2013). In other words, this suggests not that farmers are 'wrong' in their interpretations of rainfall or climate, but rather that their understanding is filtered through locally specific concerns, experiences, and expectations. This means, as Meze-Hausken (2004, p. 30) noted, that any 'analysis of subjective observations about weather and climate requires a deeper investigation of the socioeconomic, cultural and environmental conditions experienced by the affected people.' Another possible interpretation for the lack of correspondence between farmer perception and climate data is the lack, in many cases, of local meteorological data (Simelton et al. 2013, Panda 2016). Panda (2016), for example, found that farmer perceptions of environmental change in India were more closely correlated with nearby rainfall stations than with those further afield.

The research reported here seeks to respond in part to these concerns, by examining the specific on-farm environmental conditions that are associated with the positive identification of drought by farmers in Jamaica. Such a study has potentially valuable policy implications. As research on climate change has shown, perceptions about weather and climate are important factors in determining the extent to which agricultural households and communities are willing and able to undertake adaptation measures in response to environmental stress. Most of this research, however, has focused on Africa and Asia (see Ovuka & Lindqvist 2000, Roncoli et al. 2002, Slegers 2008, West et al. 2008, Mertz et al. 2009, Deressa et al. 2011, Habiba et al. 2012, Tambo & Abdoulaye 2013, Klein et al. 2014, Panda 2016), leaving this issue understudied in the Caribbean. A better understanding of the link between environmental factors and drought perception might therefore be a first step in helping to build more resilient Caribbean farming communities in the face of a changing future climate.

3. METHODS

3.1. Study site

Our study was carried out in southern St. Elizabeth Parish, one of Jamaica's principal agricultural regions (Fig. 1). Farms in this parish are generally small, averaging less than 1 ha (SIJ 2007), with production oriented around fruits and vegetables for the domestic market. For a number of reasons, this region provides a particularly advantageous setting in which to examine the issue of drought perception. For one thing, the area sits within a rain shadow, and contending with dry conditions is an important part of local farmers' traditional ecological knowledge and associated agricultural practices. Previous research has documented the development of a range of specialized dry farming techniques to manage water and conserve soil moisture, including guinea grass mulching and hand and drip irrigation (Barker & Beckford 2006, Beckford et al. 2007, Gamble et al. 2010, Campbell et al. 2011, Barker 2012, Popke et al. 2016). The somewhat marginal environment for agriculture in this area means that farmers are particularly attuned to the possibility of drought. That said, our study area is also characterized by a diverse range of microclimates, with the low-lying coastal plains experiencing conditions that are drier and warmer than high-elevation communities in the Santa Cruz Mountains. This provides an opportunity to examine the extent to which there may be local variations in drought perception corresponding to variations in on-farm hydrometeorological conditions.

A second noteworthy feature of our study area is a bi-modal annual climatology typical of the Caribbean region, with 2 distinct rainy periods separated by a mid-summer dry spell (Gamble & Curtis 2008; Fig. 2). Farmers are keenly aware of this annual rainfall pattern, and have adapted their cropping calendars and agricultural strategies to take advantage of the 2 distinct growing periods. This seasonality also helps to shape the drought perception of the region's farmers, with previous research suggesting that the timing of dry periods in relation to seasonal expectations may be more important than the magnitude or duration of the rainfall deficit (Gamble et al. 2010, Campbell et al. 2011). The present study provides an opportunity to further evaluate the potential tempo-

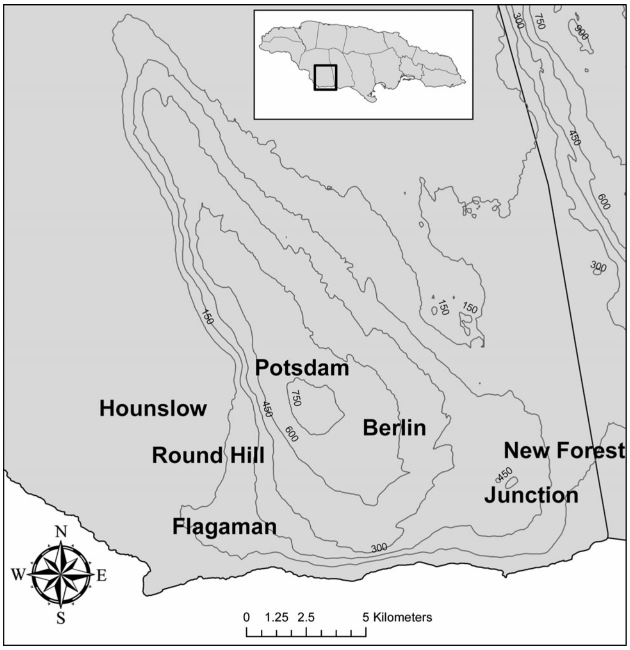

Fig. 1. Study area in Jamaica (box in inset), elevation, and communities within the study area

ral variation in drought perception, as it tracks the perceptions of farmers continuously over a 2 yr period.

