ENSO and implications on rainfall characteristics with reference to maize production in the Free State Province of South Africa

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Abstract

El Niño-Southern Oscillation (ENSO) plays an important role in the interannual variability of rainfall in most parts of southern Africa. The effects of ENSO on the rainy season characteristics and possible impacts on rainfed maize production were investigated. The rainy season characteristics of concern are the onset of rains, cessation of rains, duration of rainy season and seasonal rainfall total. 309 climate stations over the Free State Province with rainfall data from 1950 to 2008 were analysed. The rainy season indices were further subdivided into El Niño and La Niña years. The differences in averages of the rainy season indices were determined for the negative phase of ENSO versus the overall averages and for the positive phase of ENSO versus the overall averages. The results of the onset of rains show no clear pattern in the Free State with some areas experiencing late onset and others early onset in both El Niño and La Niña years. However, the cessation of rains occurs early during the El Niño and late in La Niña years over most parts of the province. Consequently, the duration of the rainy season is shorter than normal in El Niño years and longer than normal in La Niña years. Seasonal rainfall is also lower than normal in El Niño years while in La Niña years more cumulative rainfall in mostly observed. As a result, maize production is favoured in La Niña years and reduction in production is normally observed during El Niño years.

Keywords: Cessation of rain; duration of rainy season; ENSO; maize production; onset of rain; seasonal rainfall.

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1. Introduction

Weather and climate variability is the major factor affecting inter-annual variability of crop production and yield in all environments and thus climate information has to be considered in agricultural planning activities and decision making (Sreenivas et al., 2008; Das and Stigter, 2010). In most semi-arid conditions in southern Africa, rainfall is among the most important elements affecting agriculture as soil water availability is one of the limiting resources for crop growth and development (Mukhala, 1998). This limiting factor over the Free State Province is mostly caused by unreliable seasonal rainfall, and high variability of onset of rains and cessation of rains (Fauchereau et al., 2003; Usman and Reason, 2004; Reason et al., 2005; Hachigonta et al., 2008; Moeletsi, 2010). Onset of rains marks the beginning of the agricultural season in most places in South Africa especially when occurring after the last frost date. The timing of the occurrence of onset of rains can have an impact on agricultural productivity with late onsets resulting in decreased yields (Camberlin and Okoola, 2003). Planting after early onset of rains can improve agricultural productivity potential due to a longer growing period, but care has to be taken when planting maize earlier than November in most areas in the Free State because of high chances of false onsets (Sivakumar, 1990; Moeletsi, 2010). Cessation of rains is the other important rainy season index of importance to agriculture. Early cessation may result in short growing period affecting long season crop varieties while late cessation favours crop production in most places. Seasonal rainfall is mostly used to judge the performance of agricultural season in relation to water supply to crops (Odenkole, 2006). According to du Plessis (2003), maize seasonal water requirements in South Africa range from 450mm to 600mm depending on the environment.

Climate variability attributed to changes in weather and climate events like El Niño and La Niña cannot be avoided; but through research on how different climate modes of variability affect crop production, the negative impacts of climate variability should be able to be minimized. El Niño-Southern Oscillation (ENSO) phases play an important role in the climate variability of most southern African regions and better understanding of the teleconnections between the ocean and atmospheric conditions is of great importance (Reason and Mulenga, 1999; Ropeleskwi, 1999; Tyson and Preston-Whyte, 2000; Mason, 2001; Nicholson et al., 2001). The widely used indices for monitoring El Niño or La Niña events are the sea-surface temperatures (SSTs) anomalies in the eastern tropical Pacific and Southern Oscillation Index (SOI) (Richard et al., 2000; Nicholson et al., 2001; Nash and Endfield, 2008). During El Niño, the SSTs over the equatorial Pacific ocean are anomalously high and the SOI value is negative while during La Niña the SSTs over the equatorial Pacific are anomalously low and the SOI value is positive (Vogel and Drummond, 1993; Zebiak, 1999).

Agriculture in the Free State is mostly rainfed with less than 10% of the arable land being under irrigation. The main rainy season in the Free State starts in September/October and ends in April/May (Moeletsi, 2010). Due to high variability of inter-annual and intra-seasonal rainfall over most parts of southern Africa agricultural productivity is affected (Richard et al., 2000; Tyson and Preston-Whyte, 2000). Free State Province produces over 30% of the maize in South Africa however the average maize yield over the province varies a lot from one year (DAFF, 2010). According to de Jager et al. (1998), rainfall variability is the major factor causing fluctuations in Free State maize production. The other factors affecting maize over the Free State are early cessation of frost, late onset of frost, hail especially in November to January (Moeletsi, 2010). El Niño-Southern Oscillation (ENSO) is related to rainfall in most parts of the southern Africa region with the negative phase being attributed to drought conditions and positive phase being associated with above normal rainfall amounts (Nicholson et al., 2001; Rouault and Richard, 2003; Tsubo and Walker, 2007; Tyson and Preston-Whyte, 2000). Thus, in El Niño years the rainfall season is less favourable for crop production with serious water deficit during the maize growing period, whilst in contrast, La Niña years are characterised by enhanced rainfall events mostly associated with better yields in most semi-arid areas in southern Africa (Landman and Mason, 1999; Nicholson and Selato, 2000; Landman et al., 2001; Fauchereau et al., 2003; Rouault and Richard, 2003; Tsubo and Walker, 2007; Moeletsi, 2010).

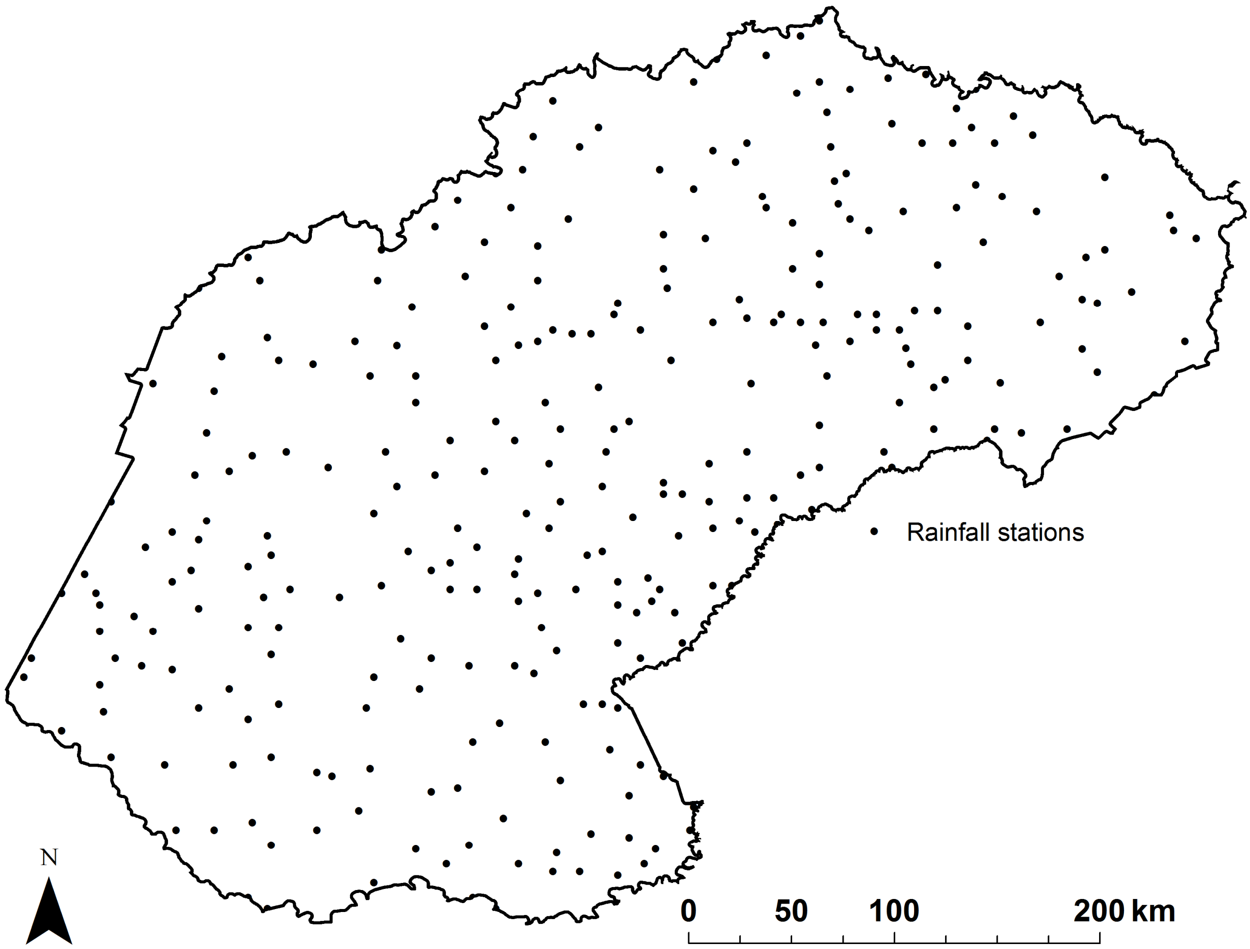
In this study, the effects of El Niño and La Niña phenomena on the rainy season characteristics (onset of rains, cessation of rains, duration of rainy season and seasonal rainfall total) were evaluated to determine risk associated with climate variability on rainfed maize production.

2. Materials and methods

2.1 Study area

This study was conducted in the Free State province of South Africa. The province is situated between the latitudes 26.6 degrees South and 30.7 degrees South of the equator and between the longitudes 24.3 degrees East and 29.8 degrees East of the Greenwich meridian (Fig. 1). It is the country's third-largest province making 10.6% of South Africa's land with an area of around 129 825 square kilometres (Davis et al., 2006). The climate of the province is mostly semi-arid except the eastern and northeastern parts where humid-subtropical climate is experienced according to the Köppen climate classification. Average annual rainfall ranges from 300 mm to over 900 mm with more than 70% of the rainfall occurring in September/October to April/May (Moeletsi, 2010). During these months the rain producing systems like tropical-temperate troughs causing cloud bands that extend southward from the tropics are frequent (Washington and Todd, 1999; Tyson and Preston-Whyte, 2000; Hachigonta et. al., 2008).The other important atmospheric circulation types significantly causing rainfall to southern Africa are the low-level easterly waves, frontal systems and cut-off lows (Tyson and Preston-Whyte, 2000). The topography of the province is diverse with altitudes of <1200 m in the southern and western parts and >1800 m in the eastern Free State.

