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Start, end and dry spells of the growing season in semi-arid southern Zimbabwe

W. Mupangwa[a,b,*], S. Walker[b], S. Twomlow[a]

[a] ICRISAT, Matopos Research Station, P O Box 776, Bulawayo, Zimbabwe
[b] Department of Soil, Crop and Climate Sciences, University of Free State, P O Box 339, Bloemfontein 9300, South Africa

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A B S T R A C T

Smallholder agriculture in semi-arid Zimbabwe is dependent on the seasonal characteristics of rainfall. The determination of start, end and length of the growing season, and the pattern of dry spells during the season is useful information for planning land preparation and planting activities. This study was designed to assess whether there has been any changes in the start, end and length of growing season and the pattern of 14 and 21 day dry spells during the season. Daily rainfall data were collected from five meteorological stations located in southern Zimbabwe. Results indicated that no significant changes in the start, end and subsequent length of growing season occurred over the past 50–74 years. There was no significant change in the number of wet days per season over the period reviewed. There is a high probability of 14 and 21 day dry spells during the peak rainfall months. The relationship between start and end of growing season is stronger as aridity increases. We conclude that growing seasons have not changed significantly over the past 50–74 years in southern Zimbabwe. As smallholder agriculture continues to be affected by dry spells and droughts, there is scope in exploring rainwater management technologies in rainfed cropping systems.

1. Introduction

Semi-arid southern Zimbabwe experiences frequent droughts and dry spells during the growing season, making rainfed cropping risky (Cooper et al., 2008). In some years the rains start early while in others they arrive late. Abrupt end of the growing season has been reported in some semi-arid parts of sub-Saharan Africa (Usman and Reason, 2004). This annual variability makes the selection of crop types and varieties, and planning of planting dates critical, yet also difficult, for successful cropping in rainfed systems (Hussein, 1987; Kinsey et al., 1998; Raes et al., 2004). Crop yields are often reduced significantly due to the late start and early cessation of the growing season. This is further complicated by the occurrence of long dry spells during the January to February period when most crops are in their vegetative and reproductive growth stages. Increases in dry spell lengths and reductions in wet day frequencies have been reported in Malawi, Zambia and Zimbabwe (Tadross et al., 2007). Effective rainfall for planting has been arriving late over much of southern Africa (Tadross et al., 2007). In southern Zimbabwe, as in other parts of sub-Saharan Africa, it is common for drought or long dry spells to occur during the growing season (Usman and Reason, 2004).

The existence of relationships between start, end and length of growing season, and number of wet days per growing season is critical for planning farming activities before the start and during the season (Mugalavai et al., 2008). Studies conducted in semi-arid parts of West Africa indicated that there is a significant relationship between the start of rains and the length of the growing season (Sivakumar, 1988). Other studies have revealed that the length of the growing season is more sensitive to the start of the rains than to the cessation (Oladipo and Kyari, 1993). Analysis of rainfall data from the more humid northern Zimbabwe indicated that the length of growing season increases with earlier start of the rains (Chiduza, 1995). A strong ($R^2 = 0.76$) relationship between start and length of the growing season has been reported in some parts of semi-arid southern Africa (Kanemasu et al., 1990).

This study was designed to assess changes in the start, end and length of the growing season using historical daily rainfall data derived from five meteorological stations located in semi-arid southern Zimbabwe. The study also assessed the patterns of wet days, 14 and 21 day dry spells during the growing season. The relationships between start, end and length of the growing season were determined.

* Corresponding author. ICRISAT, Matopos Research Station, P O Box 776, Bulawayo, Zimbabwe. Tel.: +263913930140; fax: +263838307.
E-mail addresses: w.mupangwa@cgiar.org, mupangwa@yahoo.com (W. Mupangwa), walkers.sci@ufs.ac.za (S. Walker), stephen.twomlow@unep.org (S. Twomlow).

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Table 1
Geographical description of meteorological stations and rainfall database of the five stations used in the analyses.

Station	Latitude	Longitude	Data period	Duration of data set	Agro-ecological region (NR)
Bulawayo	−20.22	28.62	1930–2001	71	IV
Matopos	−20.38	28.50	1939–2008	69	IV
Mbalabala	−20.35	28.95	1931–1994	64	IV
Filabusi	−20.55	29.28	1921–1995	74	IV
Beitbridge	−22.22	30.00	1951–2001	50	V

