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Rainfall variability and drought characteristics in two agro-climatic zones: An assessment of climate change challenges in Africa

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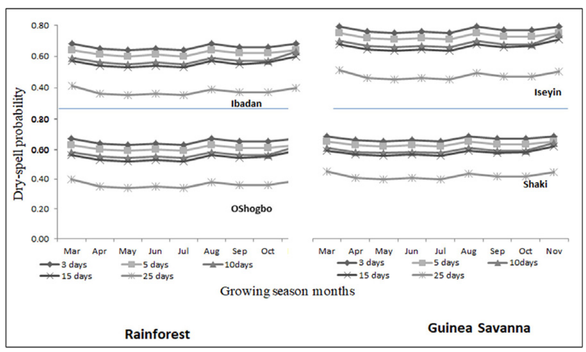
HIGHLIGHTS

- Drought characteristics were linked to climate change.
- Seasonality statistics reveal more variable and drier growing seasons.
- Rainfall is less reliable recently in the growing months.
- Farmers' perceptions of drought fundamentally mirror climatic patterns.

GRAPHICAL ABSTRACT



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ABSTRACT

This paper examines drought characteristics as an evidence of climate change in two agro-climatic zones of Nigeria and farmers' climate change perceptions of impacts and adaptation strategies. The results show high spatial and temporal rainfall variability for the stations. Consequently, there are several anomalies in rainfall in recent years but much more in the locations around the Guinea savanna. The inter-station and seasonality statistics reveal less variable and wetter early growing seasons and late growing seasons in the Rainforest zone, and more variable and drier growing seasons in other stations. The probability (p) of dry spells exceeding 3, 5 and 10 consecutive days is very high with $0.62 \leq p \geq 0.8$ in all the stations, though, the p-values for 10 day spells drop below 0.6 in Ibadan and Osogbo. The results further show that rainfall is much more reliable from the month of May until July with the coefficient of variance for rainy days <0.30, but less reliable in the months of March, August and October (CV-RD > 0.30), though CV-RD appears higher in the month of August for all the stations. It is apparent that farmers' perceptions of drought fundamentally mirror climatic patterns from historical weather data. The study concludes that the adaptation facilities and equipment, hybrids of crops and animals are to be provided to farmers, at a subsidized price by the government, for them to cope with the current condition of climate change.

1. Introduction

In many parts of Africa, drought is increasingly becoming a major challenge for agricultural production, with negative impacts on both crops and livestock. Several studies have shown that prolonged periods

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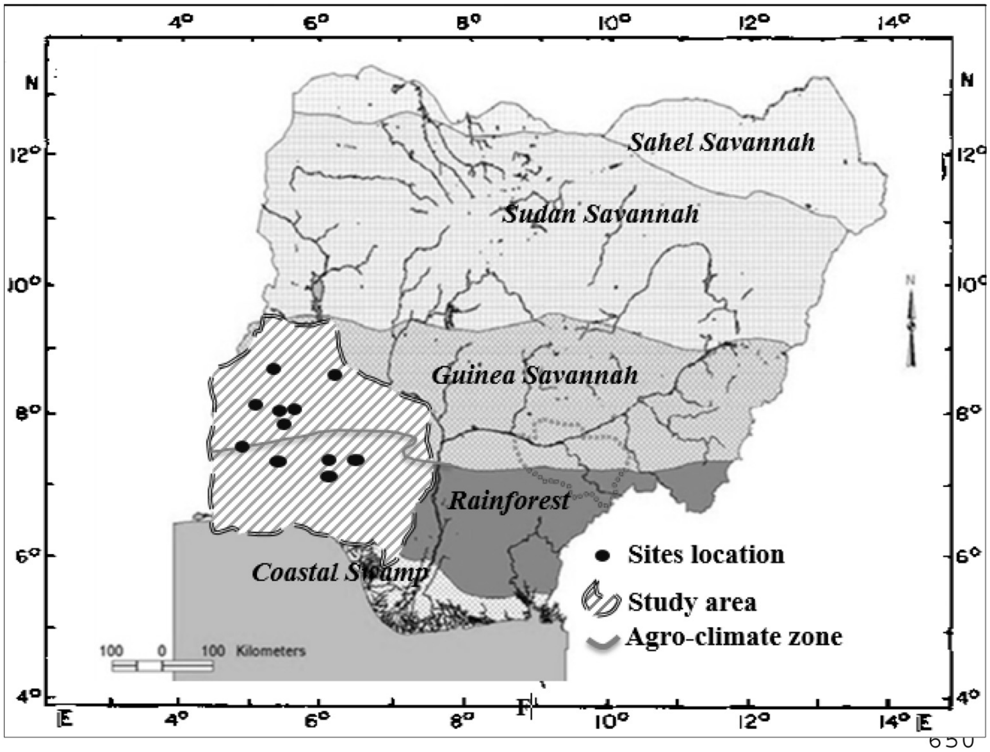

Fig. 1. Map of Southwestern Nigeria, showing the study area.
Source: The map was produced by one of the authors (A.A) using Quantum GIS 1.18 (http://www.qgis.org/en/site/).

of drought can devastate rural families in Africa since majority of them depend on agriculture for their food and income (Abaje et al., 2014; Amwata et al., 2016; Meze-Hausken, 2000; Mupangwa et al., 2011), and drought leads to crop loss and death of livestock (Ayanlade et al., 2010; Hellmuth et al., 2007; Njiru, 2012; Rusinamhodzi et al., 2012; Tambo and Abdoulaye, 2013). Recent studies have shown that drought is one of the climatic extreme events which are an insidious natural hazard, leading to water shortage, with notable adverse impacts on crops, livestock and income of rural farmers. Some of these studies have shown that drought has significant negative impacts on poorer farming communities who have less diversified livelihoods and few economic alternatives (Araujo et al., 2016; Ifeanyi-Obi, 2016; Rouault and Richard, 2003; Zhan et al., 2016). The level of impact of drought on agricultural communities varies, and depends on the socio-economic status of the communities, length and intensity of the drought.