Fig. 1. Distribution of rainfall stations used in the analysis of rainy season characteristics over the Free State Province showing 5 districts.



2.2 Data

Rainfall data used in this study was obtained from the Agricultural Research Council-Institute for Soil, Climate and Water (ARC-ISCW) and South African Weather Service (SAWS). Rainfall stations with 30 or more years of continuous dataset with over 90% data efficiency (i.e. less than 10% missing daily values) were selected for the analyses. However where the spatial network of stations was sparse stations with 20 or more years of data were used as complementary stations to aid in obtaining better interpolated surfaces. Overall 84% of the stations had more than 30 years of rainfall data while 16% of the stations used in the analysis had between 20 to 30 years of continuous rainfall data. Daily rainfall data was used in all the analyses of the rainfall season characteristics of the Free State Province. The analyses started in 1950 and used data up to and including 2008. The study utilises 309 observation stations data from 1950 to 2008, figure 1. All the missing values at the selected stations were estimated by using the Inverse Distance Weighting methodology outlined in equation 1 (Longley et al., 2001). The methodology uses up to 5 weather stations within the radius of 50km. For the analysis, the data was arranged in years starting from July to the following June to make the summer rainfall season fall in one continuous dataset.

$$y_t = \frac{\sum_{i=1}^{m} x_t^i / D_i^2}{\sum_{i=1}^{m} 1 / D_i^2} \qquad (1)$$

Where y_t is the estimated value of the missing data, x_t^i is the value of the i^{th} nearest weather station, m ranges from 2 to 5 and D_i is the distance between the target station and the i^{th} nearest weather station.

2.3 Methodology

Mapping of all the rainy season indices were done using the inverse distance weighting interpolation model imbedded in the spatial analyst tool of the ArcGIS 9.3 software.

2.3.1. Determination of rainy season characteristics

In this study the onset of rains is defined as the last day starting from July each year in which rainfall of 25mm or above has been accumulated over the previous ten days and also at least 20mm has to be accumulated in the subsequent 20 days (Reason et al., 2005; Tadross et al., 2005). This is the criterion commonly used to determine the beginning of the rainy season is most semi-arid areas in southern Africa for rainfed maize production (SADC-RRSU, 2004; FEWSNET, 2009). The additional 20mm of cumulative rainfall over the next two dekads ensures that there is enough moisture not only for germination but also to sustain maize crop through the early development stage. The onset of rain was determined for all the agricultural years at all 309 stations. The end of the rainy season is obtained by searching for the last day starting from December each year on which the cumulative 25mm over ten days occurs. The length of the rainy season is calculated by subtracting the starting date of the rain in Julian days from 365 (366 for leap years) and adding the number of Julian days for the end of the rains if the start of the season is before 31 December. If the start of rain/season is in January onwards, the rainy season length is obtained by subtracting the start date of rains (Julian days) from the end date of rains (Julian days). Seasonal rainfall for the agricultural season was obtained by summing daily rainfall from 1 September to 31 May for each of the stations for all the years.

2.3.2. Determination of the effects of El Niño and La Niña

To determine the association of rainy season characteristics with ENSO episodes, the dates for the onset, cessation, duration of the rainy season and seasonal rainfall were divided into two groups according to the El Niño and La Niña years using the SOI whereby negative values (average monthly SOI from June to November of less than -4) denote El Niño and positive values (average monthly SOI from June to November exceeding 4) denote La Niña year (Table 1) (NOAA, 2010). The average onset, cessation, rainy season length and seasonal rainfall were determined for each of the stations for the El Niño years, La Niña years and all the years. The overall mean of onset date, cessation date, duration of rainy season and seasonal rainfall was compared with mean values during the El Niño and La Niña years. The differences between the average of the rainy season index obtained from all the years and index during El Niño or La Niña years were obtained. Negative anomalies show earlier than normal onsets and cessation dates while positive anomalies show later than normal onsets and cessation dates.

Table 1

El Niño and La Niña years from 1950 to 2008.

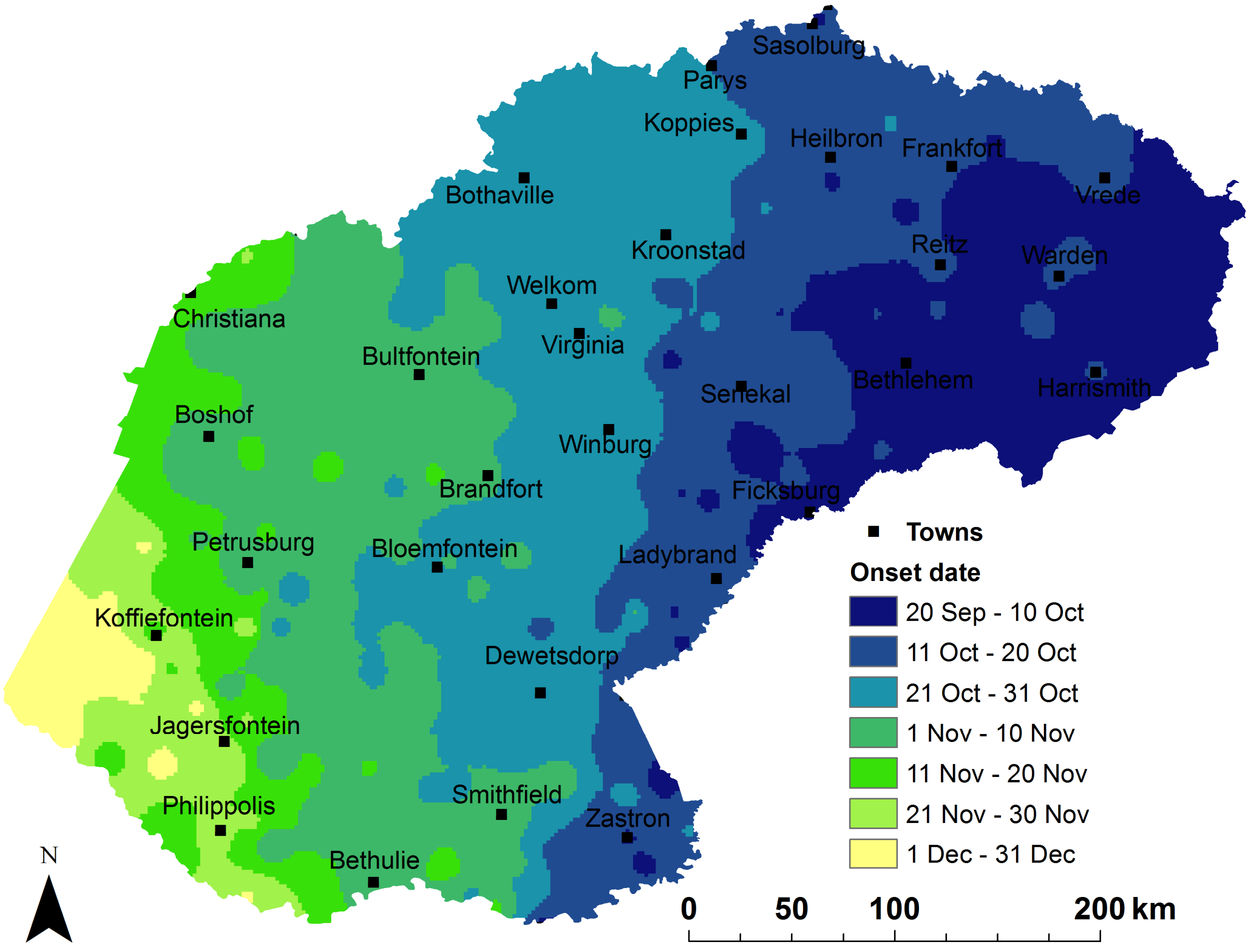
El Niño years	La Niña years
1951/52; 1953/54; 1957/58; 1963/64;	1950/51; 1954/55; 1955/56; 1956/57;
1965/66; 1969/70; 1972/73; 1976/77;	1962/63; 1964/65; 1970/71; 1971/72;
1977/78; 1982/83; 1986/87; 1987/88	1973/74; 1974/75; 1975/76; 1981/82
1991/92; 1992/93; 1993/94; 1994/95;	1984/85; 1988/89; 1996/97; 1998/99;
1997/98; 2002/03; 2004/05; 2006/07	1999/00; 2000/01; 2007/08 2008/09

3. Results and discussion

3.1. Onset of rainy season

As shown in Figure 2, average dates for the onset of rain are early over the eastern parts of the province and relatively late over the western and southern parts. The earliest onsets occurring between 20 September and 10 October are evident in the vicinity of Bethlehem, Frankfort, Ficksburg, Harrismith, Warden and Vrede in the northeast and eastern Free State Province (Fig. 2). The timing of onset of rain in these areas facilitates earlier soil preparation and planting of maize crop. Early onset at these places can be attributed to occurrence of cut-off lows or westerly waves or early development of northwest cloud bands extending from the tropics to interior of South Africa (Washington and Todd, 1999; Tyson and Preston-Whyte, 2000; Hachigonta et. al., 2008) but it has to be noted that, the circulation patterns affecting rainy season characteristics are beyond the scope of this paper. Most parts of the central, northern and southern Free State mean onset of rain dates occurs between 11 October and 10 November. Areas west of Koffiefontein in the far western parts records latest mean onset of rain occurring in December.

Fig. 2. Average onset dates of rainy season over the Free State Province.



