

Water for Agriculture in Zimbabwe

Policy and Management Options for the
Smallholder Sector



Edited by
Emmanuel Manzungu, Aidan Senzanje and Pieter van der Zaag

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UNIVERSITY OF
ZIMBABWE
Publications

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First published in 1999 by
University of Zimbabwe Publications
P.O. Box MP 203
Mount Pleasant
Harare
Zimbabwe
Reprinted 2000
ISBN 0-908307-63-2

Printed by Mazongororo Paper Converters
Typeset by the University of Zimbabwe Publications.

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PART I

RAINFALL

Introduction

The importance of rainfall, particularly in a semi-arid country like Zimbabwe, attracts a lot of debate. The debate takes a variety of forms. Technicians such as climatologists, meteorologists and statisticians tend to be preoccupied with issues such as processes of rainfall formation and rainfall trends (short and long term). Rainfall forecasting has thus become sophisticated over the years with the increased expense justified on the perceived need to be precise about rainfall patterns. The rationale is that rainfall forecasting needs to be based on a solid scientific footing. Zimbabwe, like many other countries, has its own Department of Meteorological services tasked with 'reading the skies' and informing the nation on the outcome. Central to the activities of the Department is to give insights into rainfall patterns and how they are likely to affect agriculture. This is important not only for agriculture but also for the economy at large. Makarau, in Chapter 1 analyzes rainfall trends in the country since the turn of the century. He uses statistics to good effect to point out that rainfall in Zimbabwe is becoming more variable and more extreme which is bad news to agriculture and the entire economy. Makarau also adds a sobering thought. In his own words the popular dictum that the past is a key to the future is no longer applicable because "what will happen in the future is not necessarily limited to what has happened in the past" because of man's economic activities.

This cause and effect of rainfall is also taken up by de Groen and Savenije in Chapter 2. The authors contend that the causes of rainfall patterns, contrary to popular beliefs, may not lie in far-way phenomena such as the El Nino but 'closer home' where human activities that interfere with evaporation patterns may be responsible. Their research effort is still developing, at least in Zimbabwe. However, their thesis warrants serious attention. Debate on rainfall is not the preserve of technicians. Farmers faced with drought, attempt to make sense of all this. To them drought is not a chance event. Rather it is explained in terms of particular cause and effect relationships. But perceptions are not static: they are a product of being within certain social, political or religious networks. This is what Vijffhuizen in Chapter 3 documents for a 'community' in the south eastern part of Zimbabwe. Here rain-making, although shrouded in religious/traditional discourse, has distinct political connotations.

It must be added, however, that the political dimension of rainfall, referring here to control aspects relating to rainfall, is not unique to farmers. Technicians are no exception. Conflict of theories and interpretations is not just a battle of ideas but a battle for control — after all a rejected theory or interpretation represents a net loss of influence. There is also another dimension to this — information is power. People who possess the information can act as gate-keepers. It will be apparent in the other chapters that rainfall is not just a natural, physical product but a socio-political one as well.