2. Materials and methods

2.1. Site description

Historical rainfall data were collected from five meteorological stations located in Matebeleland South province of southern Zimbabwe (Table 1) which is part of the Limpopo River Basin (Fig. 1). The Limpopo River Basin lies in southern Africa between 20 and 26°S, and 25 and 35°E (FAO, 2004). Total annual rainfall (based on the July–June calendar) varies from 584 mm at Bulawayo (Mupangwa, 2008) to less than 400 mm in the south eastern lowveld (Thuli and Beitbridge) in the Zimbabwe part of the Limpopo basin (FAO, 2004; Unganai, 1996). The rainy season stretches from October to April with the peak rainfall period occurring between December and February. In-season dry spells occur frequently during the January to February period impacting negatively on crop production in southern Zimbabwe. The average daily maximum temperatures vary from 30–34 °C during summer to 22–26 °C in winter. Minimum temperatures average 18–22 °C during summer and 5–10 °C in winter (FAO, 2004). Evaporation in the Limpopo River Basin varies from 1600 mm/year to more than 2600 mm/year and is highest during the rainfall season (FAO, 2004).

2.2. Dry and wet days

Meteorologically speaking a wet day definition of '*any day with more than 0.85 mm accumulated in 1 or 2 days*' (Love et al., 2008) might suffice. However, for crop production purposes in a region experiencing daily pan evaporation of 5–8 mm (Woltering, 2005) rainfall of 0.85 mm has very limited influence on crop growth. Stern et al. (2003) suggest that for other purposes a threshold of 4.95 mm can be used to define a wet day. For the purposes of our study in semi-arid southern Zimbabwe the following definitions were used for dry and wet days:

- Dry day: Any day that accumulates less than 5 mm of rain.
- Wet day: Any day that accumulates 5 mm of rain or more.

2.3. Start, end and length of growing season

The start, end and length of the growing season were defined as:

- Start: the first day after 1 October when the rainfall accumulated over 1 or 2 days is at least 20 mm and followed by a period of not more than 10 consecutive dry days in the following 30 days (Stern et al., 2003).
- End: the last day between 1 January and 30 June that accumulates 10 mm or more rainfall.
- Length of growing season: This was calculated by subtracting the date of the beginning from the date of ending of the growing season.

The condition of having no dry spell of more than 10 days after start of growing season eliminates the possibility of a false start of the season. A period of 30 days is the average length for the initial growth stage of most crops (Allen et al., 1998). Most crops would have emerged and be well established after 30 days. The cut off point for end of season catered for late maturing or late planted crops. After 1 June temperature normally drops quite significantly (FAO, 2004) and crop growth rate is slowed down (Evans, 1979; Sundararaj and Thulasidas, 1980). Given the above definitions Instat Statistical Programme (Version 3.33) (Stern et al., 2003) was used to analyze the daily rainfall data for start and end of season, and length of the growing season using the July to June calendar.

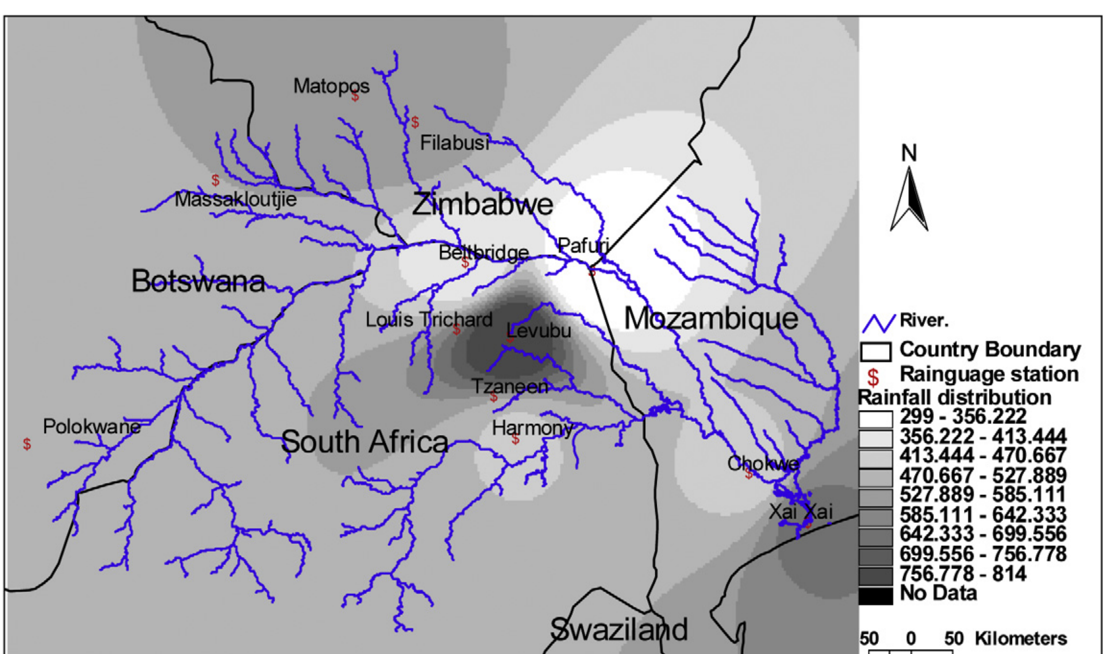

Fig. 1. The Limpopo River Basin showing the distribution of mean annual rainfall over the basin (*Source: ICRISAT GIS laboratory, 2010*).