Third, the issue of drought perception may be particularly salient in southwestern Jamaica because the area has experienced a number of significant droughts over the past decade. In their examination of a drought event in 2008, Campbell et al. (2011, p. 146) asserted that 'this is an agricultural system under stress,' a finding corroborated both by more recent periods of dry weather and by interviews that we conducted with more than 100 farmers from 2009 through 2015. Following the drought of 2008, the region was hit by the Caribbean-wide drought of 2009–2010 (Farrell et al. 2010), and again by droughts in the summers of 2013 and 2014. Fulton (2014) reported that during 2013, more than half of the farming acreage in the parish of St. Elizabeth was negatively affected by drought, with reductions in crop yields ranging between 29 and 40%, and our own work has documented some of the dynamics and impacts of the 2014 drought (Moulton et al. 2015, Poore et al. 2016).

During interviews, farmers have frequently pointed to the challenges and negative consequences associated with recent droughts. During 2014, a farmer stated that 'the drought really mash up we' suggesting that farmers were significantly impacted (carrot farmer, Top Hill), while another lamented that 'a lot of farmers lose produce because of the drought … we farm with the expectation that there is going to be rain. If there is no rain all that money gone down the drain' (melon farmer, Ballard's Valley). Farmers not only express concern about the increasing incidence of drought, but also observe that the traditional wet and dry seasons are becoming less predictable, a development that many attribute to climate change. 'It is not predictable when you are going to have rainfall,' noted a melon farmer in Dazeland. 'Climate change makes it harder,' he continued, 'the months we used to count on as rainfall months, now it is not. We [are] not getting any rain.'

There is ample evidence, then, both from extant scholarship and our own fieldwork, to suggest that farmers believe that drought is an issue with which they must increasingly contend. What has not been investigated to date, however, are the factors that might lead farmers to positively identify drought, or the extent to which such environmental factors vary seasonally or geographically. The current study presents an opportunity to provide a preliminary lens on these issues.

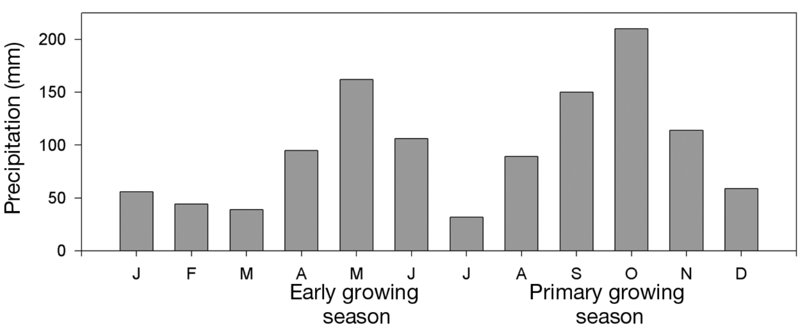

Fig. 2. Mean monthly rainfall (mm) for the 30 yr period 1951–1980 (provided by the Jamaica Meteorological Service) and the growing seasons for southern St. Elizabeth Parish, Jamaica

3.2. Data collection and analysis

The results presented here are drawn from data collected over a 2 yr period on 15 farms in southern St. Elizabeth as part of a larger examination of the relationships between farm-level water budgets, drought perceptions, and water management strategies deployed by individual producers. The farms were selected through snowballing to achieve spatial distribution and the safety of the units and represent the total spectrum of topographic, hydroclimatic, and farm capitalization conditions in the study region. Meteorological instruments, including a tipping bucket rain gauge (rain mm), a soil moisture probe at 10 cm depth (% water content), and a temperature sensor (°C), were deployed on each farm from 15 June 2013 through 15 May 2015. The instruments were placed adjacent to farm fields in order to avoid disruption by farmer activities and damage to the instruments. Consequently, the instruments may not capture the exact hydrometeorological conditions of the crops in the field, but they are close enough to the fields to record representative variability in moisture conditions created by farm-level processes. Rainfall was recorded in increments of 0.254 mm and all other data were collected at 6 h intervals. During the first year, several soil moisture probes were damaged by farmers as they worked their fields, and probes were therefore redeployed 5 cm deeper (15 cm total depth) in July 2014. To account for this redeployment, soil moisture data presented here have been standardized through transformation of raw data for each time series into a *z*-score ([observation − mean]/standard deviation), a common technique used in climatology to standardize data with different units, means, and ranges (Wu et al. 2001, Dogan et al. 2012, Jain et al. 2015). Statistical tests (Mann-Whitney rank sum) were conducted on the 2 wk precipitation and temperature data recorded before and after sensor redeployment to determine whether a change in climate might confound the normalization of the soil moisture data. These tests indicated that the 2 wk aggregated precipitation and temperature were not statistically different ($p > 0.05$), and thus variation in soil moisture across the entire study period is appropriate for comparison (since variation in soil moisture is in response to similar climatic conditions before and after sensor redeployment).