The difference in mean onset of rainfall dates in El Niño years compared with the overall mean onset of rainfall show a lot variation over the Free State Province (Fig. 3). Some areas experience earlier than normal onset (anomalies less than -4 days), other place show that onset of rains in El Niño years are later than normal (anomalies of greater than 5 days) and there is also a greater area of near normal dates (anomalies between -4 and 5 days). Notable area where onset dates are earlier than normal is over the vicinities of Bethulie, Jagersfontein and Smithfield over the southern and southeastern parts. There are also sporadic cases of earlier onsets around Boshof, Bothaville, Ladybrand, and Winburg. Early onsets can elongate the growing period and thus benefiting the maize crop provided the rainy season ends at normal or later than normal dates. Later than normal onset dates are mostly over the vicinities of Frankfort, Reitz and Sasolburg over the northern and northestern parts. There are also patches of later onset of rains around Bultfontein, west of Dewetsdorp and Koffiefontein. The late onset of rains can highly cause short growing season in cases of early end or normal end of the rainy season. The results clearly show no consistency over the whole Free State and are comparable to the findings by Reason et al. (2005) in Limpopo which shows that in certain El Niño years onset of rain is earlier while in other El Niño years the onset is very late. By contrast, Tadross et al. (2009) find out that in El Niño years onset of rains are earlier than normal (but consistent rains are late) over the southeastern Africa, while in contrast, Tadross et al. (2005) associated El Niño years with later onset in southern Zimbabwe.

Fig. 3. The difference between mean onset date in El Niño years and overall mean onset date over the Free State Province.

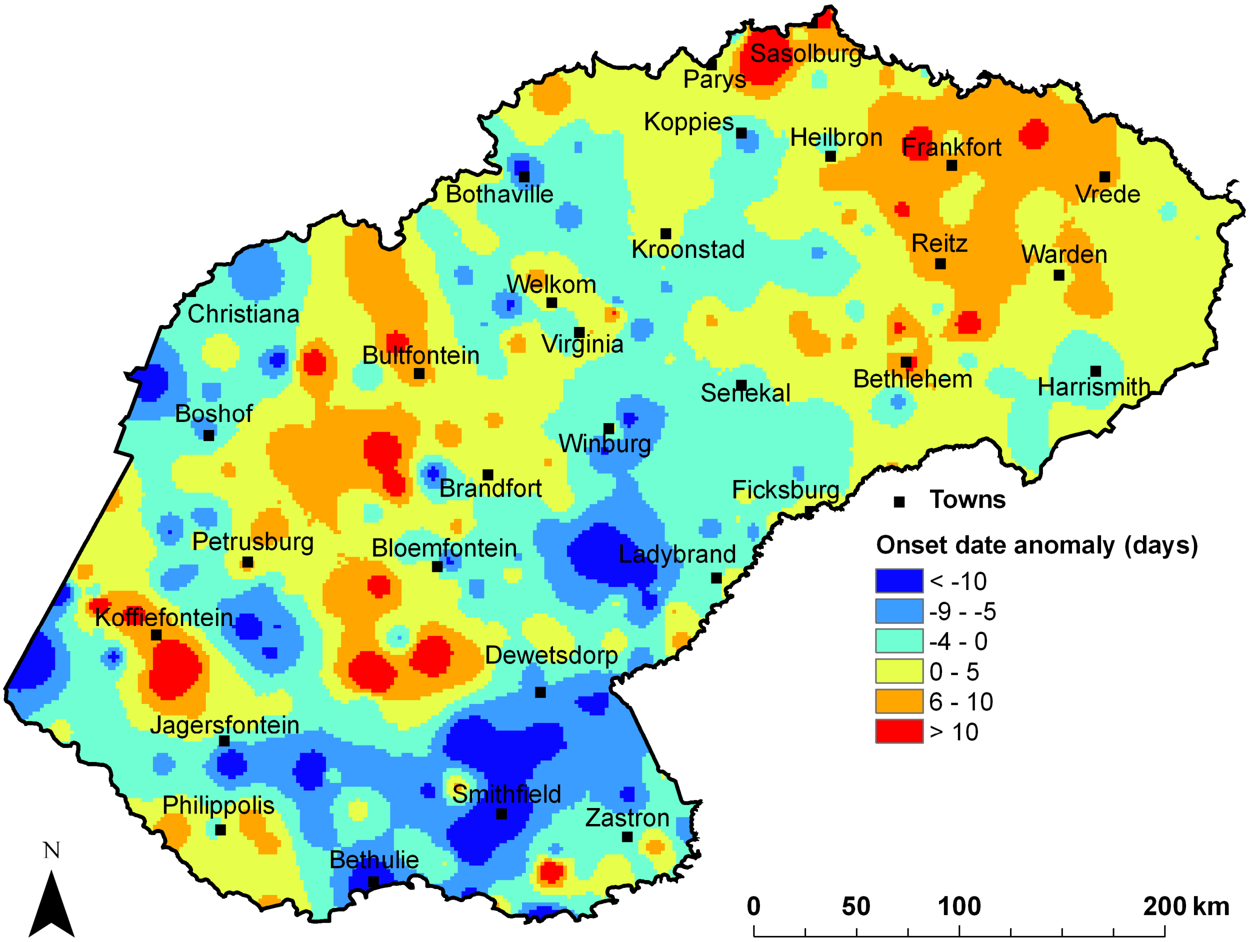
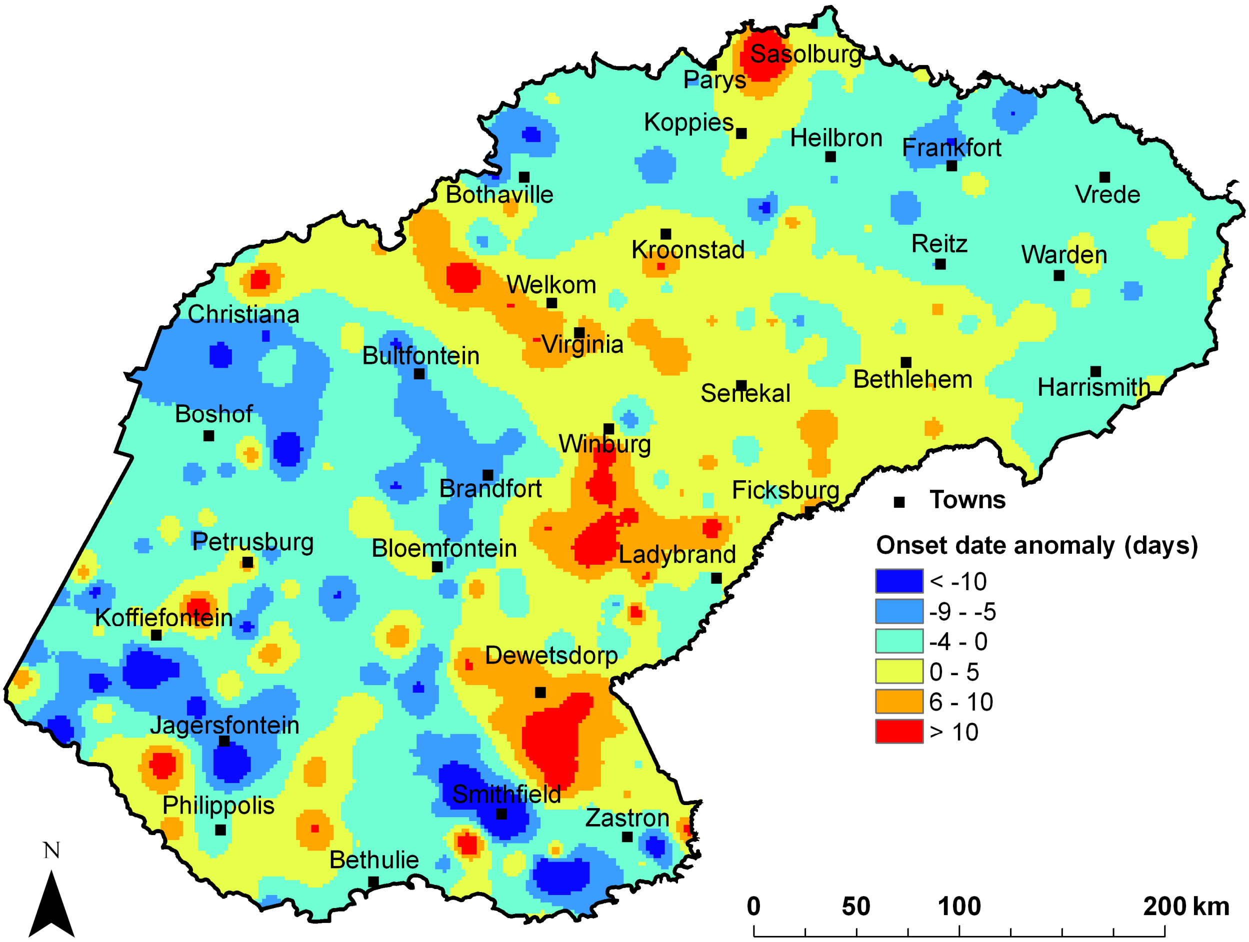


Figure 4 shows that in La Niña years, onset of rain does not follow any pattern just like the results obtained in El Niño years with some places having earlier than normal while other regions experience near normal to later than normal onsets. Most parts of the northern, eastern and central Free State have their mean onset of rain date in La Niña years more or less at the same time as the long-term mean onset date. The deviation from the longterm mean dates ranges from -4 to 5 days at these regions. Later than average/normal onset date of rain is evident at pockets all over the province. Earlier than normal onset in La Niña years occurs dominantly over the sourthern, southwestern and western Free State with some places having negative anomalies exceeding 10 days. Very early onset of rain can have a negative impact on maize production because it mostly results in shortened rainy season period. These results are more or less similar to the findings by Reason et al. (2005) which shows inconsistent arrival of rain in La Niña years while in contrast, studies by Tadross et al. (2009) shows later onset of rain.