Table 2
Median dates for the start and end of the growing season based on daily rainfall data obtained from five meteorological stations in southern Zimbabwe.

Station	Median start date	Standard deviation (days)	Median end date	Standard deviation (days)
Bulawayo	8 December	31	4 April	32
Matopos	2 December	30	29 March	31
Mbalabala	3 December	26	1 April	27
Filabusi	28 November	26	3 April	30
Beitbridge	7 December	31	25 March	29

The *F*- and *t*-tests were conducted using Genstat 9th Edition to confirm the significance of change in start and end of growing season, length of growing season and number of wet days per growing season. Regression analysis was conducted to determine the relationship between (a) start and end of growing season, (b) start and length of growing season, (c) start and number of wet days per growing season, and (d) number of wet days and length of growing season at each meteorological station. A *t*-test was applied to check whether slopes of the regressions were significantly different from zero.

2.4. Dry spell analysis

Daily rainfall data for each station were directly used to assess dry spell trends. The direct method of analyzing climate data is applicable if the data record is at least 30 years long (Stern et al., 1982). The daily rainfall data were fitted to the simple Markov chain model as outlined by Stern et al. (1982, 2003). The Markov chain model was run so that it gave the probability of getting 14 and 21 day dry spells within 30 days following a wet day using the July to June calendar. Fourteen and 21 day dry spell length were chosen because rainfall forecasts during the crop growing period (October–April) are currently being issued for seven, 14 and 21 day periods in Zimbabwe. The analyses were performed