CHAPTER 1**Zimbabwe's Climate: Past, present and future**

A. MAKARAU

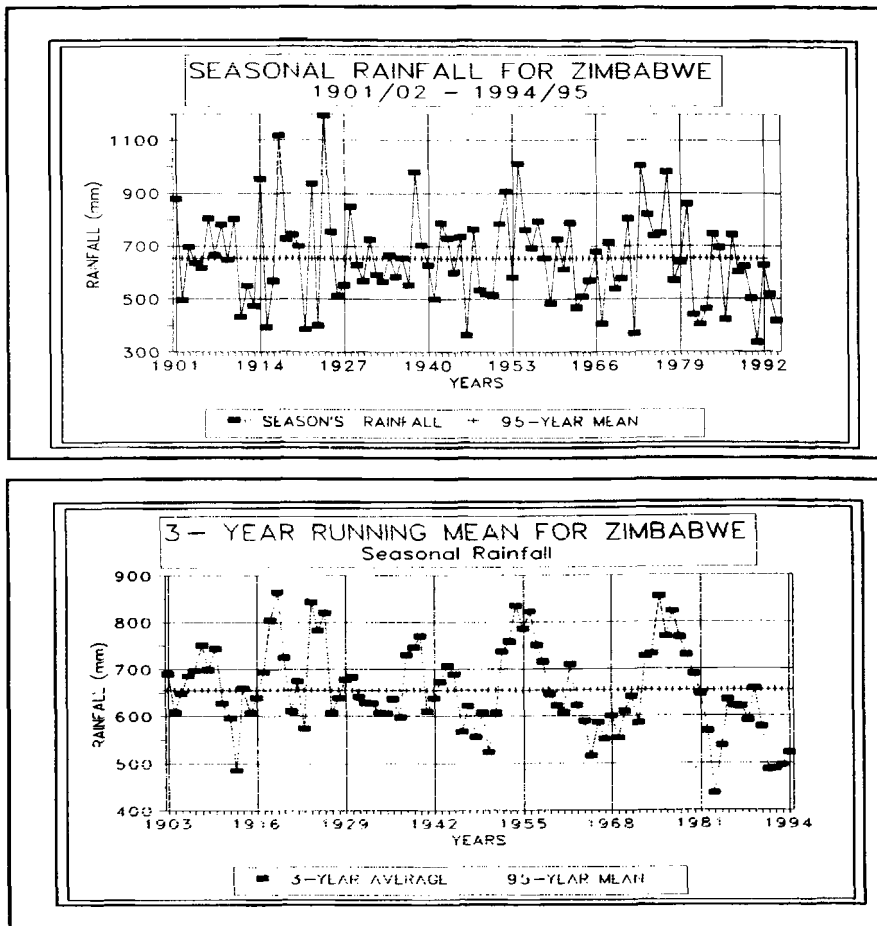
There are very few socio-economic activities upon which climate does not have a direct bearing. For agriculture, on-farm operations, from planting time through pesticide application, weeding and irrigation to harvesting and marketing, are largely dependent upon timely utilisation of climate information. In order to achieve more sustainable agricultural production, it is important for policy makers and the agricultural community to understand and accept the variability of climate both inter-annually and intra-seasonally. Many long-term projects, for example, dam construction, have until recently, been based solely upon historical analogues and past climatic data with little or no regard for the future. This assumption no longer holds true, as increasing concentrations of greenhouse gases appear to be causing a significant warming of the global climate. Are today's water resources designed to cope with the uncertainty in the water supply that may exist under an altered climate? Will the traditional farming techniques continue to be applicable in a new climate regime? There is, therefore, an urgent need to refine long-term planning estimates and even devise new strategies by taking into account the current knowledge about climate change and variability.

This chapter is designed to illustrate Zimbabwe's climate over the past century, project trends and sketch possible future scenarios on the basis of present weather patterns. For easier interpretation, only rainfall and temperature are discussed. Recommendations are then made for agriculturists and water resource decision-makers which are relevant for short and long-term planning.

SIGNALS IN ZIMBABWE SEASONAL RAINFALL DATA**Inter-annual variability**

The behaviour of annual rainfall in Zimbabwe can best be summarised by Figure 1.1. The figure shows a time series analysis of the country's area-averaged seasonal rainfall from 1901/02 to 1994/95, inclusive. The top graph denotes the seasonal rainfall while the bottom graph indicates three-year moving averages. In both figures the long term mean is included.

Figure 1.1. Zimbabwe's rainfall from 1901 to 1995



The pattern illustrates a high year to year variability. Meteorological drought years, defined in this chapter as when the Zimbabwean summer rainfall is at least a standard deviation below the long-term mean, include 1912, 1914, 1916, 1922, 1924, 1947, 1960, 1964, 1968, 1973, 1982, 1983, 1984, 1987, 1992 and 1995. (In this case, the year in question is centred on January.) Of these, the 1991/92 rainfall season was the worst, followed by the drought of 1946/47. During the same period, and by using the converse definition of the above for abnormal rainfall, the country had excess rainfall in 1901, 1914, 1917, 1922, 1924, 1928,

1938, 1952, 1954, 1973, 1977 and 1980. The return interval is more widely spaced compared to drought years, especially since the middle of this century. More disturbing is the fact that, apart from large interannual variability, Zimbabwe seasonal rainfall is on the decline. The linear equation of change is given by:

$$R = 703.44 - 1.03 * T,$$

where R is the rainfall (mm) and T is the number of years after 1901.

The linear trend indicates a reduction of approximately 100 mm since the turn of this century, a result confirmed by quadratic and exponential analyses (not shown). The reduction is more pronounced at station level.