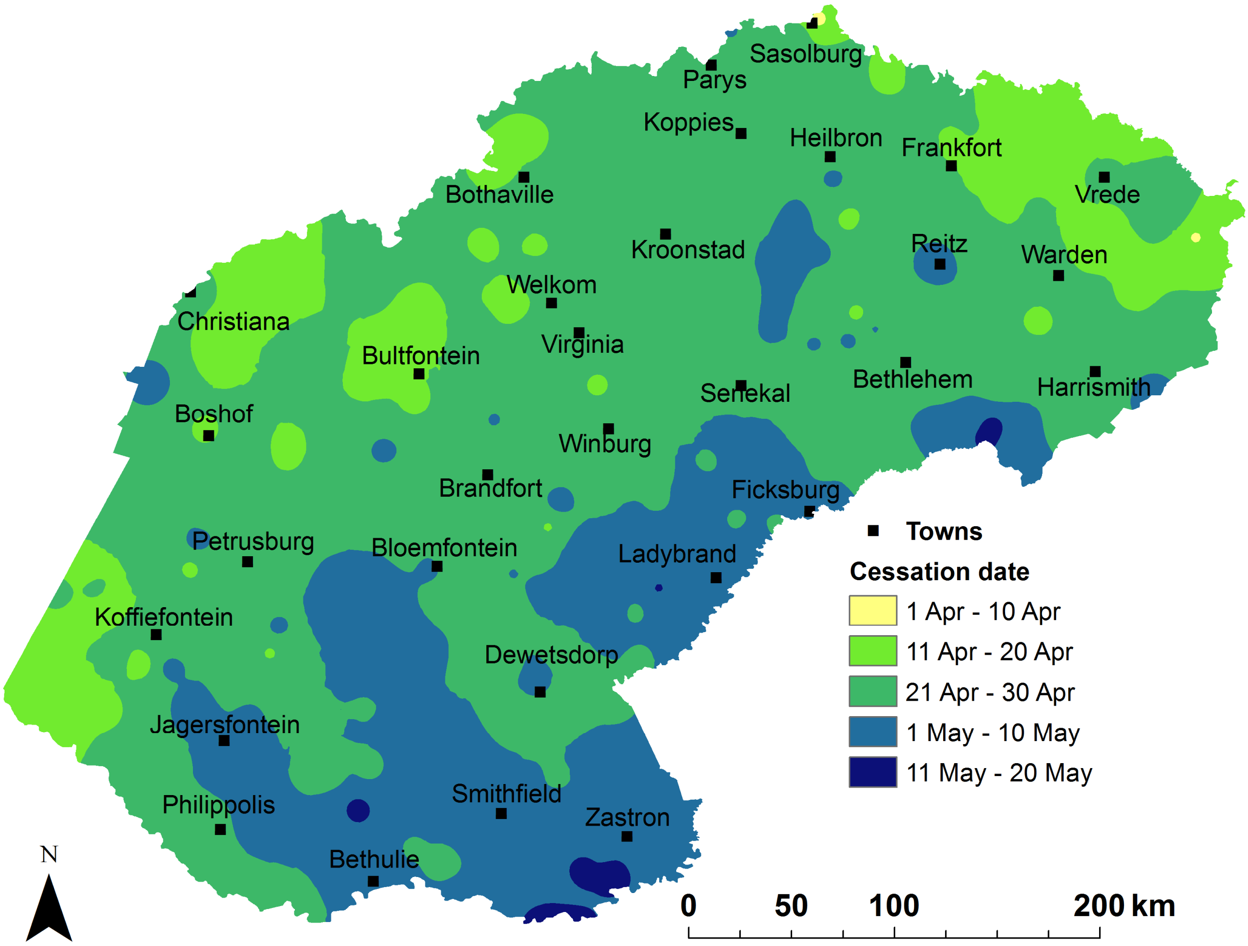
Fig. 4. The difference between mean onset date in La Niña years and overall mean onset date over the Free State Province.



3.2. Cessation of rainy season

Most parts of the Free State Province have their mean/average dates for the cessation of rain between 21 April and 30 April (Fig. 5). Over most of the southern parts of the province, mean dates for the cessation of rain occurs in May. Patches over the eastern Free State also show relatively later cessation dates as compared to other places. Late cessation of rains is attributed to the passage of frontal systems which prevails during transition periods at these places. There are places over the northeastern and western parts where mean cessation of rain occur from 11^{th} to 20^{th} April.

Fig. 5. Average cessation dates of the rainy season over the Free State Province.



The difference in mean cessation of rain date in El Niño years and mean overall cessation of rains over the most parts of the Free State is mostly negative (Fig. 6). There are few pockets of near normal (-4 to 5 days) to slightly later than normal (6 to 10 days) cessation of rain. Negative bias illustrate earlier than normal cessation of rain in El Niño years. The cessation of rains can be more than 14 days earlier than average in scattered patches all over the province with the exception of the southern parts where negative anomalies ranges from 0 to 9 days. Earlier than normal cessation of rains shortens the length of the growing period affecting productivity of medium or long season maize cultivars. Study by Tadross et al. (2009) also showed earlier cessation of rain with negative implications on agriculture while Hachigonta et al. (2008) didn't establish any relationship between late cessation with the negative phase of ENSO.

Fig. 6. The difference between mean cessation date in El Niño years and overall mean cessation date over the Free State Province.

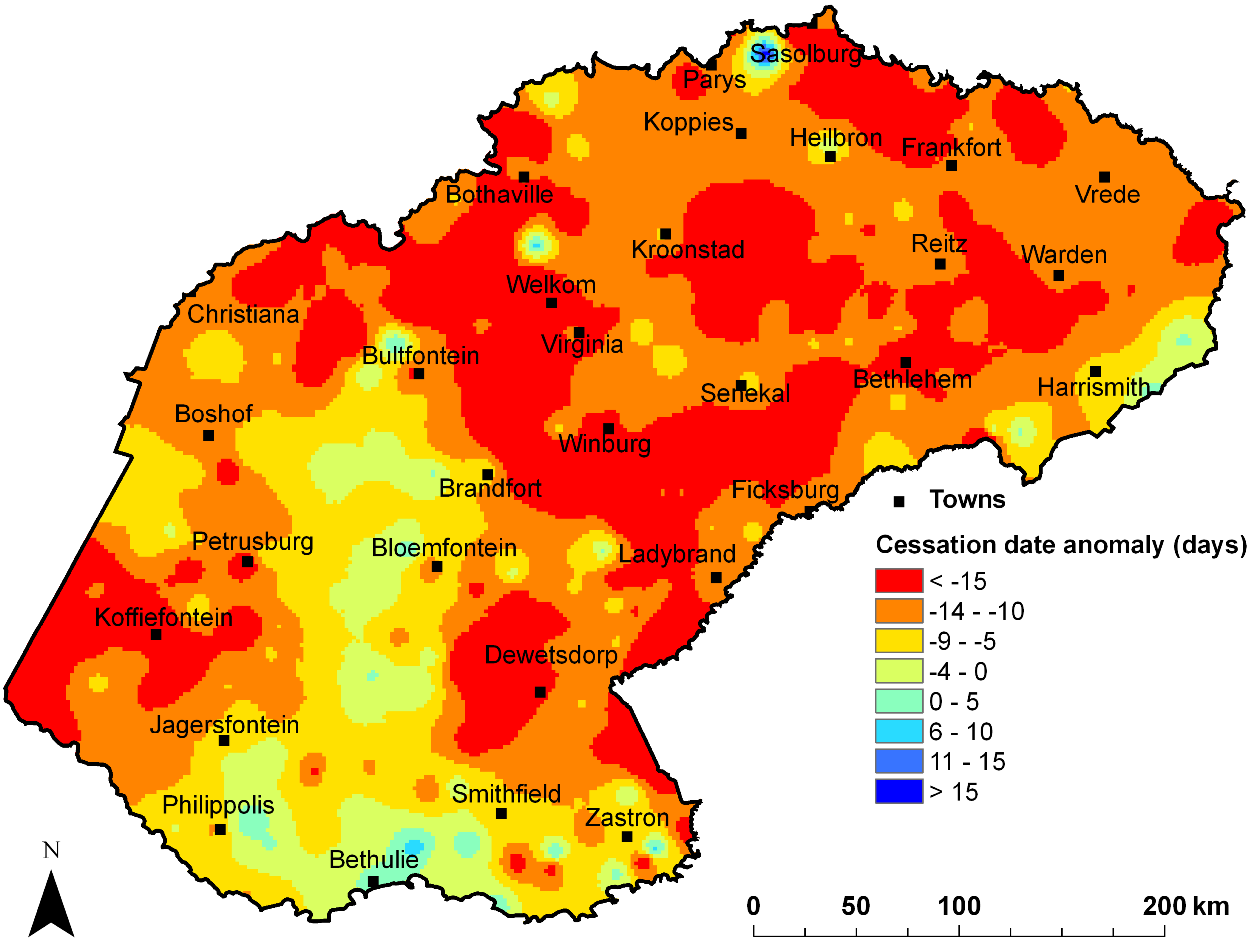
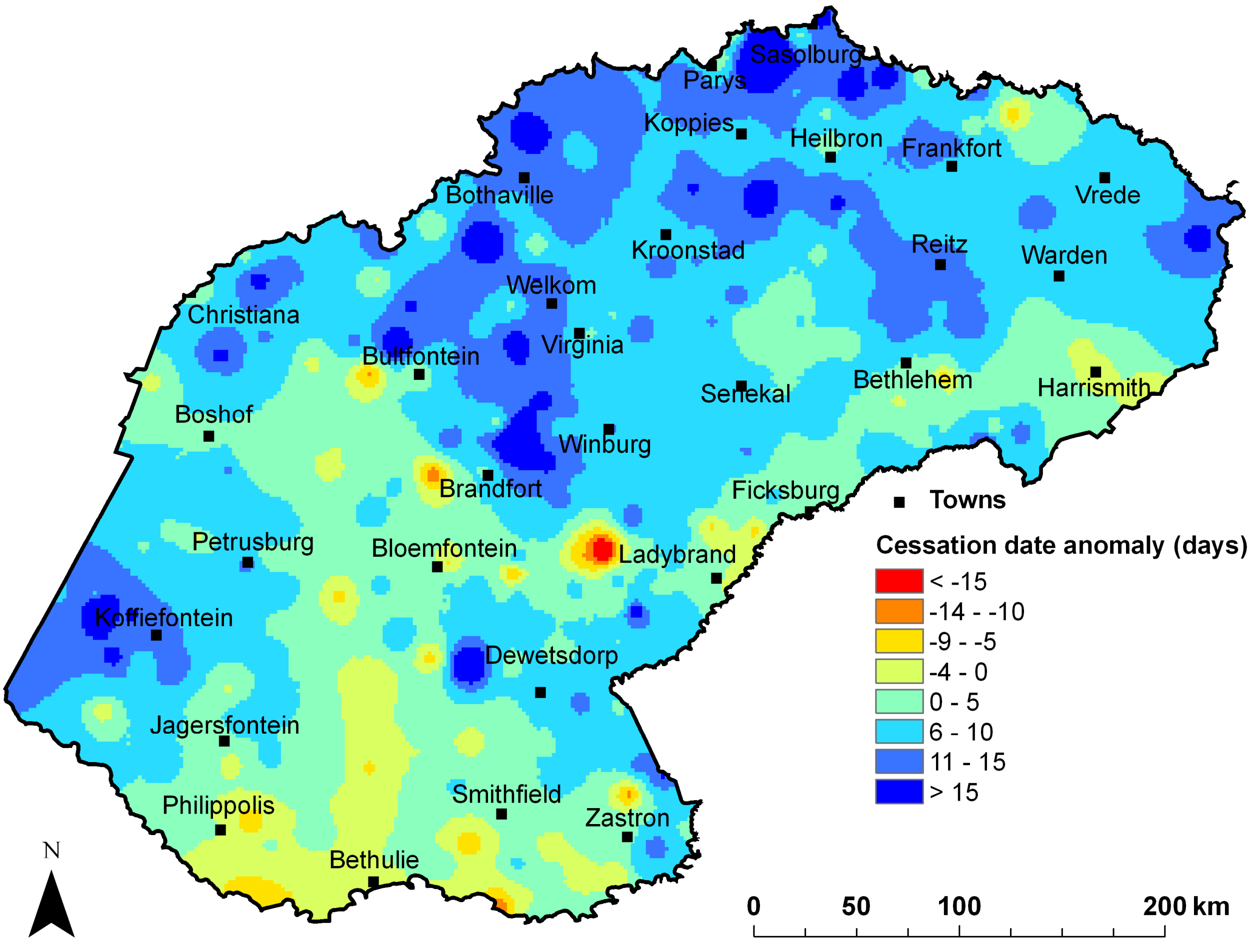