Although there are many definitions of drought in the literature, this study focuses on agro-climatic drought— a prolonged period of abnormally low rainfall resulting in a persistent shortage of water (Ogungbenro and Morakinyo, 2014; Omotosho et al., 2000; Sanogo et al., 2015; Wang, 2005). For smallholder farmers, who depend on rainfed agriculture in many parts of Nigeria, abnormal deficiencies in rainfall, dropping below what can be considered the drought threshold, have resulted in unfavourable conditions for agricultural production (Ogungbenro and Morakinyo, 2014; Oguntunde et al., 2011) Consequently, the cumulative rainfall deficit exceeds the drought threshold with pronounced impacts on agricultural production. Low crop productivity from drought conditions can lead to food insecurity, as demand for crops exceeds supply. When there is a prolonged dry spell and drought conditions persist, rural farmers pay dearly, since the majority of them are poor and vulnerable (Lybbert and Carter, 2015; Odekunle, 2004; Udmale et al., 2014; Zarafshani et al., 2012). Prolonged drought affects crop and livestock production and also leads to loss of household income of rural farmers relying mainly on rainfed agriculture in many parts of Africa (Omotosho et al., 2000; Sanogo et al., 2015).

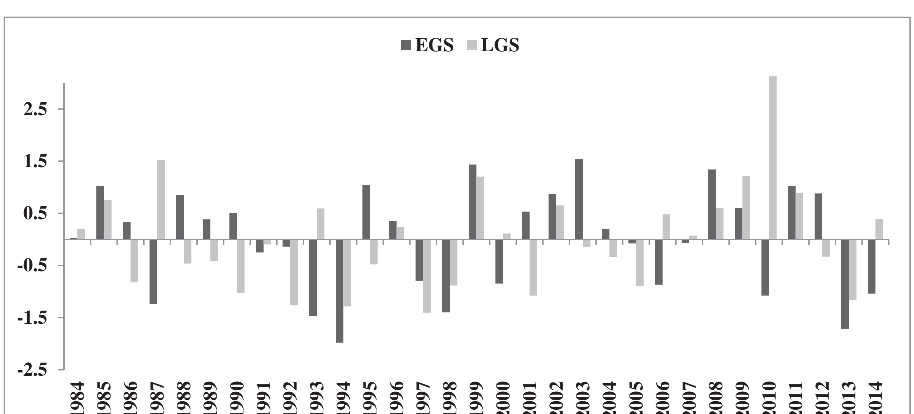

Fig. 2. Standardized anomalies of annual rainfall during 1984–2014 for two growing seasons in Ibadan. EGS represents early growing seasons while LGS represents late growing seasons.

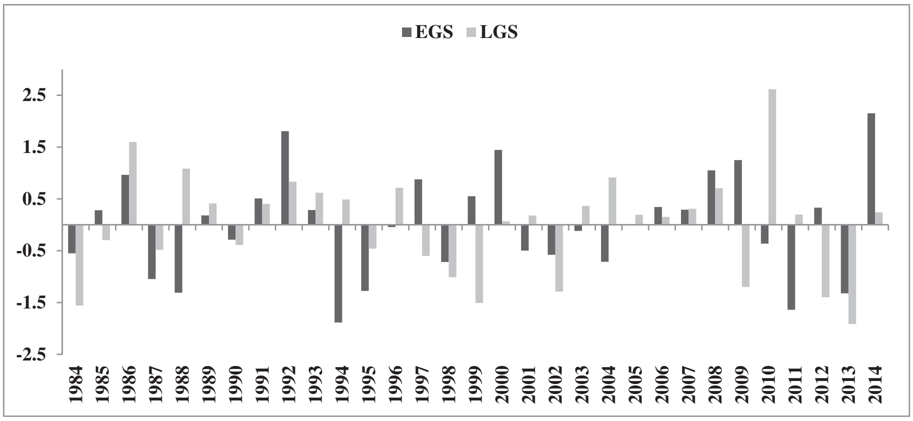

Fig. 3. Standardized anomalies of annual rainfall during 1984–2014 for two growing seasons in Osogbo. EGS represents early growing seasons while LGS represents late growing seasons.

In Nigeria, for example, drought is not the only cause of crop loss but it also leads to the death of livestock in many parts of the country (Abaje et al., 2014; Tambo and Abdoulaye, 2013). Although crop and livestock production provides employment and a major source of income for many people in Nigeria, prolonged dry spells have become much more common in recent years, characterized by low crop yields, and poor nutrition and death of livestock (Adegboyega et al., 2016; Odekunle, 2006). Multi-year droughts are now common which some scientists perceive to be a transitional phase in climate change (Ezeh et al., 2016; Usman and AbdulKadir, 2014). Despite the significant impacts of drought on agriculture in Nigeria, few studies have been conducted (Adebayo and Menkir, 2015; Adegboyega et al., 2016; Adeogun et al., 2015; Oluwaranti and Ajani, 2016) to assess the drought characteristics, frequency, and probability, based on historical meteorological data and evaluation of the major coping strategies adopted by smallholder farmers. Nevertheless, out of these studies, only few have considered the sensitivities of farmers (especially pastoralists) to drought. Therefore, this study examines the variability in rainfall and drought characteristics, using meteorological data collected from five weather stations in Southwestern Nigeria. The paper aims at assessing the frequency and probability of prolonged dry spell over a period of 30 years from 1984 to 2014, including the major coping strategies of smallholder farmers in the Rainforest and Guinea savanna agro-climatic zones of Nigeria. The study was based on the hypothesis that extreme drought events are among the climate change challenges farmers face in many parts of Africa, especially the smallholder farmers, as the majority are poor and vulnerable. And, that climate change leads to crop loss and livestock deaths in dryer parts of Africa. The study addresses on three major research questions: (1) is there spatial and temporal variation in drought characteristics within different ecological zones? (2) What are the probabilities that a dry spell would exceed a given number of days within a growing season? and (3) what are the impacts of drought on agricultural production and farmers' coping strategies? The major assumption of this study is that drought is gradually changing agricultural productivity and that its impacts on rural farmers need to be determined through the rigorous and precise investigation.