All 15 farmers were telephoned by a local project manager twice a month, once at the end of the second week of the month and once at the end of the fourth week of the month, to document farm activities and perception of drought from June 2013 to May 2015. The key phone interview question that we investigated in this study was: 'Have you experienced drought over the past 2 wk?' with 3 possible responses: 'yes,' 'no,' or 'uncertain.' Thirteen times the project manager could not reach a particular farmer, so the final number of drought perception responses was 677. It is important to note that, while we explained to farmers that we would be regularly asking them about drought, we did not provide them with a specific definition of drought, nor did the project manager document the reasoning behind any particular yes or no observation. The data set therefore captures each farmer's subjective understanding of what constitutes a drought on their farm. Our interest is in exploring whether there are patterns or regularities in these subjective impressions in relation to farm-level agrometeorological data.

The observed soil moisture, temperature, and rainfall data were aggregated to match corresponding drought perception responses at the 2 wk interval (14−15 d, depending on the month), for a total of 46 intervals. Whereas only minor gaps occurred in the phone survey data, gaps occurred more frequently in the hydroclimatic data due to instrument failure. One farmer in Flagaman had his instruments stolen in the early part of the study, so the maximum possible number of observations was 14. However, the number of farms with continuous temperature, precipitation, and soil moisture records for the entire observation period was only 10, 8, and 4, respectively. Using all available data collected across all farms, a total of 392 phone survey time periods out of a possible 677 (58%) had the full complement of hydroclimatic data. All statistical analyses were completed with this data set of 392 two-week time periods. These data offer a unique opportunity to document drought perception with greater temporal and spatial specificity than existing studies, most of which make use of surveys at a single point in time to capture perception, and large-scale or off-site datasets to measure climate conditions.

Our analysis proceeds in 3 stages. Stage 1: we assessed the extent to which the positive attribution of drought by farmers was associated with particular hydroclimatological conditions on their farms. This analysis focused on the core physical variables used to define an agricultural farm-level water budget: precipitation, temperature, and soil moisture (Wilhite 2000, Heathcote 2013). This stage of analysis was completed through data visualization and statistical analysis of aggregate time series of the physical parameters precipitation, temperature, and soil moisture. These aggregate time series represent the parameters averaged across the study area for each of the 2 wk observation periods. The number of farms that contributed to these aggregate means ranged from a minimum of 5 for one 2 wk period of soil moisture to the maximum of 14 available farms for precipitation and temperature. We also document the existence of high winds, which was mentioned as a problem by farmers in 43% of the phone surveys. Our approach is essentially inductive. First, each time series was graphed for data visualization, then the association between drought perception and the meteorological variables was examined via nonparametric Spearman rank correlation analysis, followed by comparison of meteorological variables within drought perception categories through a box plot visualization and nonparametric independent samples means and Kruskal-Wallis test, and lastly a lagged correlation analysis to determine the development and persistence of drought perception. Assuming a time series of red noise, degrees of freedom were reduced based on a one-lag autocorrelation function (Leith 1973).

Stage 2: Given the importance of the timing of rainfall to the agricultural system in southern St. Elizabeth, we examined whether the relationship between drought perception and hydrometeorological conditions varied seasonally through a seasonal analysis of drought perception frequency including a Mann-Whitney *U*-test. In this analysis, the seasons were defined as winter (December, January, February), spring (March, April, May), summer (June, July, August), and fall (September, October, November). Further, our interviews with farmers in the summers of 2013 and 2014 indicated that farmers may be particularly sensitive to interannual precipitation variation (Gamble et al. 2010, Popke et al. 2016). In particular, a dry year following a wet year may cause problems for farmers who made planting decisions in light of the previous year's rainfall. To test this finding, all 2 wk periods of rainfall and soil moisture were compared to the rainfall or soil moisture of the same 2 wk period in the preceding year to determine if the current year was wetter or drier. Specifically, this comparison took the form of mean rainfall (soil moisture) for 15–30 June 2013 subtracted from 15–30 June 2014, then 1–15 July 2013 subtracted from 1–15 July 2014, and continued through the time series to 1–15 May 2014 subtracted from 1–15 May 2015. A negative difference between the 2 periods indicates that the current year was drier than the preceding year for that 2 wk period, while a positive difference indicates that the current year was wetter than the preceding year for that 2 wk period. A 1-way analysis of variance (ANOVA) was completed to determine if the mean rainfall and soil moisture values for the coupled 2 wk periods were significantly different between the 3 farmer drought perception categories (uncertain, yes, and no).