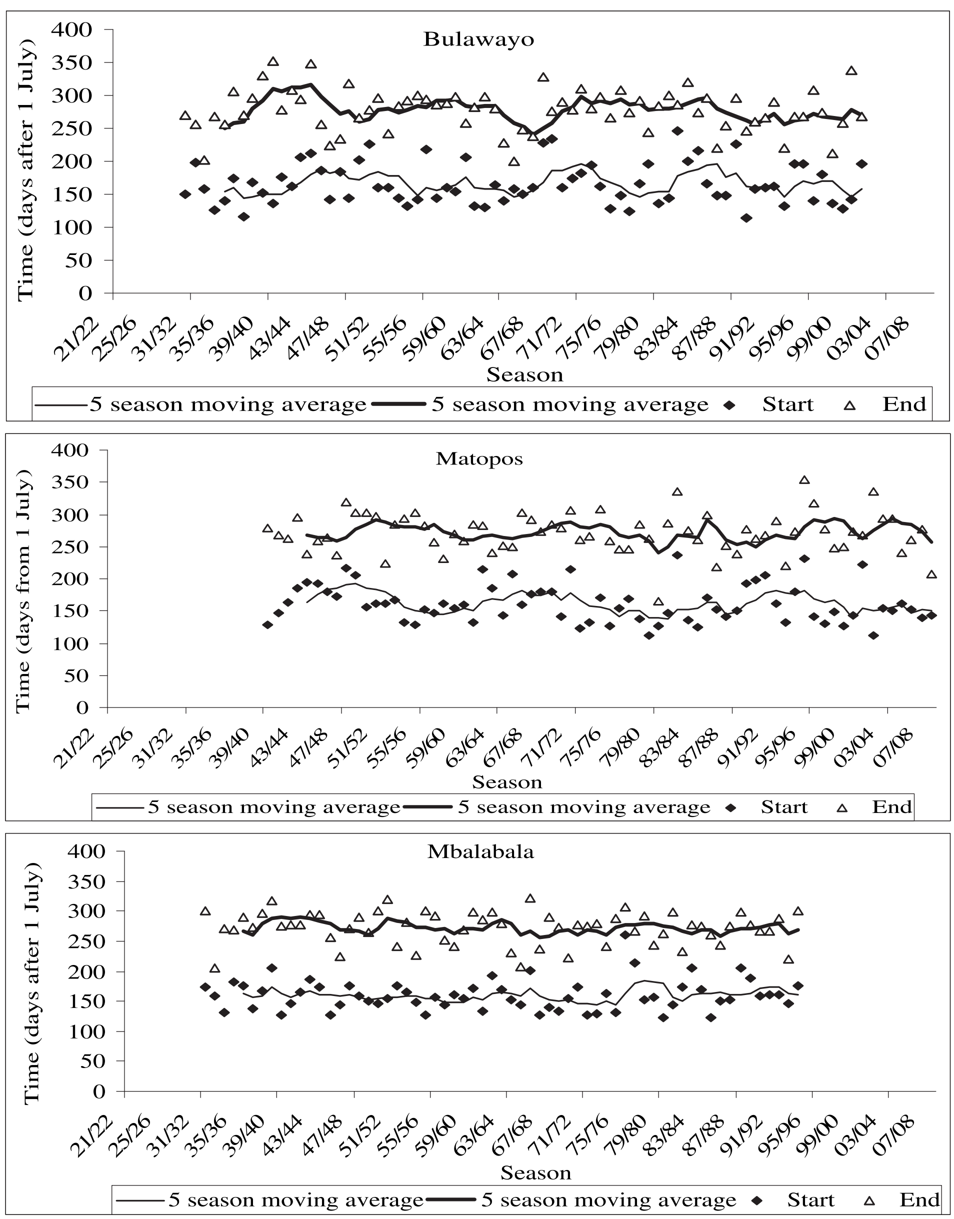

Fig. 2. Start and end of growing seasons derived from daily rainfall data for Bulawayo, Matopos and Mbalabala meteorological stations.

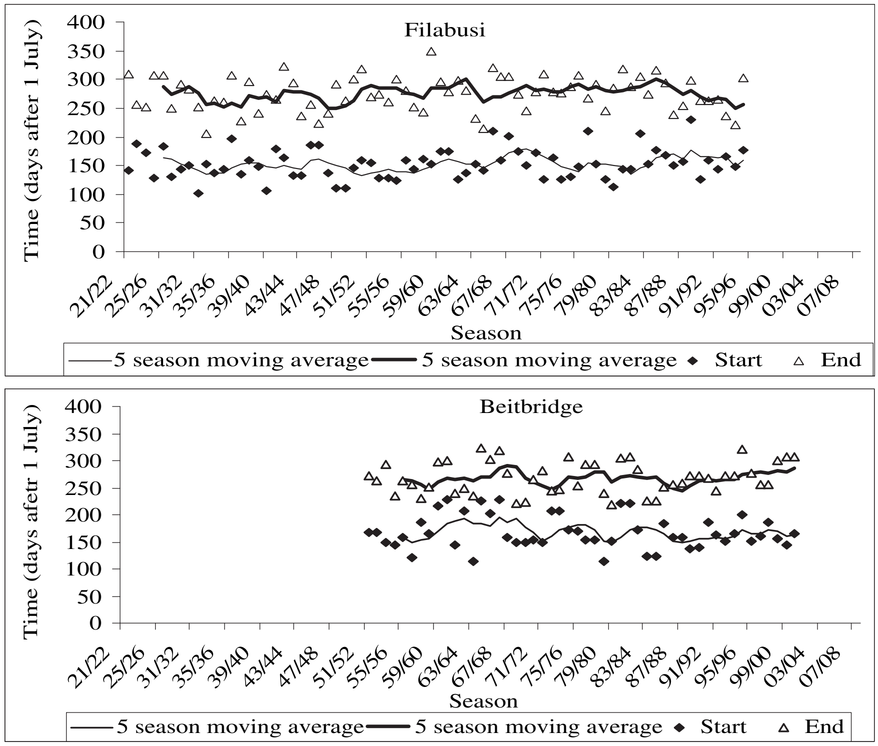

Fig. 3. Start and end of growing seasons derived from daily rainfall data for Filabusi and Beitbridge meteorological stations.

using Instat Statistical Programme (Version 3.33, http://www.reading.ac.uk/ssc/software/instat/climatic.pdf) (Stern et al., 2003).

3. Results and discussion

3.1. Start and end of growing season

No significant changes ($P > 0.05$; 95% confidence level) in the start and end of growing seasons at each station occurred across the Bulawayo (altitude = 1347 m) to Beitbridge (altitude = 462 m) transect (Table 2, Figs. 2 and 3). The variability of start and end of the growing season was similar at all stations along the Bulawayo (NR IV) to Beitbridge (NR V) transect. The growing season generally started earlier at Filabusi and ended early at Beitbridge (Table 2). The growing season started during the first week of December at all but one meteorological station along the Bulawayo to Beitbridge transect during the period reviewed (Table 2). Growing season starting as late as 18 March at Mbalabala (Table 3) can be attributed to the criteria of start of season of 20 mm of rain in one or two days used in our study. The growing season stretches for four months, ending during the last week of March and first week of April (Table 2).