2. Materials and methods

2.1. Study area and data

The study sites are the Rainforest and Guinea savanna agro-climatic zones. The Guinea savanna is characterized by annual rainfall of about 900–1200 mm. The wet season lasts for 6–8 months. The Rainforest zone experiences a bimodal peak in rainfall, with mean annual rainfall of about 1280 mm which lasts from April to October. The mean annual minimum and maximum temperature are about 24 °C and 35 °C in Guinea savanna and about 21 °C and 30 °C in the Rainforest zone (Adejuwon and Odekunle, 2006; Kang et al., 1999). Though, the Guinea savanna agro-climatic zone is further divided into two zones - Southern Guinea savanna and Northern Guinea savanna - this study concentrates mainly on the Southern Guinea savanna and part of the Rainforest. The study was carried out through analysis of a 30-year set of climatic data obtained from the Nigerian Meteorological Agency for selected locations in southwestern Nigeria spread across two agro-climatic zones: Rainforest and Guinea savanna agro-climatic zones (see Fig. 1). Earlier studies have shown evidence of the influence of rainfall on agriculture, but the majority of the studies (Ayanlade et al., 2010; McGregor and Nieuwolt, 1998; Odekunle, 2006) reported that temperatures are not a critical factor in crop choice. McGregor and Nieuwolt (1998), for

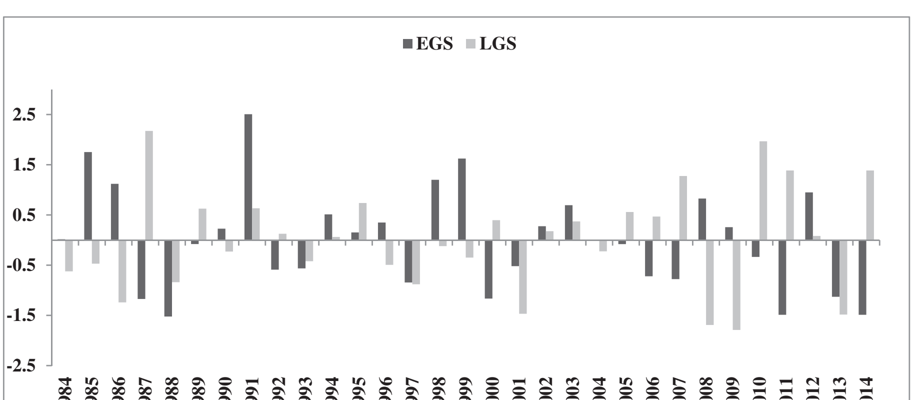

Fig. 4. Standardized anomalies of annual rainfall during 1984–2014 for two growing seasons in Iseyin. EGS represents early growing seasons while LGS represents late growing seasons.

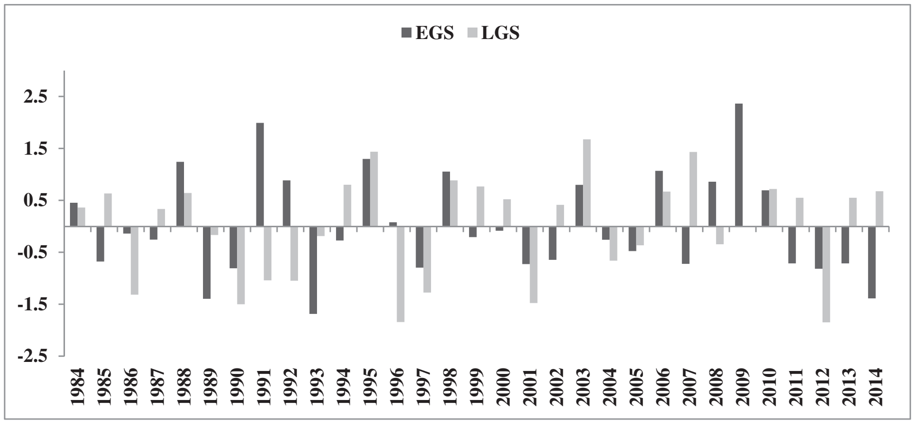

Fig. 5. Standardized anomalies of annual rainfall during 1984–2014 for two growing seasons in Shaki. EGS represents early growing seasons while LGS represents late growing seasons.

example, noted that the choice of suitable crops in tropical agriculture is based on rainfall and that temperature is not a critical factor.

Data were collected using qualitative and quantitative research methods. Quantitative data included climatic data on daily rainfall and minimum and maximum temperature. The daily climatic data were obtained from the archives of the Nigerian Meteorological Agency over a period of 30 years from 1984 to 2014. The climate data used were from five selected weather stations; Ilorin, Iseyin, Shaki, Ibadan, and Osogbo. Annual average rainfall and number of rainy days were computed using the RAINBOW software. The software is designed to carry out hydro-meteorological frequency analyses and to test the homogeneity of climatic data. The climate data was triangulated with social survey data obtained from rural farming communities in the same areas, three of villages (Akeredolu, Faforiji, and Odemuyiwa) located in the Rainforest zone while eight of the villages (Alaguntan, Eyenkorin, Igboho, Igbope, Ilora, Iseyin, Kishi and Shaki) were located in the Guinea savanna zone. The study purposively selected villages that are the major smallholder farming communities in the study sites. Survey data were mainly collected through a household questionnaire survey and focus group discussions, focusing on rural farmers' (both crop farmers and livestock farmers - mainly Fulani pastoralists) perceptions about the impacts of drought and their strategies for coping during and after the extreme weather events. In this study, multistage sampling method was used and households were selected, using systematic sampling techniques, from the communities where questionnaires were administered. Semi-structured questions were used to collect data through focused group discussions. The data from focus group discussions were used for triangulation of respondents perceptions obtained from the questionnaire and the results of analysis of climate data. The first segment of the household survey was conducted in the months of October and November of 2015, while the second segment was conducted in the months of May and June 2016. A total of 350 farmers belonging to the age group of 35–75 years were selected, in all the villages, using a multistage sampling method.

2.2. Seasonal rainfall fluctuations

Drought characteristics were assessed using seasonal rainfall fluctuations. Standardized Rainfall Anomalies (SRA) was calculated for two major growing seasons: early growing season (EGS) and late growing season (LGS). EGS comprises the first peak of the rainy season (April–Mid August) and LGS the second peak (late August–October). SRA were calculated using Eq. (1),

$$\mathrm{SRA} = \frac{\mathrm{R_t} - \mathrm{R_m}}{\sigma} \tag{1}$$

where Standardized rainfall anomaly (SRA) is a function of R_t - the annual rainfall value in year *t*; R_m in a long-term mean annual rainfall over the period of study, 1980–2014, while σ is the standard deviation of annual rainfall for the whole study period.