Stage 3: We examined the geographic patterns associated with drought perception in relation to topography, because our study area is characterized by a variety of microclimates. This analysis entailed mapping drought perception frequency and a Spearman rank correlation between elevation and drought perception.

4. RESULTS AND DISCUSSION

4.1. Core physical parameters associated with perceived drought

The relationship between core physical parameters and perceived drought is illustrated by a time series plot (Fig. 3). The overall frequency of responses to the question 'Have you experienced drought in the past two weeks?' was 225 yes, 129 no, and 38 uncertain. As shown in Fig. 3, there are clear differences over the course of the study period in the proportion of farmers indicating drought. A majority of farmers perceived their farms to be under drought stress during more than half (57 %) of the 2 wk periods from June 2013 to May 2015. Farmers were unanimous in their perception of drought during 10 consecutive weeks in the summer of 2014 and again at the end of the study period in May 2015. None of the farmers surveyed indicated drought over 6 wk in November and December of 2014. Thus, not surprisingly, perception of drought corresponds to the bimodal nature of the annual rainfall in 2014, with wet seasons in late spring/early summer and fall having lower percentages of perceived drought. As mentioned in the introduction, 2014 and 2015 were also years of below-normal precipitation, especially in the summer months (Poore et al. 2016).

Correlation analysis indicates that perception of drought has a significant negative correlation with rainfall ($r = -0.65$, $p < 0.05$), suggesting that farmers associate low precipitation with drought (Table 1). A weaker positive correlation exists between farmer perception of drought and temperature ($r = 0.37$, $p < 0.05$), which is somewhat surprising given that high temperatures can lead to greater evapotranspiration and lower soil moisture conditions. One explanation may be that, given the low temperature range in the study area (approximately 21–31°C for 6-hourly observations over the study period), variations in temperature are not large enough, in the farmers' minds, to have a significant impact on the occurrence of drought. However, temperature may play a secondary role in perception of drought as will be discussed below. Soil moisture has a significant, inverse association with frequency of perceived drought ($r = -0.63$, $p < 0.05$), suggesting that farmers are more likely to perceive drought when their soil is dry. The correlation analysis also indicates that reported high winds have a strong, positive association with frequency of drought perception ($r = 0.66$, $p < 0.05$). Such an association could suggest that high winds cause an increase in evaporation from fields. It has also