Employing a three-year smoothing filter (to reduce noise in the annual time series), the pattern indicates a cyclic fluctuation from the 1920s with troughs (periods of low rainfall) around 1931, 1946, 1964 and 1983 and peaks (high rainfall episodes) in 1937, 1954 and 1974. This suggests a cycle periodicity of 17–19 years, implying roughly a nine-year change from peak to trough. Also significant is the apparent increase in the amplitude of the interannual cycle, implying that floods and droughts are becoming more severe. This is in partial agreement with the findings of Jury *et al.* (1992) who also observed that wet summers over South Africa and Botswana were getting wetter. Also, periods of dry seasons are lengthening.

Further analysis of the summer rainfall in the country (Figure 1.2) reveals, in order of decreasing spectral power, periodicities of 2.3 years (28 months) closely followed by the 18.0 year cycle. Two other significant modes can be noted, namely 2.7 and 3.8 years. A number of other periodicities are noted in the two to five year range. The 28-month year cycle has only recently been identified in southern Africa rainfall and linked with the quasi-biennial oscillation (QBO) of stratospheric zonal winds (Mason, 1992) as well as the tropospheric biennial variability of the Southern Oscillation (Ropelewski *et al.*, 1992). Several studies (eg., Rasmusson and Carpenter, 1982; Deser and Wallace, 1987; Ropelewski and Halpert, 1987) have identified a roughly two-year cycle within the El Niño/Southern Oscillation (ENSO). The biennial cycle influences Zimbabwe summer rainfall, especially during relatively wet periods as evidenced by the frequent 'M' shape of the unsmoothed area-rainfall time series.

The 18-year cycle is not unique to Zimbabwe. Tyson (1987) cited many papers giving evidence of 18- and 10-11-year oscillations in rainfall and other parameters over southern Africa. Jury *et al.* (1992), using spectral analysis of the Southern Africa Rainfall Index (including Zimbabwe data), showed a major peak at 18.8 years with minor peaks at 2.3 and 4 years. In the Zimbabwe spectra (Makarau, 1995), the 18-year cycle is subordinate to the 2.3-year cycle. Currie and O'Brien (1988) have cited literature on the 18-year cycle and contend that it is due to a resonant, quasi-standing wave in the atmosphere as a consequence

of luni-solar tidal action. The tide is due to the moon's plane of motion inclined at a mean angle of $5^{\circ} 09'$ to the elliptic at approximately 0.053° per mean solar day, thus making a complete revolution in 18.61 years (Doodson and Warburg, 1941; Pugh, 1987). Currie (1993), using South Africa rainfall at various locations, also observed the forcing functions of luni-solar tidal influence with periodicities of 18.6 and solar-flux sunspot cycle at 10-11 years.

According to Currie and O'Brien (1988), epochs/dates of tidal maxima in this century were 1917.5, 1936.1, 1954.7 and 1973.3. When compared with seasonal rainfall in Zimbabwe, these epochs coincided with periods of heavy rainfall. Thus, it can be inferred that, barring the effects of other weather parameters, the next peak should be in the early to mid 1990s (1992/93–1995/96 seasons), implying increased rainfall over southern Africa, especially Zimbabwe, during this period. The 3.8-year cycle can be attributed in part to the El Niño.

Inter-monthly variability

Figure 1.3(a-g) show three-year smoothing filter time series of mean rainfalls for the country for the period 1901–1995 for the summer months October to April. Superimposed are the respective long-term averages and fitted linear regressions. Analyses of monthly data clearly indicate individual contributions towards the seasonal trend. Such information is vital for the determination of monthly weather forecasts, such as the timing of weather bearing systems (ITCZ, Botswana Upper High, etc.). This enables appropriate on-farm decisions to be made, like surface water resource management, purchasing of extra fertiliser and pesticides.

Significant features are apparent in the graphs as well as the summary provided by Table 1.1.

Illustrated in Table 1.1 is, firstly, the cyclic nature of the rainfall also at monthly time frames, with the 2-2.5 year (24-30 month) cycle being the most frequent. Thus, for example, in approximately every two and half years, the rainfall characteristics repeat themselves (evidenced by the "M" shape in the 3-year running mean graphs). This periodicity can be attributed to the Quasi-Biennial Oscillation and the biennial behaviour of the Southern Oscillation. Lower frequencies also exist, among them that of four years, related to the El Niño in terms of teleconnections.

Linear regression equations show that, despite the overall declining trend in the seasonal rainfall, October and April rainfalls have been increasing. Since the turn of the century the mean rainfalls have increased by up to 10 mm. The rest of the months have a positive contribution to the decline in seasonal rainfall. The greatest reductions are apparent in the months of November, January and March, the most crucial months in the phenological phases of crops. Since 1901,

Table 1.1: Area-averaged seasonal rainfall characteristics and trends for Zimbabwe for the period 1901–1995, inclusive.