To test the level of variations in the EGS and LGS rainfall, the coefficient of variance (CV) statistics were calculated for rainfall amount (RA) and a number of rainy days (RD) with their *t*-test statistics to assess the significance of variation. A rainy day was considered to be any day with at least 0.3 mm of rainfall based on Adejuwon and Odekunle (2006) and any day with rainfall <0.3 mm was counted as a dry day. The probability and the frequency of dry spells, during the growing seasons, were estimated by considering the numbers of rainy days in the growing months.

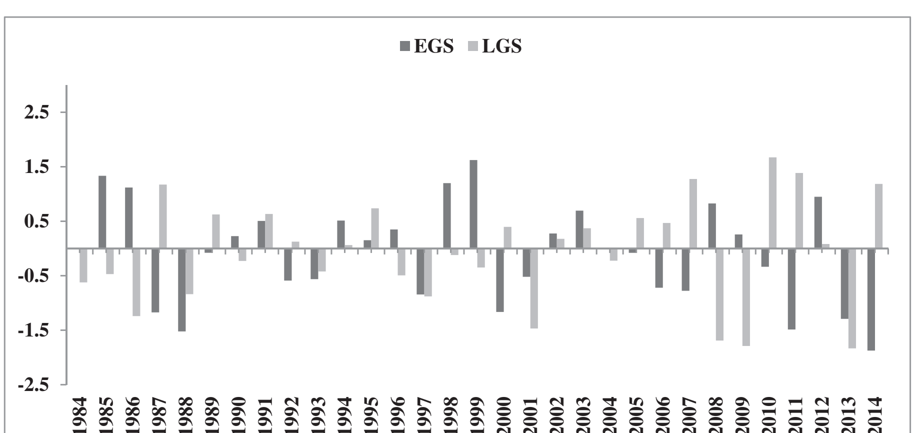

Fig. 6. Standardized anomalies of annual rainfall during 1984–2014 for two growing seasons in Ilorin. EGS represents early growing seasons while LGS represents late growing seasons.

Table 1
Monthly variability, the coefficient of variation in rainfall amount and rainy days for the growing season in Ibadan.

	March	April	May	June	July	August	September	October
RA	77.77	128.10	154.40	178.71	166.85	132.58	183.55	173.72
CV-RA	0.65	0.40	0.36	0.40	0.52	0.84	0.41	0.36
RD	6	9	12	17	18	16	15	16
CV-RD	0.40	0.25	0.21	0.25	0.37	0.69	0.26	0.21

T.test values = 0.034*, which indicates a significant differences in seasonal rainfall amount @ $p = 0.05$.

Thus, the probability (P) that a dry spell would exceed a given number of days (b) was calculated using Eq. (2). This was achieved by calculating as a preliminary the probability (P_b) that a dry spell longer than b days will occur during the growing seasons (Eq. (3)); the probability (P_a) that a dry spell not longer than a days will occur during the growing seasons (Eq. (4)); while the probability (q) that a dry spell may be equal to or longer than specific days were calculated using Eq. (5).

$$p = (1-p_b) = 1-\left[1-\frac{1}{N}\right]^n \tag{2}$$

$$\text{where} \quad p_b = (p_a)^n = \left[1-\frac{1}{N}\right]^n \tag{3}$$

$$\text{but,} \quad p_a = (1-q) = \left[1-\frac{1}{N}\right] \tag{4}$$

$$\text{and,} \quad q = \frac{1}{N} \tag{5}$$

Here, the probability that consecutive dry days would occur were established by considering the number of the days in the month n, and the total possible number of days N in the growing seasons.

Information about the coping strategies adopted by farmers and farmers' perception of drought was gathered through questionnaires and focus group discussions in the eleven communities. This was assessed based on the number of responses and their percentage. Climate data from Ilorin were used to interpret farmers' perceptions in Eyenkorin; Iseyin data were used for Iseyin; Shaki data were used for Alaguntan, Igboho, Igbope, Kish and Shaki; while Ibadan data were used for Ilora; and Osogbo data were used for Akeredolu, Faforiji, and Odemuyiwa. These are the nearest meteorological stations to the farming communities in two agro-climatic zones.

3. Results and discussions

3.1. Anomalies in seasonal rainfall amount and agro-climatic characteristics

The annual rainfall anomaly (SRA) results are presented in Figs. 2–6. Two major results are obvious from SRA: (1) there are variations in the rainfall amount received during growing seasons in different agro-climatic zones (Figs. 2–6), and (2) there appears to be inter-seasonal variations in SRA between 1984 and 2014. Though the annual temperature has relatively increased in recent years, the rainfall annual values and variability appear much more varied. The stations in the rainforest show more years of near average rainfall compared to the stations in the Guinean Savanna. For example, the results show near average rainfall in Ibadan (1984, 1991 and 2007) and Osogbo (1990, 2005, 2006 and 2007) with $-0.1 \le \text{SRA} \ge 0.1$, compared to other stations. The highest positive anomalies were observed during LGS in 2010 for both Ibadan and Osogbo with SRA ≥ 2.5 (Figs. 2 and 3). The stations in Guinean Savanna recorded more negative anomalies in rainfall amount but the wettest EGS were recorded in 1991 for Iseyin (SRA = 2.5); in 1999 for Ilorin (SRA = 1.6); and in 2009 for Shaki (SRA = 2.4). In general, the inter- station and seasonality data revealed less variable but wetter EGS and LGS in Ibadan and Osogbo, and more variable and drier EGS and LGS in other stations (Figs. 2–6). These results show that rainfall variability in both agro-climatic zones during LGS is markedly high. The reasons for this are explored in the next sections.