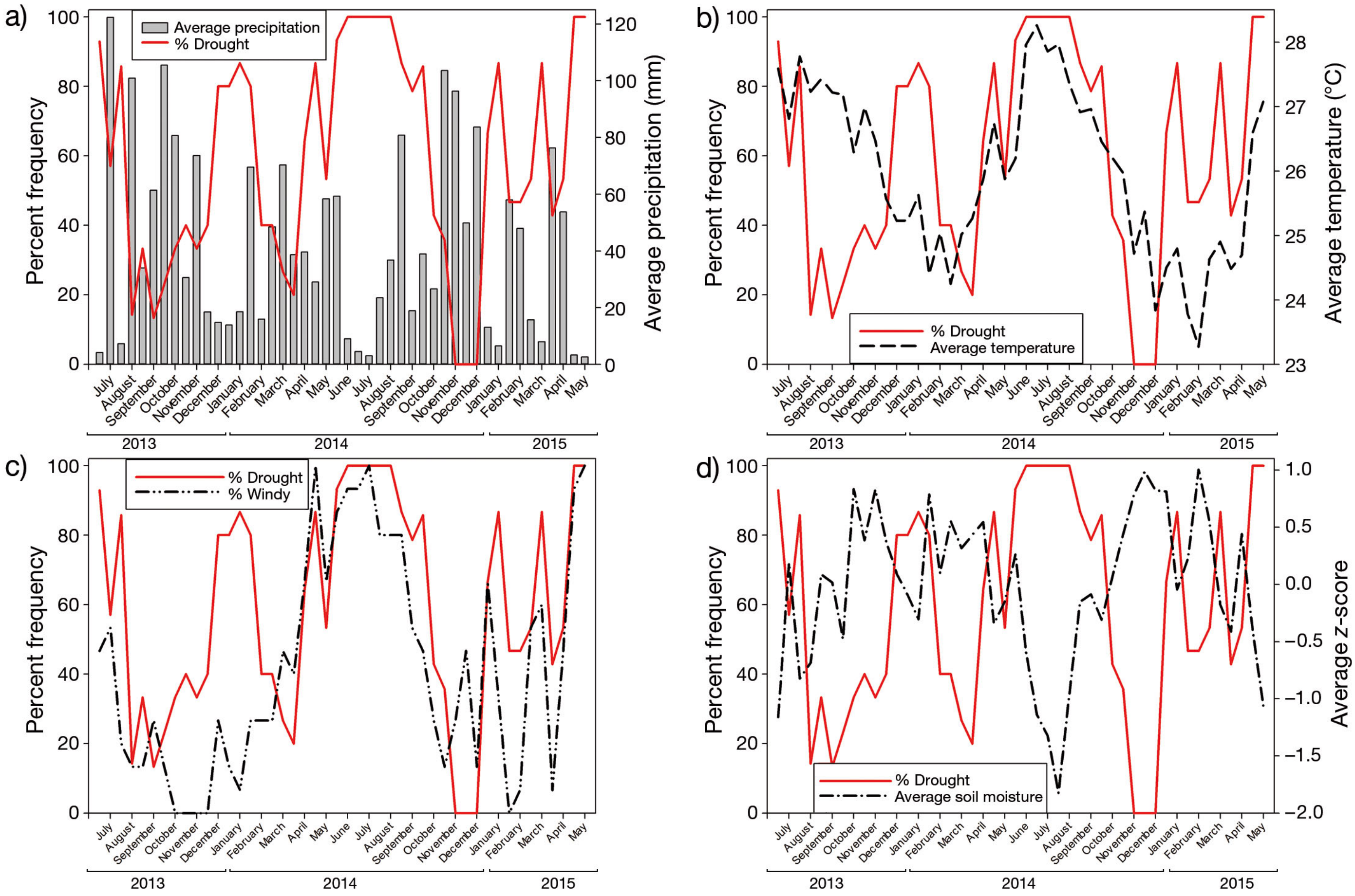

Fig. 3. Study area aggregated time series plots, 15 June 2013 to 15 May 2015 for percent of farmers indicating 'yes' to the question 'Have you experienced drought in the past two weeks?' (red lines) and (a) mean 2 wk total rainfall, (b) mean 2 wk temperature, (c) percent of farmers reporting high winds and (d) mean 2 wk soil moisture (z-score)

been documented that a faster Caribbean Low Level Jet is related to moisture divergence away from Jamaica and subsequent drought (Whyte et al. 2008).

These results overall are consistent with the accepted meteorological framework of drought (Wilhite 2000): low precipitation, dry soil, and high winds. The only exception to this accepted framework is the low degree of association between temperature and drought. However, it should be noted that temperature and soil moisture have a significant, strong negative correlation ($r = -0.69$, $p < 0.01$). This suggests that in the study area, high temperatures dry out soils, and the dry soil maintains warm local air temperature due to a lack of evaporative cooling after the initial drying. Consequently, even though temperature may not be directly associated with drought by farmers, its physical impact is reflected in soil moisture levels, and farmer recognition of the importance of soil moisture in the occurrence of drought may represent a holistic view of moisture conditions on a farm. In short, low soil moisture values are the cue that farmers appear to use to recognize the drying effect of high temperatures, as opposed to taking a cue directly from air temperature, separate from moisture conditions.

Table 1. Correlation coefficients between frequency of perceived drought and observed physical variables, including 2 wk lag increments for southern St. Elizabeth Parish, Jamaica, 15 June 2013 to 15 May 2015. *Statistically significant at $p < 0.05$

Lag time (wk)	Mean precipitation (mm)	Mean temperature (°C)	Mean soil moisture (% water content)	Frequency of reported high winds
0	−0.65*	0.37	−0.63*	0.66
2	−0.41	0.13	−0.30	0.58
4	−0.26	0.01	−0.21	0.41
6	−0.14	−0.01	−0.03	0.36
8	−0.13	−0.16	0.18	0.30