The most abrupt end of season at Bulawayo was recorded in 1964/65 when the season ended on 15 January (day 200) (Table 3). At Beitbridge, which lies in the most arid part of the transect, the season ended earlier than other stations along the transect. This is consistent with results from Aviad et al. (2004) which showed that as aridity increases the season starts late and ends early. The most abrupt end of season at Beitbridge was recorded on 20 January. The most delayed end of season was in 1958/59 and occurred on 13 June. The abrupt end of the growing seasons observed in the long-term analysis agrees with observations made in semi-arid southern Zimbabwe during the 2007/08 growing season (Mupangwa, 2008). The 2007/08 growing season ended on 24 January 2008 in semi-arid districts of southern Zimbabwe. Rainwater harvesting, soil water management techniques and conservation agriculture practices would play a critical role in prolonging the period of soil water availability to crops in such seasons as 2007/08.

The length of growing season decreases as aridity increases (Aviad et al., 2004). Smallholder farmers in Beitbridge face the prospects of a shorter growing season compared to those in NR IV as it only began on 7 December and ended on 25 March giving a length of only 108 days. This is further complicated by the fact

Table 3
Dates for the earliest and most delayed start and end of the growing season along the Bulawayo to Beitbridge transect.

Station	Earliest start	Most delayed start	Earliest end	Most delayed end
Bulawayo	28 October	3 March	15 January	16 June
Matopos	21 October	23 February	13 December	1 June
Mbalabala	30 October	18 March	21 January	16 May
Filabusi	10 October	14 February	20 January	13 June
Beitbridge	10 October	14 February	20 January	13 June

Table 4
Length of season and number of wet days per season in semi-arid southern Zimbabwe.

Station	[a]LGS (days)	Standard deviation (days)	Number of wet days	Standard deviation (days)
Beitbridge	100	30	12	6.3
Bulawayo	111	41	21	9.6
Filabusi	122	36	22	8.7
Matopos	110	37	22	9.3
Mbalabala	112	31	24	9.6

[a] LGS = length of growing season.

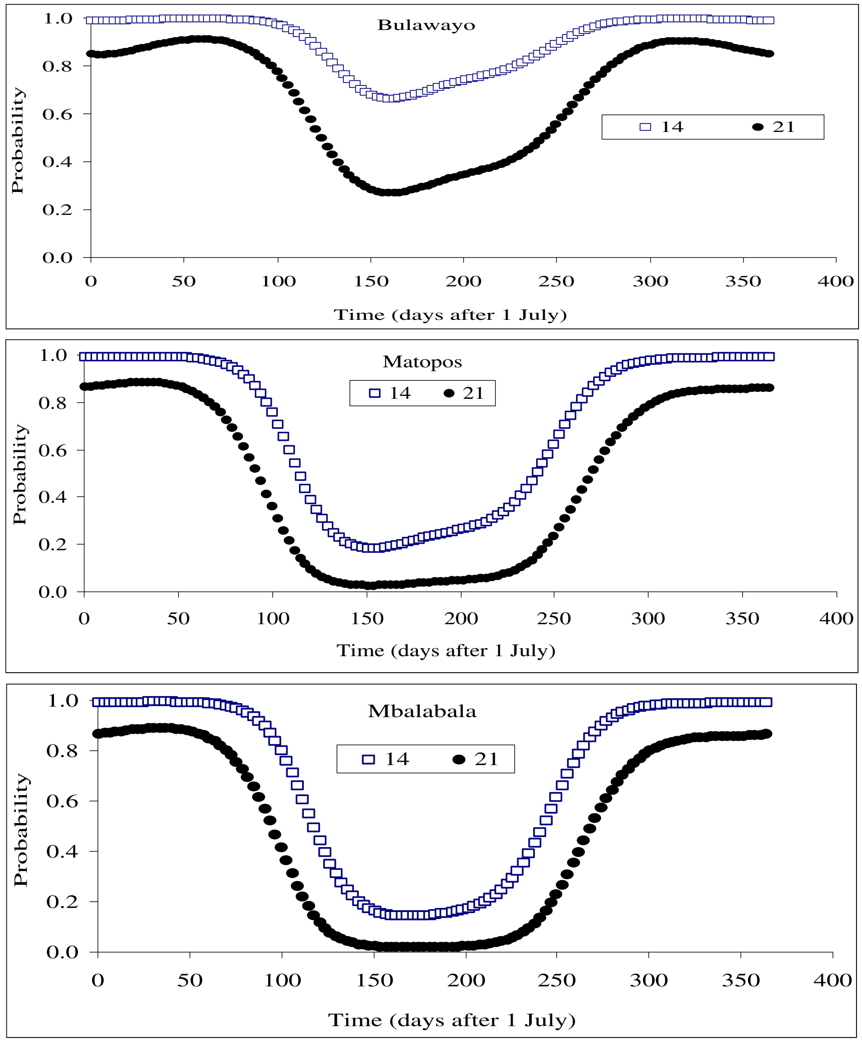

Fig. 4. Probability of getting 14 and 21 day spells within 30 days from a wet day based on the fitted first order Markov chain probability values for Bulawayo and Matopos meteorological stations in southern Zimbabwe.

that start of growing season in Beitbridge is also more variable than its end (Table 2). Farming practices that allow timely preparation of the land and planting are more critical in the Beitbridge area so that farmers can make effective use of rainfall received during the November to December period.