Variations in rainfall amount and differences in the number of rainy days during the growing season for different stations are presented in Tables 1–5. RA (mm) represents rainfall amount in millimeters; CV-RA is coefficient of variation in rainfall amount; RD is the number of rainy days in a month; and CV-RD is the coefficient of variation in the rainy days. The total average rainfall amount received in both Ibadan and Osogbo (Tables 1 and 2) are higher than other stations (Tables 3–5). These values imply that the amount of rainfall received in the Rainforest agro-climatic zone is higher than that in the Guinea savanna. Monthly variations in the rainfall amounts and number of rainy days in the growing season were assessed using the coefficient of variation (CV-RA and CV-RD). Studies have revealed that a CV >30% implies high variations in rainfall amount and distribution patterns (Kisaka et al., 2015; Pai et al., 2011). Thus, in the present study, CV-RA > 30% implies high rainfall variations, meaning that rainfall is less reliable and CV-RD < 30% implies less variations with rainfall much more reliable. Furthermore, numbers of rainy days in the Rainforest are more those for the Guinea savanna and this are simultaneously replicated in the values of CV-RD for the growing season months. The general results show that rainfall amount received in the growing months are highly variable with CV-RA > 30 in the growing seasons for all stations (Tables 1–5). In all stations, the months of March and August are highly variable with the highest CV-RD. For instance, the CV-RA for March and August were 0.65 and 0.84 respectively in Ibadan; 0.56 and 0.68 respectively in Osogbo; 0.69 and 0.68 for March and August respectively for Shaki; 0.67 and 0.45 for March and August respectively for Iseyin, and 0.63 and 0.64 respectively in Ilorin (Tables 1–5). Likewise, the CV-RD values were generally high also for the months of March and August (Fig. 7). These values imply that the onset months (March and last dekad August) and cessation moths (first dekad of August and October) for EGS and LGS respectively are not reliable. The results from CV-RD further indicate that rainfall is

Table 2
Monthly variability, the coefficient of variation in rainfall amount and rainy days for the growing season in Osogbo.

	March	April	May	June	July	August	September	October
RA	78.84	120.91	154.94	177.18	170.25	133.08	200.48	196.42
CV-RA	0.56	0.37	0.36	0.32	0.53	0.68	0.35	0.31
RD	4	8	11	15	14	12	18	12
CV-RD	0.31	0.22	0.21	0.17	0.38	0.58	0.20	0.26

T.test values = 0.031*, which indicates a significant differences in seasonal rainfall amount @ $p = 0.05$.

Table 3
Monthly variability, the coefficient of variation in rainfall amount and rainy days for the growing season in Shaki.

	March	April	May	June	July	August	September	October
RA	57.45	102.35	151.07	162.65	145.59	148.33	195.38	133.31
CV-RA	0.69	0.53	0.37	0.36	0.50	0.68	0.35	0.50
RD	3	5	9	11	14	13	15	7
CV-RD	0.44	0.31	0.22	0.21	0.25	0.53	0.20	0.35

T.test values = 0.114, not significant differences in seasonal rainfall amount @ $p = 0.05$.

much more reliable from the month of May until July but less reliable in the months of March, August and October (Fig. 7).

A similar scenario had earlier reported by Odekunle (2004), that rainfall is more reliable for growing seasons in Ikeja, Ondo, Ilorin, Kaduna, and Kano from the end of the second dekad of May but less reliable from the second dekad of October. What is apparent from the present study, therefore, is that both Ibadan and Osogbo are located in the core part of the Rainforest zone, thus experience lower variability in rainy days in both EGS and LGS compared to other stations which are located in the Guinea Savanna. This is revealed by significant differences in the seasonal rainfall amount and number of rainy days (Tables 1–5) in both Ibadan ($p = 0.034$ @ 0.05) and Osogbo ($p = 0.031$ @ 0.05), but not significant in Iseyin ($p = 0.111$@ 0.05), Ilorin ($p = 0.101$@ 0.05) and Shaki ($p = 0.114$ @ 0.05). The awareness of the dynamic of rainfall amount and number of rainy days, during the growing seasons, can help farmers and agricultural extension service to have better understanding, not only of the rainfall onset, duration and cessation but also choice of planting data and crop variety (Amadou et al., 2015; Hansen et al., 2011; Tadross et al., 2009; Wilhelmi and Wilhite, 2002; Wilhite, 2016; Wood et al., 2015).

3.2. Probability of dry spells

Observations of climatic data illustrate that the probability of dry spells occurring within the growing seasons varies from month to month. To consider the intensity of dry-spells, we further assessed the probability that dry spells will exceed specific numbers of consecutive days. Generally, the probability of dry spells exceeding the selected thresholds are generally lower in Ibadan and Osogbo compared to other stations. The results show a high probability that dry spells exceed 3 and 5 consecutive days during the growing seasons in all the stations (Figs. 8–12). The probability is much higher in the months of March ($p = 0.76$, 0.77 and 0.86), August (p = 0.76, 0.78, and 0.80), and October ($p = 0.77$, 0.79 and 0.83)in Iseyin, Ishaki and Ilorin (Figs. 10–12) with probability values for 3 consecutive days and for 5 consecutive days within March ($p = 0.70$, 0.75, and 0.81), August ($p = 0.72$, 0.74, and 0.76) and October ($p = 0.73$, 0.76, and 0.76) respectively. The probability that dry spells exceed 25 consecutive days within a growing season month (this does not have to be a 25 day dry spell that begins and ends within a particular calendar month) is very low in all the stations with $0.37 \leq p \geq 0.62$. These values imply that rainfall is much more reliable from the months of May till July in EGS but September in LGS for cropping. The major finding of this study is that the probabilities that dry spells exceed 3, 5, 10, and 15 consecutive days are very high in Iseyin, Ishaki and Ilorin (Figs. 10–12) compared to Ibadan and Osogbo (Figs. 8 and 9).

The reasons for this are obvious, not only because the two set of settlements are located in difference agro-climatic zones, with different rainfall amount and a number of rainy days, but also the rainfall frequency, duration, and amount are directed typically by the movement of the Intertropical Discontinuity (ITD). The ITD is the boundary between two air streams: tropical maritime (mT) and tropical continental (cT). The mT is relatively warm and moist air mass while cT is relatively cool, dry and stable air mass. The implications of the ITD movement on the rainfall pattern in Nigeria have been reported in many studies (Abatan et al., 2016; Ayanlade, 2009; Fuwape et al., 2016; Ilesanmi, 1971; Odekunle, 2006; Odekunle et al., 2005). The spatial and temporal movement of the ITD plays a fundamental role in the spatial variability of rainfall over Nigeria as well as in another part of West Africa, with rainfall decreasing from the southern to the northern part of the region.