Figure 7 shows the difference between mean cessation date in La Niña years and overall mean date with great area over the Free State Province showing a positive bias. This is an indication of later than normal cessation of rain in La Niña years with high likelihood of elongated rainy season period to suit the planting of long season cultivars with high yielding potential. The deviations mostly range from 6 to 15 days with patches of anomalies exceeding 15 days all over the province. There are few exceptions especially over the central and southern parts where near normal (-4 to 5 days) cessation of rain is evident. Cessation of rain in Zambia showed no direct links between La Niña and timing of the cessation of rain (Hachigonta et al. 2008). The study that is in agreement with these results is that of Tadross et al. (2009).

3.3. Duration of rainy season

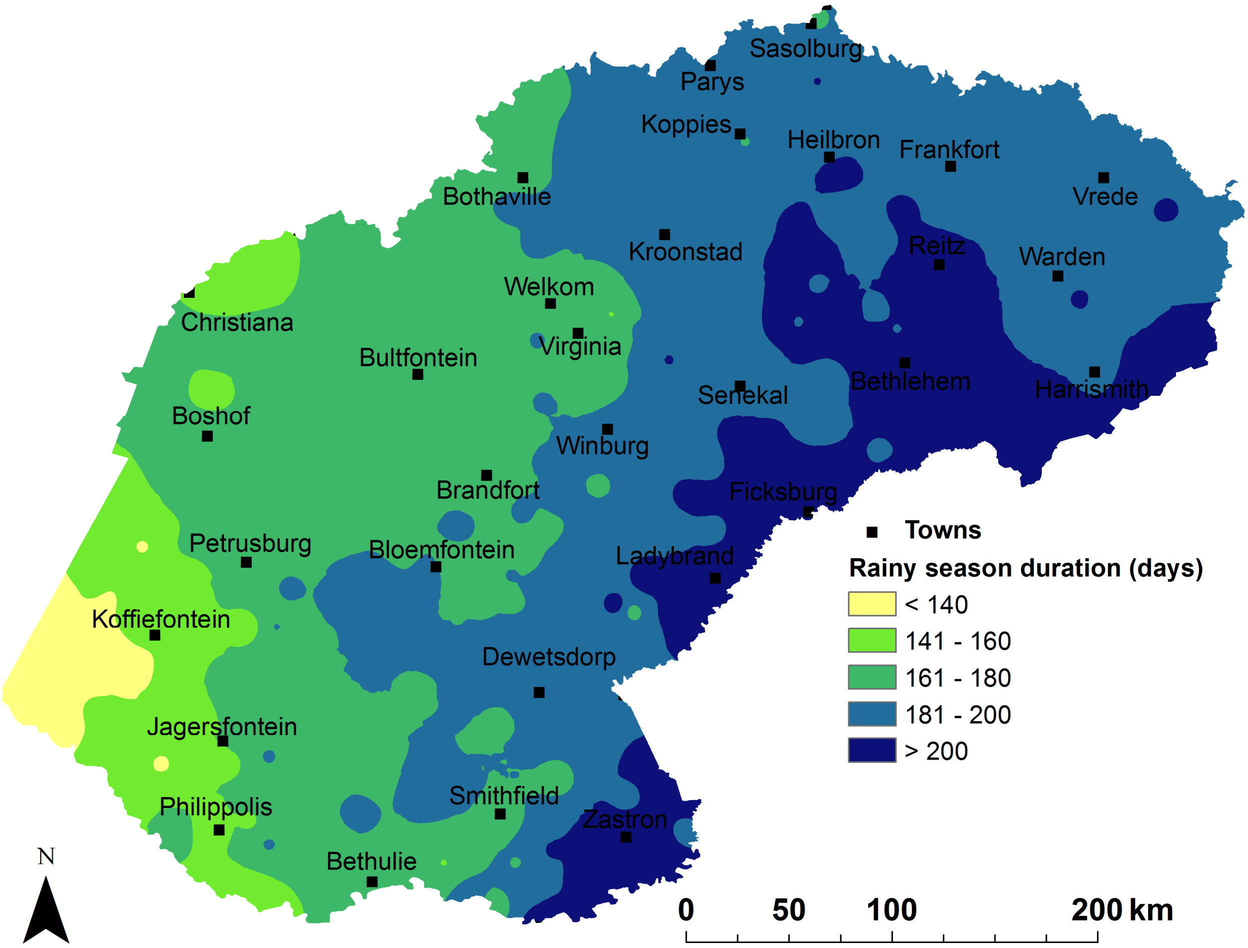
Most parts of the northern and eastern parts of the Free State Province experience rainy season duration of between 181 to 200 days (Fig. 8). The far eastern and places along the border with Lesotho have longer rainy season duration with over 200 days. The length of the

Fig. 7. The difference between mean cessation date in La Niña years and overall mean cessation date over the Free State Province.



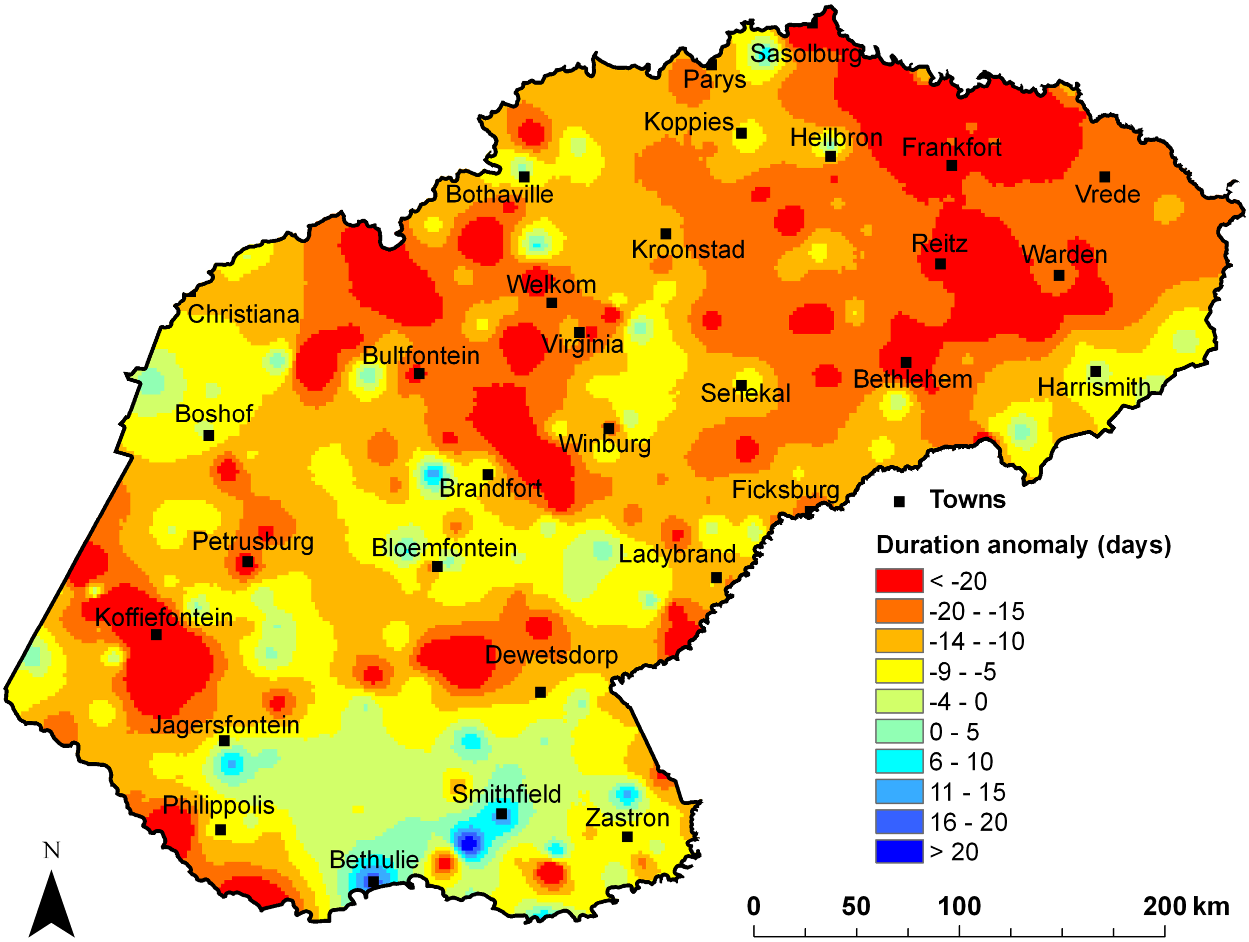
growing period of more than 180 days is sufficient for the planting of all maize varieties, but depending on the planting date, farmers have to cautious in planting varieties with high heat requirements because of the early onset of frost over the eastern Free State (Moeletsi, 2010). The areas on the western and central Free State (vicinity of Boshof, Brandfort, Bultfontein, Petrusburg and Virginia) experience average rainy season length of between 161 and 180 days. Shortest rainy season duration of below 140 days is evident over the southwestern parts (West of Koffiefontein). The results clearly show that the medium season variety with an average 120 days or long season variety exceeding 140 days depending on the date planted can flourish in most parts of the Free State. Long season varieties can mostly be applicable to places over the northwestern and central parts of the country where frost-free period is longer and heat accumulation rate is higher during the months of September, October, April and May (Moeletsi, 2010).