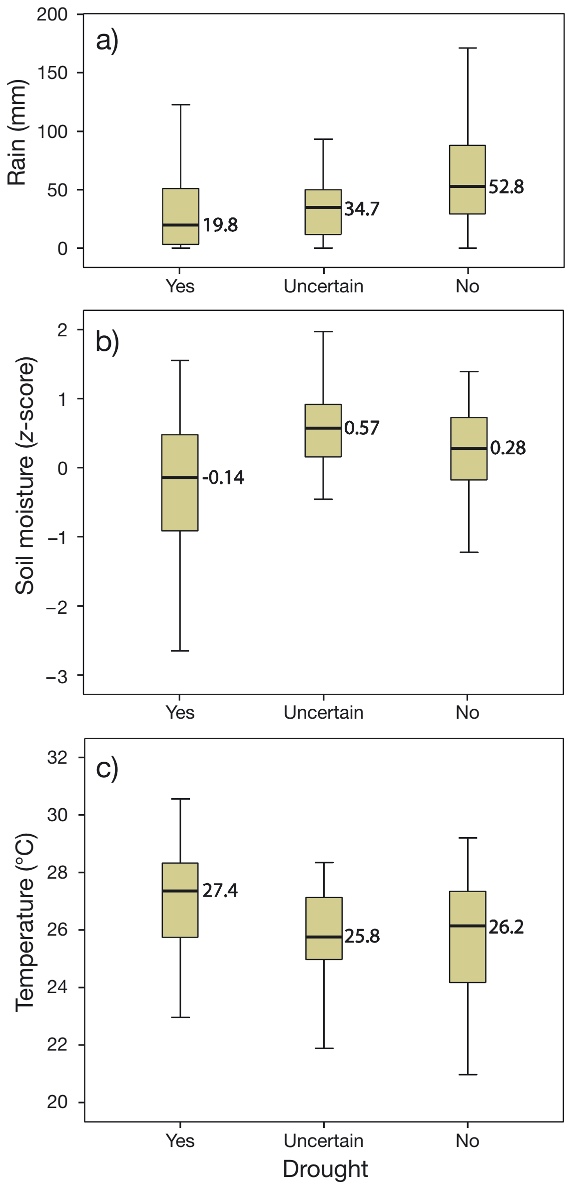

Fig. 4. (a) Rain, (b) soil moisture, and (c) temperature distribution associated with each of the drought perception responses ('yes,' 'uncertain,' and 'no'). Boxes capture the 25th to 75th percentile values, with the median (50th percentile) represented by a horizontal line and labeled. Whiskers: maximum and minimum values

We next examined the distributions of hydrometeorological conditions (temperature, precipitation, and soil moisture) associated with each of the 3 drought perception responses (yes, uncertain, and no) obtained over the course of the study period (Fig. 4). Results show that the 'yes' drought class had the lowest median rain and soil moisture values and highest median temperatures (Fig. 4). This is consistent with the above interpretation that farmers are aware of the hydroclimatic environment on their farm in perceiving drought. The 'uncertain' class unexpectedly had the highest median soil moisture of the surveyed drought classes.

Because the impacts of drought can accumulate slowly over time, perception of drought onset is not always obvious. We therefore examined the correlation of drought perception with the core physical parameters at a series of 2 wk lags (Table 1). The analysis indicates that the association between rainfall and drought perception, and between soil moisture and drought perception is statistically significant during the concurrent 2 wk period, but loses significance with any lag. The association between farmer-perceived high winds and perceived drought has a longer lag effect due to the persistence of the wind. In fact, the autocorrelation in the wind perception is quite high (larger than the drought perception), leading to a substantial reduction of the degrees of freedom and lack of statistical significance. Nevertheless, these results suggest that farmers read cues for identifying drought on a relatively short time period of 2 wk with the exception of high winds which may persist for a 2 wk to 1 mo period before drought, as they serve to alter rainfall patterns prior to drought being identified by a farmer.

4.2. Seasonal differences in drought perception

In our examination of the 2008 drought in St. Elizabeth, we found that farmers are often more concerned with the timing of drought than its magnitude or duration (Gamble et al. 2010). We thus sought to determine whether the environmental conditions associated with perceived drought remained consistent over different seasons. Only during the fall were non-drought conditions perceived more often than drought conditions, while the rest of the year farmers perceived drought to non-drought at a ratio of at least 2:1 (Table 2). The Mann-Whitney *U*-test indicates that in spring and fall, all 3 meteorological variables are significantly different between the 'yes' and 'no' drought-perception categories, indicating that less rain, high temperatures, and low soil moisture are associated with droughts. In the summer, rain and soil moisture are significantly different for drought classes but temperature is not, and in winter only temperature is significantly different between drought categories.

In general, these results are consistent with seasonal climate patterns and associated planting strategies in St. Elizabeth. Farmers in the region consider fall to be their major growing season with the best

Table 2. Median seasonal frequency of drought-perception responses ('yes' and 'no') and results of the Mann-Whitney *U*-test comparing median meteorological variables by season. The number of responses (n) is given in parentheses

	DJF			MAM			JJA			SON		
	Yes (n = 52)	No (n = 28)	p	Yes (n = 60)	No (n = 23)	p	Yes (n = 81)	No (n = 28)	p	Yes (n = 32)	No (n = 50)	p
Rain (mm)	25.3	27.7	0.815	26.4	48.5	0.000	10.2	78.1	0.000	24.3	70.4	0.42
Temp (°C)	25.5	24.6	0.035	27.0	15.3	0.004	28.4	17.7	0.139	27.6	26.6	0.013
Soil moisture (*z*-score)	+0.48	+0.35	0.482	+0.01	+0.42	0.042	−0.91	−0.26	0.014	+0.04	+0.52	0.013

hydrometeorological conditions, and over the course of the study period, this is the one season during which farmers did not perceive drought a majority of the time. Most farmers consider spring to be a secondary growing season, and it is perhaps not surprising therefore, that farmers would be attuned to all 3 physical variables (precipitation, temperature, and soil moisture) in both spring and fall. Dry conditions are typical during the annual 'mid-summer drought' from June through August, and over the study period, this season recorded the highest prevalence of perceived drought, as well as the highest variability in both rainfall and soil moisture. During the summer months, temperature does not appear to be a significant factor in perception of drought. This may be due to the low variability and range in temperature during this season (as discussed earlier), or the fact that, since this is typically a dry spell, farmers are more focused on the occurrence of rain. In winter, by contrast, temperature is the only variable with a significantly different mean between those who did and did not perceive drought.