3.3. Farmers' perceptions of drought in relation to climate change and coping strategies

This section presents the results from the focus group discussions (FGD) held in eleven farming communities (Akeredolu, Alaguntan, Eyenkorin, Faforiji, Igboho, Igbope, Ilora, Iseyin, Odemuyiwa, Kishi and Shaki) within the Rainforest and Guinea Savanna in Nigeria. The definition of drought by the farmers was evaluated with criteria such as the rainfall onset and cessation, dry-spells of different lengths and the occurrence and magnitude of the little dry season (Adejuwon and Odekunle, 2006). It is evident from the FGDs that nearly 85% of the populations in the selected communities are farmers, almost all cultivating without mechanical equipment. Thus, prolonged droughts have major impacts on their agricultural productions. Therefore, we asked the farmers questions relating to the definitions of the drought. The majority of farmers (nearly 69%) defined drought as a period of "prolonged dry spell during rainy seasons" and others as "no rainfall in some days of rainy season" (Table 6). They said that dry spells or drought (*ogbele* in Yoruba, the local language) is "a time with very little or no rainfall". With changes in climate however, it has been observed that "sometimes little rain falls for a short time and prolonged drought is more frequent". The drought has now become a frequent occurrence with lengthening dry spells such that plants get dry and the soil becomes hard to till.

From these definitions, it appears that farmers in these agro-climatic zones have a clear understanding of drought and the climatic circumstances they find themselves in. The most common responses from the questionnaire and the FGDs are that the farmers have experienced: late rainfall onset in the past 30 years; changes in duration and cessation of rainfall; and frequent and lengthy dry spells within the growing seasons. Many of them observed frequent occurrence of droughts during the rainy seasons and believed that it has been a result of climate

Table 4
Monthly variability, the coefficient of variation in rainfall amount and rainy days for the growing season in Iseyin.

	March	April	May	June	July	August	September	October
RA	50.40	105.99	134.21	170.41	168.34	175.37	199.15	159.86
CV-RA	0.67	0.35	0.39	0.36	0.43	0.45	0.32	0.36
RD	3	7	10	13	12	10	16	10
CV-RD	0.42	0.20	0.24	0.21	0.28	0.51	0.27	0.21

T.test values = 0.111, not significant differences in seasonal rainfall amount @ $p = 0.0$.

Table 5
Monthly variability, the coefficient of variation in rainfall amount and rainy days for the growing season in Ilorin.

	March	April	May	June	July	August	September	October
RA	52.34	98.63	132.12	158.54	141.32	141.03	191.98	103.12
CV-RA	0.63	0.51	0.35	0.35	0.49	0.64	0.35	0.51
RD	3	7	10	13	12	10	16	8
CV-RD	0.42	0.32	0.20	0.21	0.21	0.56	0.22	0.36

T.test values = 0.101, not significant differences in seasonal rainfall amount @ $p = 0.05$.

change. The farmers complained bitterly that drought has threatened agriculture and subsequently food security, the income of farmers and their livelihood. Many of the farmers believe that extreme climatic events are caused by "a supreme being" who has "decided to recompense for the sins they have committed". Most of the farmers thought that recurrent and prolonged droughts are one of the signs of climate change. They explained further how climate change has strongly affected their farm production. Many complaints were recorded from the maize farmers who complained that the "rain started this year (2016) in early March only to stop in early April destroying their maize seedlings". The majority of the farmers perceived that rainfall onset, duration, and cessation have not been normal over the past ten years. These sensitivities by farmers, therefore, confirm the results from the meteorological patterns presented in the sections above.

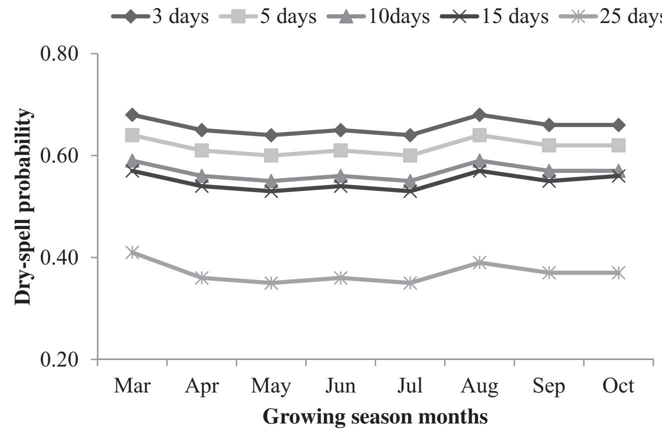

Fig. 8. Probability of dry-spell exceeding 3, 5, 20, 15 and 25 consecutive days in growing seasons in Ibadan.

Most farmers had observed some prolonged dry spells within the months of March, April, and August, which affect the planting dates. Marginally available financial resources and know-how for designing and implementing effective adaptation measures worsen this condition.