Fig. 8. Average rainy season duration over the Free State Province.



When comparing the average length of the rainy season in El Niño years to the overall average length, most places over the Free State show negative bias (Fig. 9). The results of the difference between mean duration of rainy season in El Niño years and mean duration of rainy season over the Free State mostly range from -5 to over -20 days. Shorter than normal rainy season in El Niño years clearly have an affect on the choice of the maize cultivar to be planted. The short rainy season duration is mostly attributed to very early cessation of rains in El Niño years. Cessation of rains over most parts of Free State occurs in mid-March to early April in El Niño years instead of normal occurrence in mid-April. Short agricultural season over the high lying areas (with low heat accumulation rate) of the eastern and northern Free State would possible result in reduced maize productivity caused by failure of the crop to reach maturity before setting of frost (Moeletsi, 2010). In other areas (of relatively short rainy season compared to the eastern and northern parts), short growing season in El Niño years decrease rainy season further hence impacting productivity negatively on farms where medium to long season maize varieties are planted. The advice for farmers during the preparation stages (pre-planting) in the Free State Province would be to plant short season and drought tolerant varieties if the El Niño event is forecasted.

Fig. 9. The difference between mean rainy season duration in El Niño years and overall mean rainy season duration over the Free State Province.

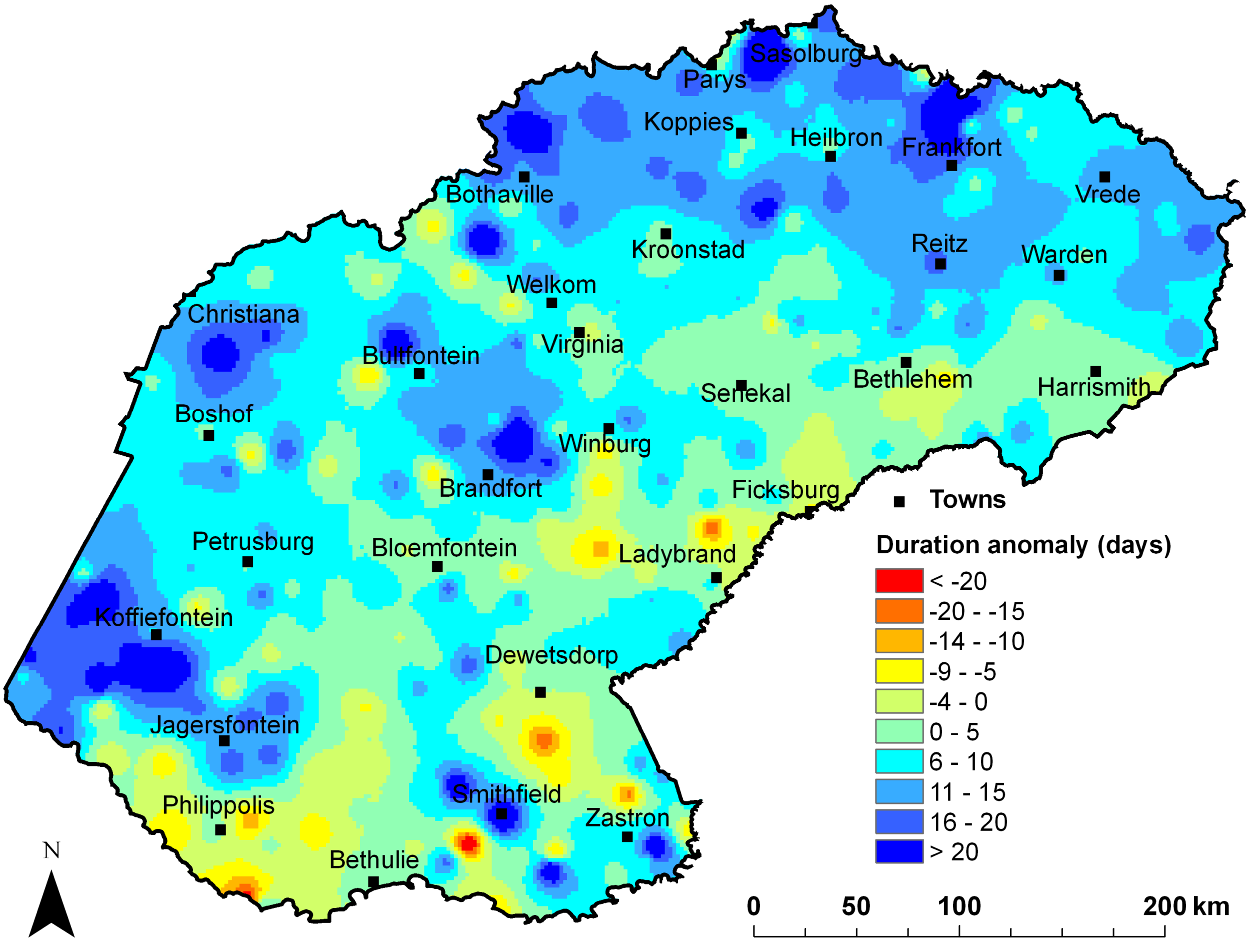


The difference between the average length of the rainy season in La Niña years and normal (mean) length of the rainy season over the Free State is mostly longer by over 6 days (Fig. 10). There are patches of slightly shorter (anomalies below 0) rainy season duration over the southern parts and much longer (over 20 days) in the northern, western and southeastern parts of Free State Province. In La Niña years longer duration of the rainy season over the Free State Province would make the planting of medium to long season maize cultivars which have a higher yield potential than short season varieties possible.

3.4. Seasonal rainfall

Average cumulative rainfall from September to May varies quite a lot in the Free State Province (Fig. 11). Low amounts of less than 300mm are evident in western parts increasing gradually towards the east and northeast peaking to values exceeding 650mm over the far northern (vicinity of Sasolburg) and northeastern parts (vicinity of Bethlehem and Harrismith). Even though maize is adaptable to adverse conditions like low rainfall and drought negatively

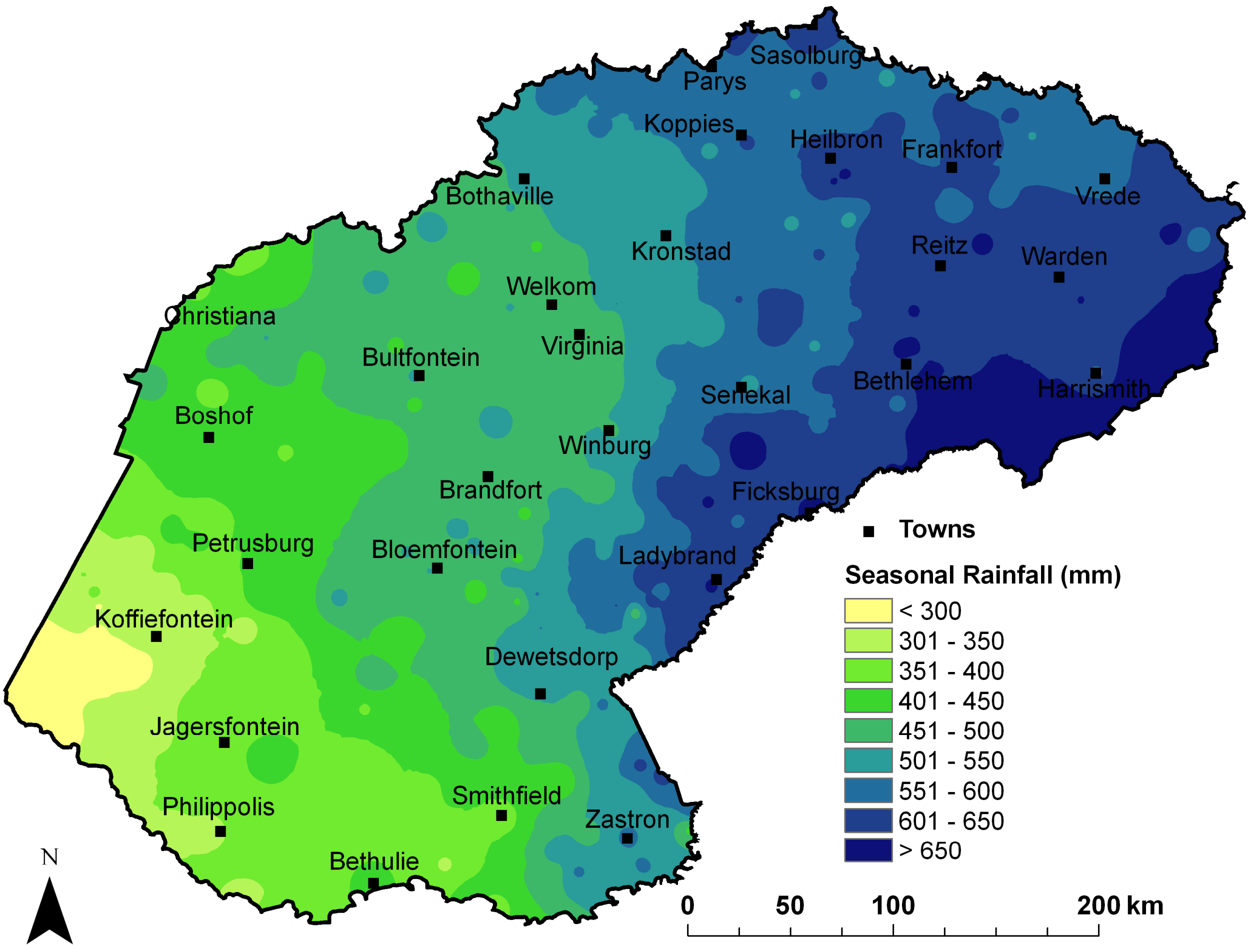
Fig. 10. The difference between mean rainy season duration in La Niña years and overall mean rainy season duration over the Free State Province.