The lack of significant long-term changes suggests that the characteristics of the growing season are influenced by other factors such as rainfall distribution (Twomlow et al., 2006) in addition to total rainfall and date of start of the rains. In Zimbabwe, years that recorded the highest rainfall do not correspond with years having the highest crop yields (Oosterhout van, 1996). Distribution and reliability of rainfall during the growing season have a stronger influence on the characteristics of the growing period than total rainfall (Dennett, 1987; Adiku *et al.*, 1997). In semi-arid areas of Zimbabwe, as in other parts of sub-Saharan Africa, high spatial and temporal rainfall variability during the growing season increases the risk of mid-season dry spells. Long-term simulation results (Mupangwa, 2008) indicated that there is more than a 20% probability of getting no yield in the conventional and conservation agriculture systems under semi-arid conditions of southern Zimbabwe. Therefore, other indices that can represent rainfall distribution and variability need to be developed.

3.2. Length of season and number of wet days per season

The length of growing season decreased along the Bulawayo to Beitbridge transect (Table 4). For the period reviewed at each station, the growing season averaged 111 days at Bulawayo, 110 days at Matopos, 112 days at Mbalabala, 122 days at Filabusi and 100 days at Beitbridge. Based on these results sorghum varieties such as SV 2, SV 4 and Macia which require 110–127 days to maturity (Mgonja *et al.*, 2005) can be successfully grown around the Bulawayo, Matopos, Mbalabala and Filabusi stations. Pearl millet varieties such as PMV 2 and PMV 3 which require 80–90 days to reach maturity (Monyo, 2002) can be grown along the Bulawayo to Beitbridge transect. The prospect of having a crop reach maturity gives smallholder farmers in southern Zimbabwe an incentive to plant early.

Results from our study showed an average length of the growing season of 111 days across the five stations. The 111 days length of growing season is much higher than 96 days reported by Morse (1996) for Zimbabwe's NRs II, IV and V. The differences in length of growing season could be ascribed to differences in the criteria used in defining the start and end of growing season. Tadross et al. (2007) reported that a growing season of 90–120 days can be experienced in southern African countries such as Malawi and

Zambia. The above analysis confirms that there is no general rule of thumb that the season length is related to the amount of rainfall received but can have a relationship with the number of wet days or effective rainfall events. So if this southern part of Zimbabwe has an average season length of only 111 days, agronomists need to use this information in selecting suitable cultivars for smallholder farmers. The ultra short cultivars could be an option and this will help farmers to be able to plant early and produce a crop with less exposure to dry spells. The longest growing season of 162 days recorded at Beitbridge (NR V) in the 1999/00 season coincided with highest rainfall of 1177 mm as the cyclone Eline swept over the African landmass causing severe flooding.

There was a negligible difference in the number of wet days per season as one moves from Bulawayo to Filabusi station through Matopos and Mbalabala (Table 4). All four stations are located in NR IV. Our findings are inconsistent with results reported by Hudson and Jones (2002) who stated that there has been a general decrease in the number of wet days per year in southern Africa. Hudson and Jones (2002) defined a wet day as a day receiving more than 0.2 mm of rain whereas in our study we defined a day with 5 mm or more rainfall as wet based on results from Woltering (2005). A rainfall event of 5 mm or more meets the daily evaporative demand of the atmosphere based on results from south western Zimbabwe (Woltering, 2005). In addition, our study focussed on number of wet days per growing season and not the whole year. As expected Beitbridge which lies in NR V, had the least ($P = 0.01$) number of wet days per growing season.

At Bulawayo and Matopos the driest decade (1980–1990) had the lowest number of wet days per season. The 1981/82 growing season was recorded as the driest in other southern African countries and could have been associated with the El Nino-Southern Oscillation (ENSO) phenomenon (Phillips et al., 1998; Cook *et al.*, 2004). At Bulawayo and Matopos the return period of seasons with high rainfall is 18–22 years, a trend which is consistent with results from South Africa and other countries in southern Africa (Tyson *et al.*, 1975). The 1961–1978 period had the least number of wet days per season at Mbalabala which coincides with the period of lowest annual rainfall. Return period for high number of wet days per season was 21–26 years at Mbalabala and Filabusi. Further south, Beitbridge appears to receive relatively wet growing seasons after more than 20 years although the record is only 50 years long.