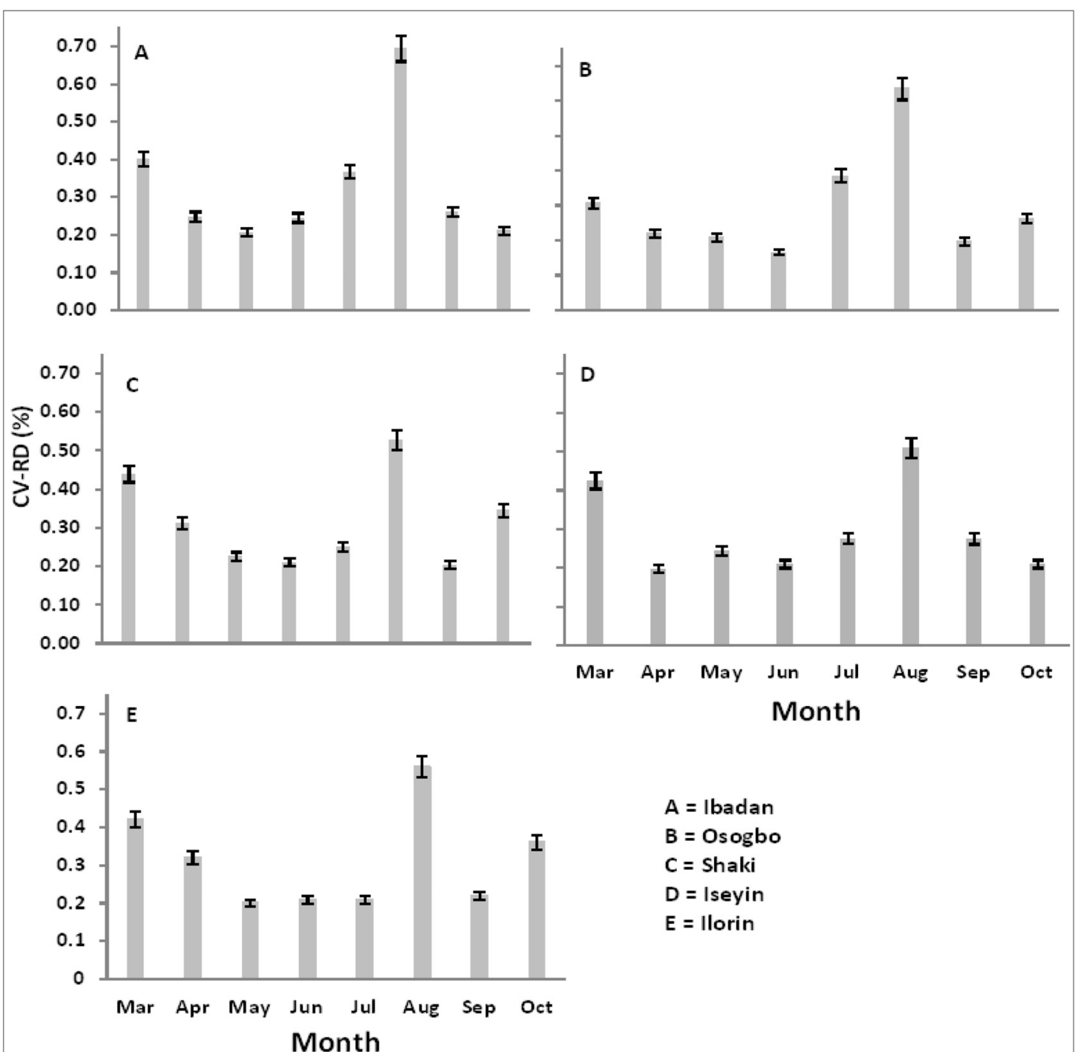

Fig. 7. Coefficient of variation in rainy days (CV-RD) during growing seasons.

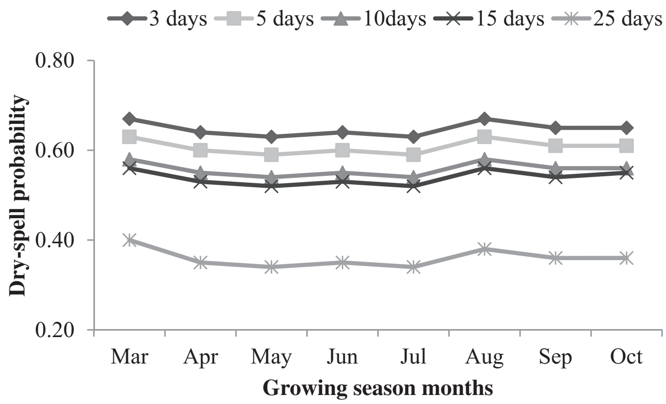

Fig. 9. Probability of dry-spell exceeding 3, 5, 20, 15 and 25 consecutive days in growing seasons in Osogbo.

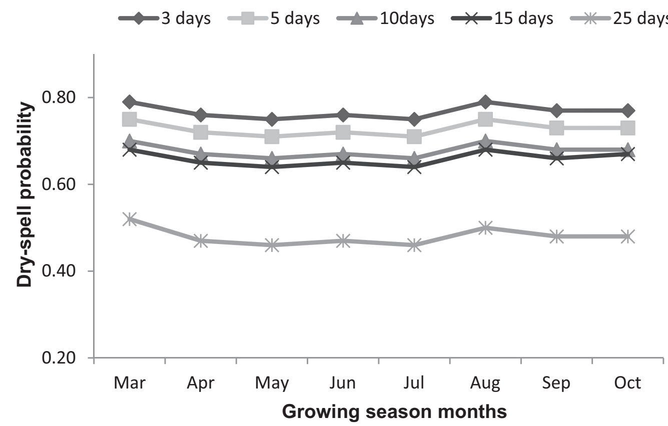

Fig. 11. Probability of dry-spell exceeding 3, 5, 20, 15 and 25 consecutive days in growing seasons in Shaki.

To cope with drought, different farmers have adopted diverse coping strategies (Table 7). The majority of crop farmers engaged in: mulching (56%); changing planting date (68%); scaling down production to reduce crop loss (58%); planting drought-tolerant crops (39%); and irrigation (48%). Another challenge, specifically for crop farmers, is the hardening of the soil which makes it difficult to till and cultivate. Farmers have to either wait for the rain to soften the ground or use mechanical implements to till the ground. Most livestock farmers, especially the Fulani pastoralists, engaged in migration to green pasture (62%) while some of them use crop residues/by-products from soybean, groundnuts, and cowpeas. Some have no other strategy than seeking an alternative source of income (Table 7). What is noticeable from both questionnaires and FGDs is that a large percentage of rural farmers depend on rainfed agriculture, so when there is no rain the farmers can only help, by hand-watering on a very small-scale, except for the few among them who can afford irrigation.

4. Conclusions

This paper reported rainfall variability and drought characteristics under climate change in two agro-climatic zones of southwestern Nigeria. The study used quantitative and qualitative research methods to assess anomalies in seasonal rainfall amounts, probabilities of dry spells, and perceptions of farmers on impacts of drought and their coping strategies in different agro-climatic zones. There are four major findings from this study: (1) there is very high spatial variability between stations, and temporal variability for each station, in consequence, there are several anomalies in rainfall in recent years; (2) in the recent years, it is has been observed that rainfall is more reliable from the month of May till July, and less reliable in the months of March, August and October; (3) the probability of dry spells within the months of the growing seasons varies, and that the probabilities of rainfall exceeding 3, 5, 10, and 15 consecutive days are very high in Iseyin, Ishaki and Ilorin compared to Ibadan and Osogbo; and (4) farmers perceptions of drought and climate change actually mirror climatic patterns from historical weather data, that drought has now become a recurrent phenomenon with longer dry seasons. Many studies have reported similar results in other parts of the world (AghaKouchak et al., 2015; Bannayan and Hoogenboom, 2015; Rojas et al., 2011; Sheffield and Wood, 2008; Wang et al., 2016; Zhan et al., 2016). For example, Sheffield and Wood (2008) had earlier projected drought occurrence under future global warming using data and multi-scenario from IPCC simulations. The results from the study exposed the recent and potential future increases in global temperatures associated with changes in precipitation and increases in extreme climate events such as droughts. Rojas et al. (2011) and Zhan et al. (2016) further noted that drought is one of the recurrent climate-related disasters occurring across many parts of the African continent. These studies showed that drought is more problematic due to lack of observational data, lack of reliable adaptation strategies, hence devastating consequences for the food security of agricultural households. Some other studies have reported that rainfall is much less reliable than previous the growing seasons (Adejuwon and Odekunle, 2006; Odekunle, 2004; Vrieling et al., 2016), thus farmers need to cope by planting drought-tolerant crops (Adebayo and Menkir, 2015; Fisher et al., 2015; Tambo and Abdoulaye, 2013).