affect their productivity (Moeletsi, 2010). Maize water requirements are likely to be satisfied resulting to high productivity in areas where cumulative rainfall exceeds 450mm while in areas of cumulative rainfall below 450mm soil water deficits would most likely impact negatively on productivity (du Plessis, 2003).

Figure 12 presents actual interpolated surface of the difference between the overall mean seasonal rainfall in El Niño years and the mean seasonal rainfall over the Free State Province. It is evident that during El Niño years accumulated seasonal rainfall is below normal as shown by negative values all over the province. Far below normal rainfall in El Niño years is an indication that crop water requirements are likely to be severely affected. The deviation from the overall mean is between 25 and 100mm all over the Free State Province with over 90% of the province recording negative deviations from 50 up to 99mm. There is sporadic occurrence of deviations exceeding 100mm. The percentage deviations from the overall mean over the whole Free State Province ranges from 2 to 41% with an average of 20% deviation. Places with more than 15% deviations or seasonal rainfall negative deviations exceeding 51mm from the mean are more vulnerable in El Niño years, hence crop production

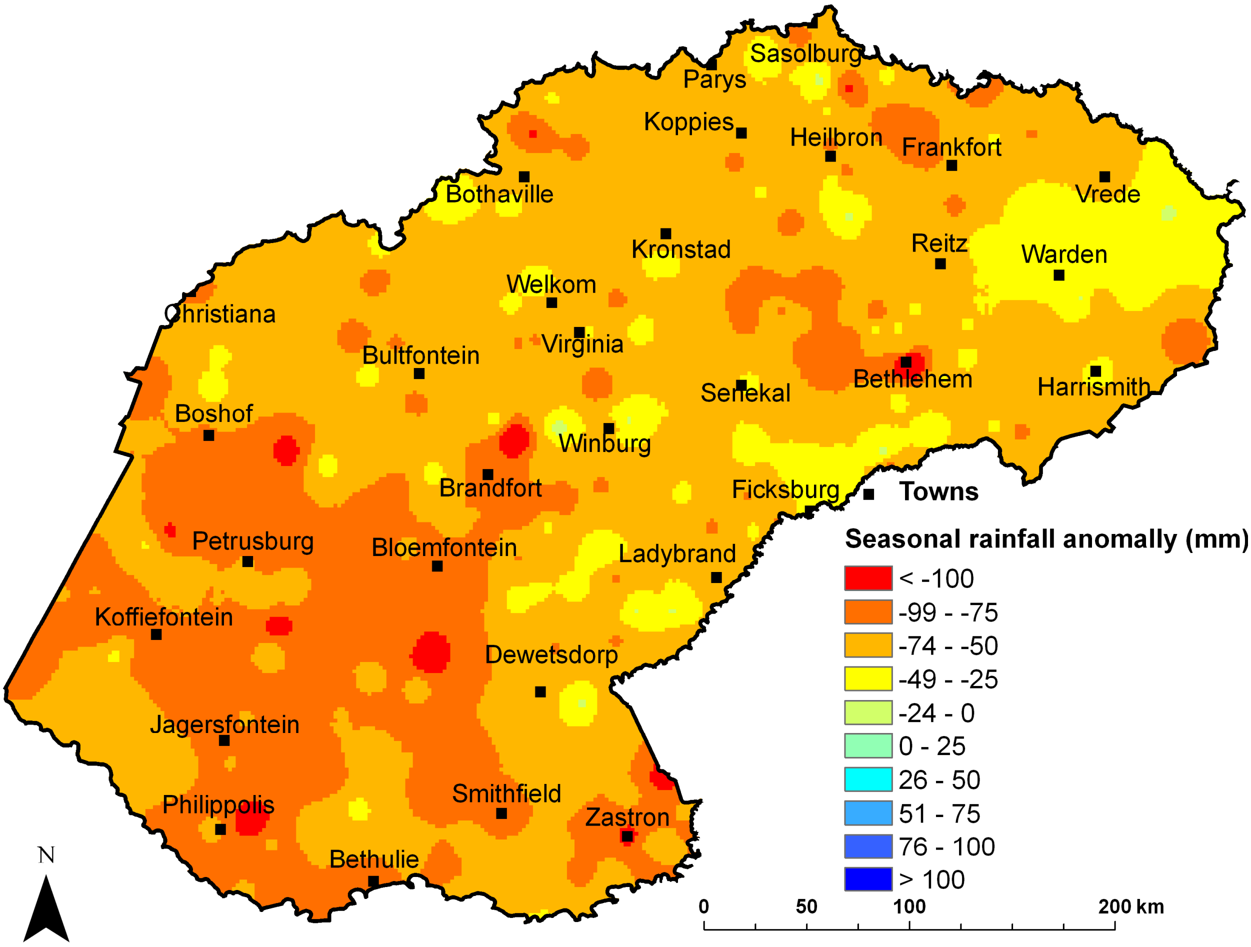
Fig. 11. Average seasonal rainfall (September to May) over the Free State Province.



can be negatively affected by reduction in rainfall. Seasonal rainfall is affected negatively during the negative phase of the SOI whereby most places in the province record between 51 and 100mm deficit. Lower than normal seasonal rainfall may translate to high chances of soil water deficiencies during the critical maize growing period causing reduction in production. During El Niño years, tropical easterly lows and waves form over the eastern Africa and Indian ocean causing southern African region to experience below normal rainfall (Tyson and Preston-Whyte, 2000). The results are consistent with the findings from the previous research which show reduced rainfall in El Niño years as compared to longterm mean rainfall (Vogel and Drummond, 1993; Phillips et al., 1998; Landman and Mason, 1999; Nicholson et al., 2001; Fauchereau et al., 2003).

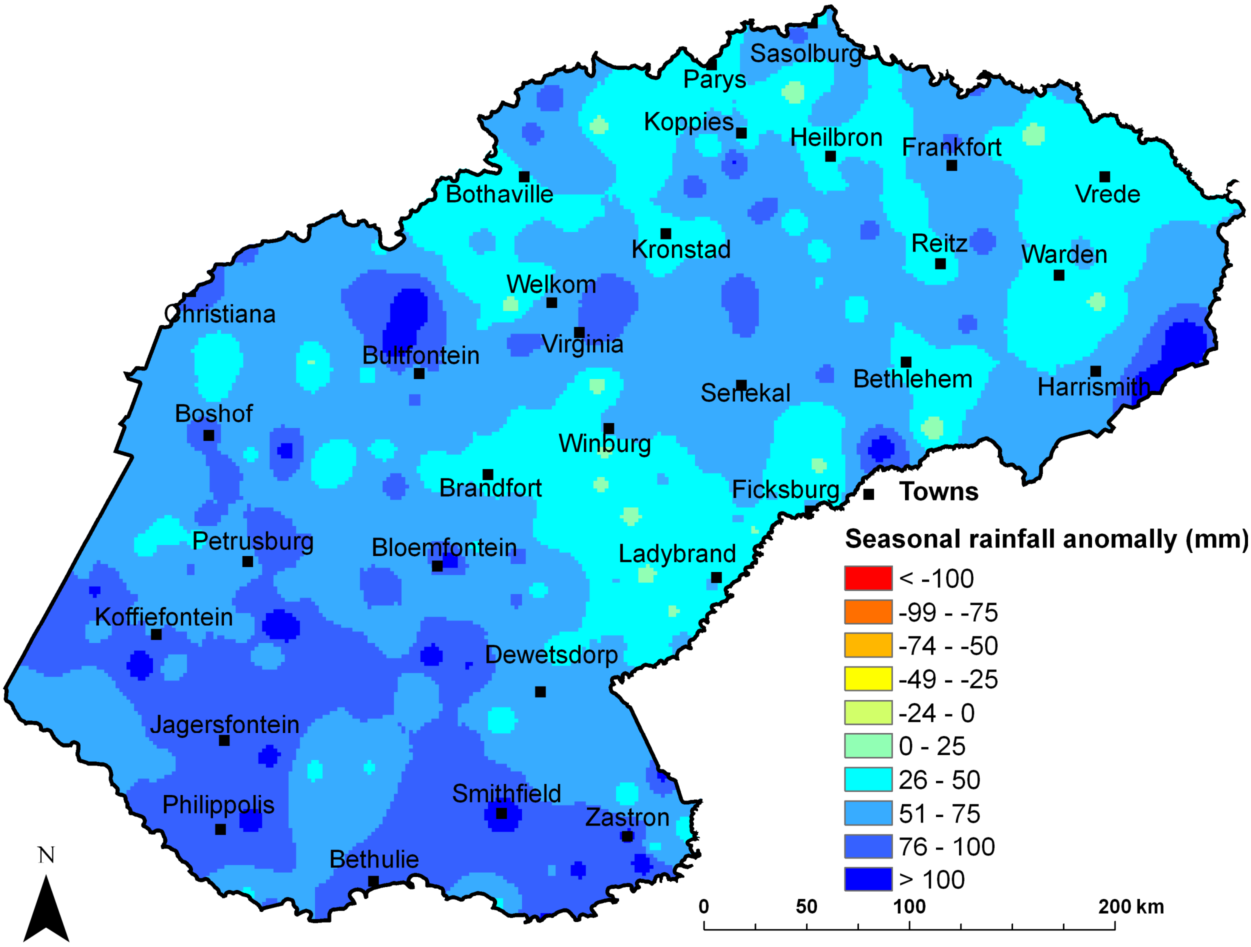
There is a scientific consensus that seasonal rainfall is higher during La Niña years as compared with long-term mean (Phillips et al., 1998; Landman and Mason, 1999; Nicholson et al., 2001; Fauchereau et al., 2003). The difference between mean seasonal rainfall in La Niña years and overall mean of seasonal rainfall is mostly positive over most the whole of the Free State. Overall the assumption that seasonal rainfall is higher in La Niña years than normal is also supported by the results of this study (Fig. 13). The central, northern and