3.3. Dry spells during the growing season

The peak rainfall period during the growing season occurs between December and February in southern Zimbabwe. The probability of getting 14 and 21 day dry spells during any time of the year is given in Figs. 4 and 5. Based on the data set reviewed, Filabusi had the highest probability of getting 14 and 21 day dry spells compared to the other four stations during the peak rainfall period (Fig. 5) suggesting that rainfed crop production is more risk at Filabusi. The probability of getting a 14 or 21 day dry spell decreased as one move from Bulawayo to Mbalabala through Matopos. Mbalabala experienced slightly more rainy days per growing season than the other four stations (Table 4). There is a 27–40% probability of experiencing a 21 day dry spell at Bulawayo between 10 November (day 133) and 8 February (day 223). During the same period there is a 66–79% probability of getting a 14 day dry spell at Bulawayo. At Matopos there is a 18–33% probability of a 14 day dry spell occurring between 10 November and 8 February. During the same period 21 day dry spells have a 3–7% probability of occurring at Matopos. Beitbridge has up to 30% probability of experiencing a 21 day dry spell between mid-November and the first week of February.

The decrease in probability of getting 14 and 21 day dry spells coincides with the peak rainfall period. The peak rainfall period occurs from December to February (Unganai, 1996). Rainfall is more reliable at Matopos and Mbalabala during the December to February peak rainfall period (Figs. 4 and 5). At Beitbridge there is a rapid increase in probability for experiencing 14 and 21 day dry spells after receiving rain. This implies that the probability of reduced crop yields or complete crop failure due to soil water

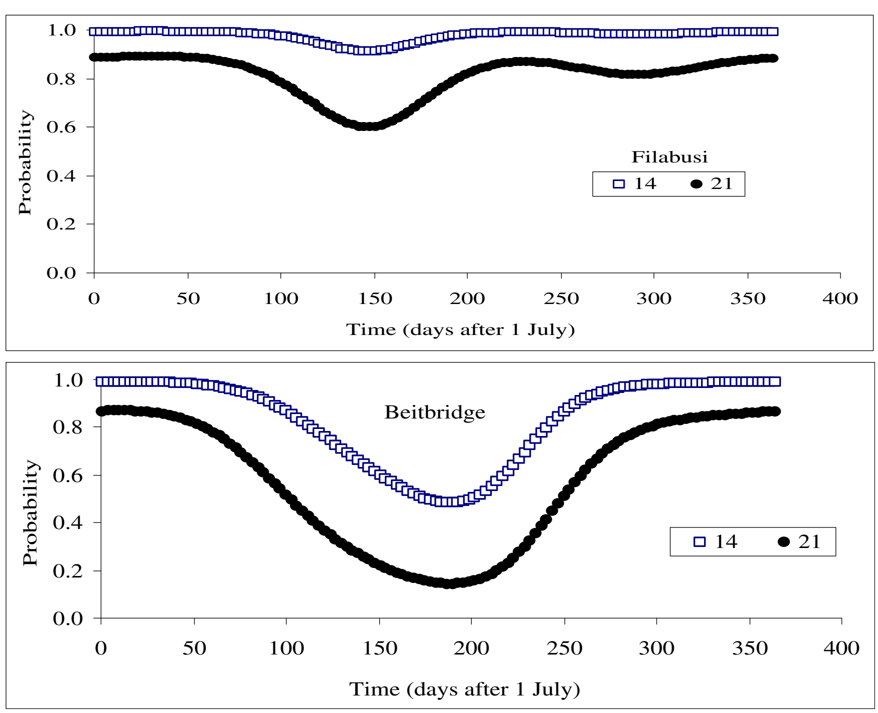

Fig. 5. Probability of getting 14 and 21 day spells within 30 days from a wet day based on the fitted first order Markov chain probability values Mbalabala, Filabusi and Beitbridge stations in southern Zimbabwe.

deficits is also high at Beitbridge. The probability of experiencing dry spells also increases at Bulawayo, Matopos, and Mbalabala after the first week of February. This coincides with the flowering and grain filling stages of most cereals grown in semi-arid smallholder systems. This poses a major challenge in soil water management in rainfed cropping systems of southern Zimbabwe and the Limpopo Basin.