Another finding from our earlier examination of drought in St. Elizabeth is that year-to-year comparisons of seasonal rains can be an important factor in farmers' perceptions of drought. The ANOVAs of the differences in conditions between the present and preceding year indicate that the differences in the mean rainfall and soil moisture for the 3 categories are statistically significant ($p < 0.001$ rainfall and $p = 0.001$ soil moisture; Table 3). Since the mean values are negative in the 'yes' category and positive in the 'no' category, it can be inferred that farmers identify drought by comparing the current year to the previous year, and if it is drier in the current year, a drought is identified. The uncertain drought perception difference value is close to 0, suggesting that when there is little difference between years, farmers are uncertain of drought conditions. It is more difficult to interpret the high positive difference in mean soil moisture conditions in the uncertain drought category.

4.3. Geographic variability in drought perception

The elevation range across the study area is significant (0–800 m), with this full range represented by the case study farms (elevation range 13–794 m). A rain-shadow effect is associated with the study area's north–south oriented Santa Cruz Mountains, creating cooler, wetter conditions on the northeastern slope and top of the mountains, and warmer drier conditions on the southwestern plains adjacent to the mountains. The frequency with which individual farmers perceived drought ranges from 33–80%, and shows considerable variability across the region (Fig. 5). This spatial variability is consistent with the expected spatial pattern in drought created by the rain shadow effect, i.e. less frequent drought perception on top of the Santa Cruz Mountains and higher drought perception on the adjacent southwestern plains.

A scatterplot and Spearman's rank correlation analysis of the 11 farms with no missing data in 2 wk precipitation and temperature for the study period supports the significant role of elevation, and resulting rain shadow, in spatial patterns of drought perception (Fig. 6). The farm-level frequency of drought perception has a high, statistically significant correlation with farm elevation ($r_s = -0.75$, $p = 0.04$), as well as each farm's aggregate precipitation ($r_s = -0.71$, $p = 0.04$), and average 2 wk temperature ($r_s = -0.86$, $p < 0.01$) over the study period. The signs of the corre-

Table 3. Mean difference in current year and previous year 2 wk rainfall and soil moisture in southern St. Elizabeth Parish, Jamaica, 15 June 2013 to 15 May 2015. The differences in mean rainfall and mean soil moisture between the 3 drought-perception response categories are significant (ANOVA, $p < 0.001$). Parentheses: no. of responses (n)

	Drought-perception response		
	Uncertain	Yes	No
2 wk rainfall (mm)	−0.5 (42)	−29.4 (151)	33.6 (37)
Soil moisture (*z*-score)	0.431 (25)	−0.303 (109)	0.206 (26)

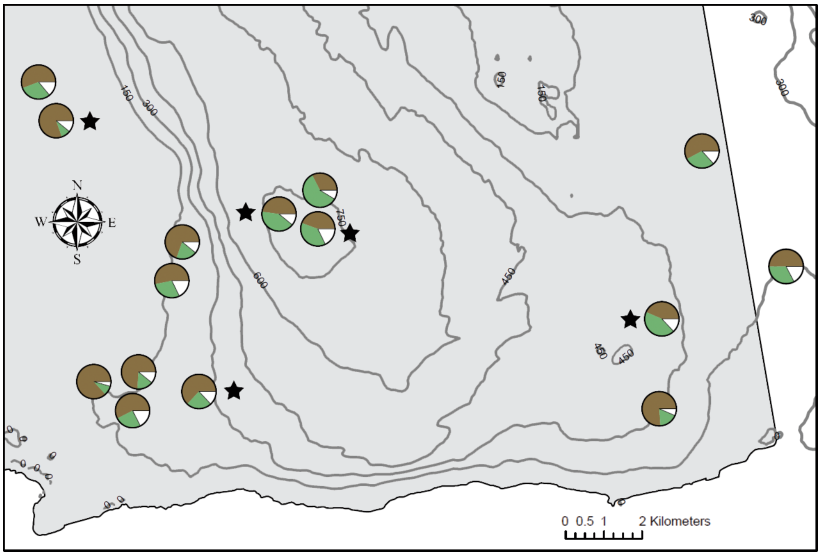

Fig. 5. Farms surveyed in southern St. Elizabeth Parish, Jamaica: location, elevation, and frequency of drought perception responses ('yes': brown; 'no': green; 'uncertain of drought': white). Stars: farms with high capital irrigation systems used in statistical analysis

lations also coincide with the expected elevation–precipitation–temperature–drought relationship: at low elevations, drought is perceived more frequently due to lower precipitation and higher temperatures, and at higher elevations, drought is perceived less frequently due to greater precipitation and lower temperatures.