Fig. 12. The difference between mean seasonal rainfall in El Niño years and overall mean seasonal rainfall over the Free State Province.



eastern parts mostly have positive deviations ranging from 26 to 75mm while the western and southern Free State deviations are mostly between 51 and 100mm with patches exceeding 100mm. The percentage deviations over the central, northern and eastern parts range from 5 to 25%. The percentage deviations over the southern parts are mostly over 30%. During the positive ENSO phase, the ascending limb of the Walker circulation forms over central Africa and tropical lows and easterly lows are evident in southern Africa forming cloud bands responsible for above normal rains (Tyson and Preston-Whyte, 2000). Higher than normal seasonal rainfall can have a positive impact on dryland maize production provided the distribution of the rains over the growing period is good and thus minimizing chances of soil water deficits at crucial stages of the maize crop. If the rains are not properly distributed, enhanced rainfall in La Niña years may cause floods causing damage to crops.

Fig. 13. The difference between mean seasonal rainfall in La Niña years and overall mean seasonal rainfall over the Free State Province.

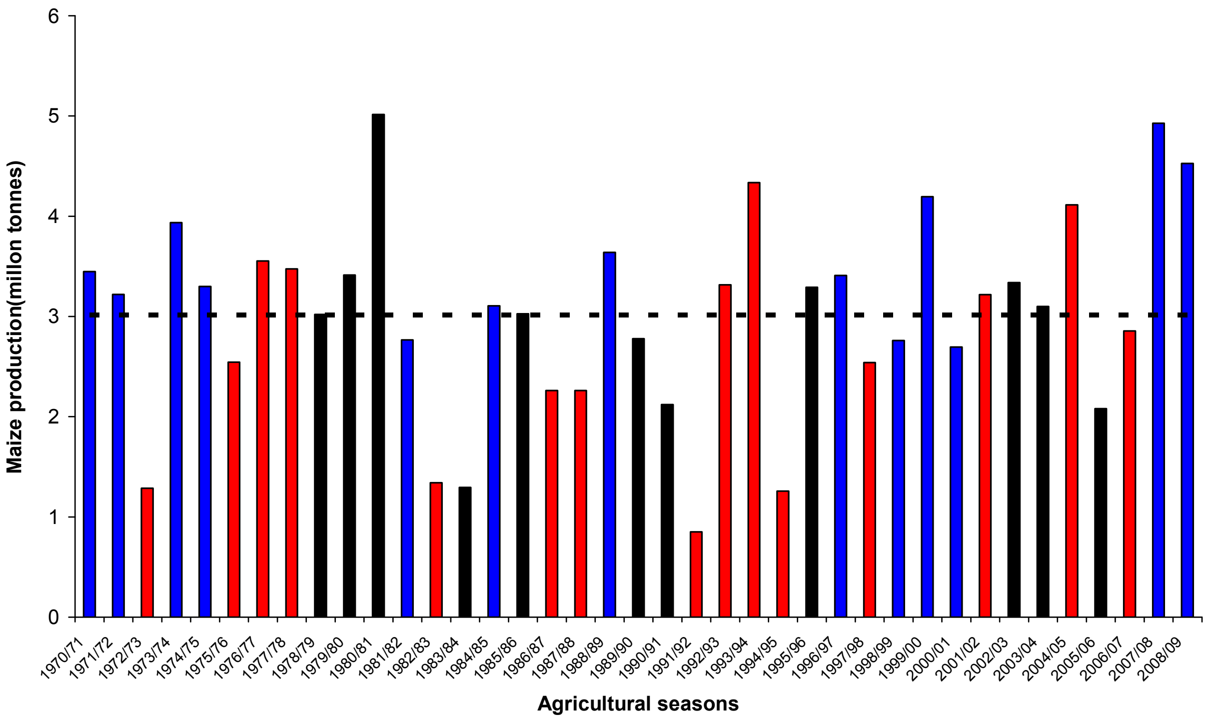


3.5. ENSO and maize yields

Maize is the most important crop in Southern Africa as it forms a staple food of most people and it is mostly planted under rain-fed conditions making it vulnerable to climate variability and change (Martin et al. 2000). Agricultural production especially dryland maize farming over the Free State Province and South Africa varies greatly from one agricultural season to another mainly due to climate variability (de Jager et al. 1998). Tsubo and Walker (2007) showed that there is a link between ENSO and summer rainfall in the Free State with low risk of planting maize in La Niña years while in El Niño years there is a relatively high risk of low yield. These findinds are further supported by this study which clearly shows reduced length of rainy season and seasonal rainfall in El Niño years. By contrast, in La Niña years rainy season duration hence growing period is longer in the Free State Province while seasonal rainfall is also higher increasing chances of favourable environmental conditions for maize production.

Figure 14 shows variation of annual production for the Free State Province from 1970 to 2008 agricultural seasons with some links between maize production and ENSO. Extremely low production is evident during the 1972/73, 1982/83, 1983/84, 1991/92 and 1994/95 seasons where annual maize production in the Free State is below 1.5 million tonnes. The production in these years is more than 50% below the mean (3 million tones) maize production in the Free State Province. Four out of five of these agricultural seasons correspond to El Niño years. These years were mostly characterised by low rainfall and increased intensity of drought over southern Africa (Landman and Mason, 1999; Nicholson and Selato, 2000; Landman et al., 2001). There are isolated cases where El Niño years are not accompanied by extremely dry conditions resulting to poor harvests and examples are the 1993/94 and 2004/05 years where high maize production was obtained in the Free State. During La Niña years (marked by above normal rains with less drought conditions) maize production in the Free State Province is mostly enhanced. From 1970 to 2008, four out of seven agricultural seasons with provincial maize production exceeding 4 million tonnes falls in La Niña years. Low association between La Niña years and maize yields is mainly due to the fact that enhanced rainfall amounts may be highly concentrated at short periods resulting to floods at some cases. High rainfall amounts have a good impact on maize production if it is distributed evenly over the growing period of the crop with no soil water deficits during the critical periods of the flowering and grain-filling.

Fig. 14. Maize production for the Free State Province and South Africa from 1970 to 2008 (red representing El Niño year and blue for La Niña year).



The relationship between El Niño and La Niña events with the length of the growing period and seasonal rainfall can further be used for agricultural planning by considering the seasonal forecasts that are being produced for the region. In fact, seasonal rainfall over southern Africa during El Niño and La Niña events is for the most part accurately predicted (e.g. Landman et al. 2009). Moreover, these equatorial Pacific Ocean events have the potential to be predictable with several months lead-time (e.g. Stockdale et al., 1998; Landman and Mason 2001; Metzger et al. 2004). Therefore, knowledge of an impending El Niño or La Niña event can help farmers to plan months ahead of the rainy season which maize cultivars to invest in.

4. Conclusions

The comparison of overall mean onset dates with the onset dates during El Niño years does not show any consistency with some areas having later than normal onsets (northern and northeastern Free State) in El Niño years while others have earlier than normal onsets (some parts of central Free State and southern and southwestern Free State). The comparison with the onsets in La Niña years showed slight positive bias over most parts of the northern, far eastern, western and southern parts of the province with mostly up to 5 days earlier than normal onsets. There are also a lot of places where the onsets in La Niña years is later than normal. One can thus conclude that the links between onset and ENSO episodes are not clear for the whole Free State. In contrast, the ENSO episodes have a good association with the cessation of rains in most parts of the province. Cessation of rains in El Niño years is very much earlier as compared with the normal for the Free State, while in La Niña years cessation of rains is later than normal over most parts of the province. The study clearly shows that ENSO episodes have an influence in seasonal rainfall amount accumulated from September to May. The difference from the mean seasonal rainfall in El Niño years and overall mean is highly negative all over the Free State hence the seasonal rainfall is reduced in El Niño years. The most affected areas are in the southern and southwestern parts of the province where percentage deviations exceed 30% in some places. As for the difference between mean seasonal rainfall in La Niña years and overall mean, most places records positive anomalies indicating that rainfall is more than normal in La Niña years. The southern Free State shows more places with percentage deviations of more 30%. There is also evidence that ENSO episodes influence productivity over the Free State Province with low production being linked to El Niño years and relatively higher maize production associated with La Niña years.

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