The results from the present study further show that farmers' perception of drought and extreme climate events mirror meteorological analysis. However, farmers have adopted different strategies to cope

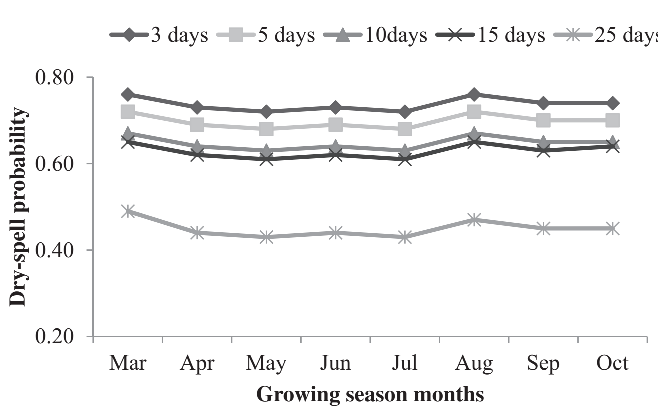

Fig. 10. Probability of dry-spell exceeding 3, 5, 20, 15 and 25 consecutive days in growing seasons in Iseyin.

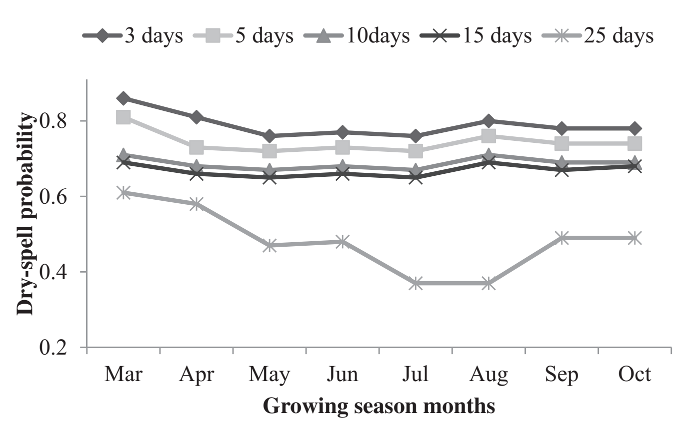

Fig. 12. Probability of dry-spell exceeding 3, 5, 20, 15 and 25 consecutive days in growing seasons in Ilorin.

Table 6
Farmers' perceptions and definitions of drought (%).

	Prolonged dry spell during rainy seasons	No rainfall in rainy season	When water supply is insufficient to cover crop or livestock water requirements	When crops dry up and livestock death
Akeredolu	46.2	31.2	12.1	10.5
Alaguntan	40.8	30.8	20.0	8.5
Eyenkorin	39.5	24.3	16.9	19.3
Faforiji	47.4	37.2	12.9	2.5
Igboho	41.2	30.2	19.5	9.2
Igbope	48.6	31.9	17.1	2.4
Ilora	41.2	36.1	16.0	6.7
Iseyin	60.1	30.1	3.0	2.8
Odemuyiwa	39.8	39.9	16.8	3.5
Kishi	49.0	31.9	12.3	6.8
Shaki	39.9	32.5	14.1	13.6

Only a single response was allowed per respondent.

with recurrent drought events in the study area. These strategies only partially compensated for the fact that agriculture would almost certainly have been better if the climate had kept constant. In all the study sites, planting dates were re-scheduled to when it is most suitable and favorable for the crops to be planted. For instance, some crops are planted at the onset of rainfall but in situations when rainfall is delayed, the planting date of the crop would be shifted to the time when the rain starts (Dong et al., 2006; Fisher et al., 2015). Some crops need to be planted at a specific time and the date cannot be changed. As for irrigation, farmers are making efforts but the issue is that they do not have enough funds for digging boreholes and when they dig wells, in most cases they do not find sufficient water during the dry season. The Fulani pastoralists complained mostly about the reduction of grazing grass and water for their cattle, though they move their cattle around for pasture. Many herders observed that cattle health is now poor and the milk obtained from their cattle has reduced greatly, compared to several earlier centuries. The cattle are moved therefore; towards the south where there is more than enough grasses for their animals to graze. Sometimes clashes occur between the herdsmen and crop farmers, because the cattle sometimes wander into farms when there is no proper supervision. Furthermore, the farmers complained about their inability to purchase material and equipment to cope with drought, because the equipment is always sold at unaffordable prices. The facilities and equipment for adaptation should be provided at a subsidized price by the government, and that efforts should be made to develop crop varieties that can cope with the current conditions of climate change in Nigeria.

Table 7
Farmers' coping strategies during droughts by category of farmers (%).

Categories of farmers	Strategies	% responses
Crop farmers	A majority of the farmers interviewed engaged in:	
	planting drought tolerant crops	39
	irrigation techniques	48
	Scale-down production	58
	Mulch thicker	56
Livestock farmers (Fulani pastoralists)	A majority of the farmers interviewed engaged in:	
	crop residues/by-products from (soybean, groundnuts, and cowpeas)	41
	Migration to green pasture	62
	Changes in housing	12
	Another source of water	36
	Use of hay	31
	Seek the alternative source of income	56
	Selling some or all stock	61
Mixed crop-livestock farmers	Timing the application of water	51
	Another source of water	69
	Sale of or increased reliance on livestock	48
	Spray plants with leaf fertilizer	53
	Temporary exit from farming	31

Multiple responses were allowed.

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Author contributions

A.A., M.R. and J.F.M contributed to the study design, method development, result analysis and writing of the manuscript; A.A. also overseen the fieldwork and carried out the FGDs; T.M contributed to the FGDs data interpretations, result discussion and manuscript preparation.

Competing financial interests

The authors declare no competing financial interests.

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