3.4. Relationships of growing season characteristics

A stronger relationship between start and end of growing season existed at Beitbridge ($R^2 = 0.23$) compared to the other four stations (Table 5). The gradient of start and end of growing season relationship was steepest at Beitbridge station implying that delayed start of season is likely followed by early cessation of the growing season. It is therefore more critical that smallholder farmers in Beitbridge access seasonal weather forecast information in order to plan their farming operations than other parts of the transect reviewed. The relationship between the start and length of the growing season was stronger at all five stations compared to the other seasonal characteristics reviewed in this study (Table 4). The strength of the linear relationship decreased as one moves from Bulawayo (NR IV) to Beitbridge (NR V) indicating more uncertainty in the length of the growing season in NR V compared to NR IV.

Regression analysis revealed a significant ($P < 0.001$) inverse relationship between the start and the number of wet days in a growing season (Table 5). A delayed start of the growing season is likely to be accompanied by a reduction in the number of wet days in a growing season implying a high risk of soil water deficits in the smallholder cropping systems during the growing season. There was a significant ($P < 0.05$) linear relationship between the number of wet days and the length of the growing season at four of the five stations under this dry environment. The linear relationship suggests that more wet days could translate into a longer growing season. It is critical for smallholder farmers in rainfed cropping systems to grow recommended crop types and varieties, address soil fertility constraints and ensure good management in order to exploit favorable soil water conditions during such long and wet growing seasons.

Table 5
Relationships of the different characteristics of the growing season in semi-arid southern Zimbabwe.

Station	Relationship	Regression equation	R^2 value
Bulawayo	Start and end	$Y = 251 + 0.16x$	0.024
	Start and length of growing season	$Y = 251 - 0.84x$	0.40
	Start and number of wet days per-season	$Y = 53 - 0.19x$	0.38
	Number of wet days and length of growing season	$Y = 48.9 + 2.9x$	0.46
Matopos	Start and end	$Y = 223 + 0.30x$	0.07
	Start and length of growing season	$Y = 223 - 0.70x$	0.31
	Start and number of wet days per-season	$Y = 47.9 - 0.16x$	0.25
	Number of wet days and length of growing season	$Y = 57.9 + 2.4x$	0.35
Mbalabala	Start and end	$Y = 217 + 0.35x$	0.09
	Start and length of growing season	$Y = 217 - 0.65x$	0.29
	Start and number of wet days per-season	$Y = 48.2 - 0.15x$	0.16
	Number of wet days and length of growing season	$Y = 65.3 + 1.9x$	0.36
Filabusi	Start and end	$Y = 244 + 0.21x$	0.02
	Start and length of growing season	$Y = 244 - 0.80x$	0.33
	Start and number of wet days per-season	$Y = 43.0 - 0.14x$	0.16
	Number of wet days and length of growing season	$Y = 79.4 + 1.9x$	0.22
Beitbridge	Start and end	$Y = 190 + 0.47x$	0.23
	Start and length of growing season	$Y = 190 - 0.53x$	0.27
	Start and number of wet days per-season	$Y = 26.6 - 0.09x$	0.16
	Number of wet days and length of growing season	$Y = 66.6 + 2.85x$	0.34

4. Conclusion and recommendations

Analysis of the characteristics of the growing season demonstrated that there have been no significant changes in the start, end and length of growing season along the Bulawayo to Beitbridge transect in southern Zimbabwe. Despite the lack of significant changes in the characteristics of the growing season, delayed start, early cessation and subsequent short growing seasons have been experienced during some years over the 50–75 year period reviewed. The growing season ends much earlier in Beitbridge (NR V) which is more arid compared to the stations in NR IV. This places strain on smallholder farmers in Matebeleland South province and therefore it is imperative to prepare land and plant on time if the recommended crop species and varieties are to reach maturity. There is a high probability of getting 14 and 21 day dry spells during the peak rainfall period (December–February), further increasing the probability of significant crop yield reduction and crop failure. There is scope in exploring rainwater harvesting technologies and conservation agriculture practices in order to prolong the period of soil water availability in rainfed smallholder cropping systems. Despite the lack of significant changes in the start, end and length of the growing season there is need to establish crop planting windows for major crops grown in the semi-arid areas of Zimbabwe.

Regression analysis indicated that as aridity increased from Bulawayo to Beitbridge, the strength of the relationship between start and end of growing season also increased. This suggests that delayed start of growing season at Beitbridge is followed by early cessation of the rains. Similarly, early start could be translated into a longer growing season. Smallholder farmers in southern Zimbabwe would need this information for deciding on crop types and varieties, and dates for land preparation and planting windows. The inverse relationship between start of season and number of wet days per growing season coupled with the high probability of dry spells during the peak rainfall period suggest the possibility of soil water deficits during the season. This further confirms the need to invest in rain and soil water management technologies in the smallholder cropping systems of semi-arid parts of southern Africa.

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