5. CONCLUSIONS

Despite a relative lack of attention within the research and policy communities, drought represents a significant hazard within the Caribbean, one that may grow more pronounced due to the impacts of climate change. As noted in a recent report (FAO 2016, p. vii), 'agriculture is the sector most vulnerable to the seasonal nature of drought' within the Caribbean, and more research is therefore needed to understand the multidimensional interactions between the environmental conditions that characterize drought and the ways in which farmers experience and respond to such conditions.

Research from other global regions, particularly Africa and Asia, have highlighted the important role that perception plays in understanding of drought in agricultural contexts. Such work makes clear that drought should be understood as more than simply a deficit of rainfall; rather, it is a multifaceted phenomenon that depends crucially upon the practices, expectations and interpretations of farmers. Importantly, these aspects of drought perception can be highly contextual, varying both seasonally and geographically. Despite this, existing studies of drought perception have had to rely upon one-time surveys and regional data sets that are unable to capture the local specificity and dynamic nature of drought perception. Further, few studies of drought perception have been completed in the Caribbean.

The research presented here builds upon our previous examinations of drought, but represents a unique, fine-grained examination of drought perception in the context of changing hydrometeorological conditions on a sample of small farms in St. Elizabeth, Jamaica. The farmers here have developed a strong tradition of local climate knowledge, and are keenly aware of hydrometeorological conditions and their relationship to drought, despite the lack of readily available, detailed meteorological data for the region.

In general, our study found that a physical environment characterized by low rain, low soil moisture, and high winds is most directly associated with drought occurrence. Our results also suggest, however, that there are important spatial and temporal dynamics that also play a role in drought perception. In terms of the geographic factors, we found that drought is more frequently identified at lower elevations, underscoring the importance of microclimates in shaping drought perception.

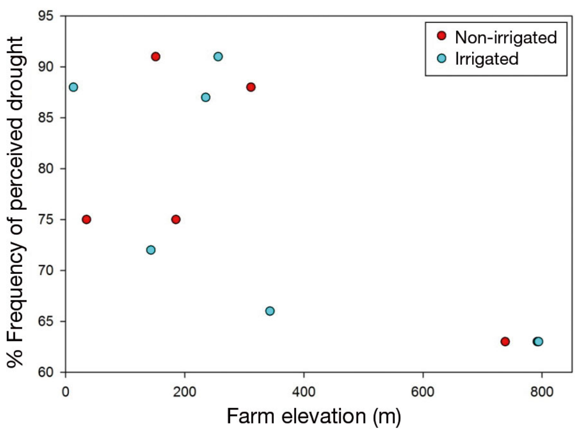

Fig. 6. Farm elevation and percent frequency of perceived 2 wk drought from March–October 2014 in southern St. Elizabeth Parish, Jamaica

In terms of the temporal dynamics of drought perception, our study reveals both seasonal and interannual patterns. Seasonally, drought is perceived more than twice as often as non-drought during winter, spring, and summer, whereas non-drought conditions are perceived twice as often as drought conditions in fall. Our results also highlight the importance of the comparison of current moisture conditions to 1 yr prior moisture conditions in farmer drought perception. If the current season is drier than the previous season, it is more likely to be perceived as a drought.

Finally, we explored the temporal dynamics associated with perceived onset of drought, finding that, with the exception of high winds, the core physical parameters are most directly related with drought perception in a short-term, 2 wk window. These results indicate that farmers in the study have a fairly immediate understanding of how the hydrometeorological environment develops on their farms.

Taken together, these results suggest that there is value in studies that combine on-going monitoring of weather and climate perception with the real-time collection of hydrometeorological data. Findings from such studies will provide insight that can enhance the ability of Caribbean policy-makers and emergency managers to respond to increased drought in a warmer environment. Among the lessons learned from this case study are: (1) that farmers have a sophisticated and dynamic understanding of local meteorological conditions. Efforts to address drought should focus on providing information that augments this local ecological knowledge and creates farmer-centered monitoring and forecasting tools. (2) Many Caribbean islands have a high degree of variability in their topography and microclimates. Drought response and mitigation planning should be sensitive to the ways in which these variations in hydrometeorological conditions can impact perception of drought, particularly inasmuch as drought perception is linked to the willingness and ability of farmers to pursue measures of adaptation. (3) Year-to-year meteorological variability may be a key factor in farmer perception of drought, and thus any monitoring or forecasting efforts that attempt to link current to previous years' moisture conditions may be well received by farmers.

Overall, as Simelton et al. (2013, p. 136) stated, '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.' Developing a more nuanced understanding of drought perception can assist greatly in this task, and allow for a more focused and locally-appropriate response to various kinds of environmental stress.

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