Period	Periodicity in descending order (years)	Regression equation
October	3.13, 2.24, 2.09	21.91 + 0.06*T std dev 18.04, s.e.m. 1.86
November	2.9, 4.6, 2.5, 23.5, 7.8	85.12 - 0.12*T std dev 33.47, s.e.m. 3.45
December	7.8, 11.8, 2.4	137.05 - 0.07*T std dev 64.77, s.e.m. 6.68
January	3.4, 4.7	183.2 - 0.5*T std dev 71.99, s.e.m. 7.42
February	3.76, 2.69, 6.27	142.11 - 0.14*T std dev 68.02, s.e.m. 7.02
March	2.69, 23.5, 7.23, 3.92	106.75 - 0.41*T std dev 56.76, s.e.m. 5.86
April	2.54, 2.09	21.55 + 0.09*T std dev 20.04, s.e.m. 2.07
October-April (season)	2.35, 2.69, 3.76	703.44 - 1.03*T std dev 175.45, s.e.m. 18.10

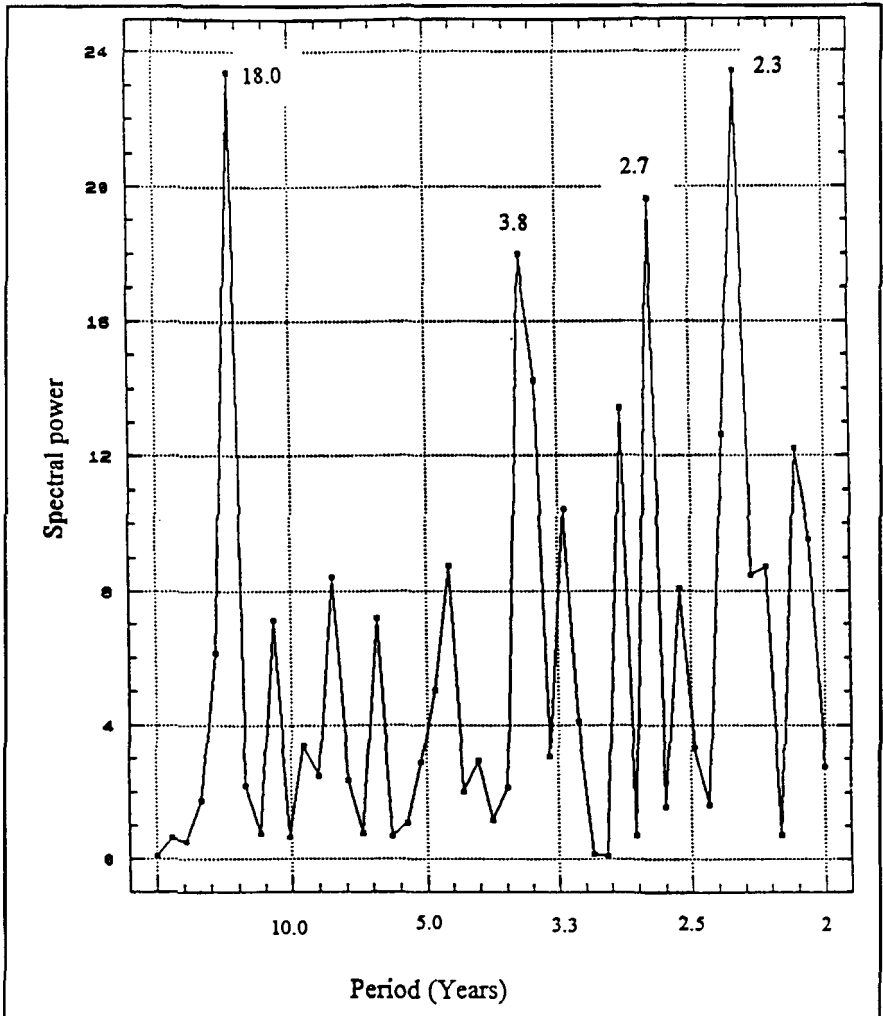
the rainfall totals in these three months have been reduced by 12, 45 and nearly 50 mm, respectively.

Intra-seasonal variability

At sub-monthly time frames, the summer season is not unimodal like monthly variability, but is pulsed with three main wet and two main dry periods, each period on average lasting up to 15 days (three pentads). The distribution of these spells and their most probable periods of occurrence are exhibited in Figure 1.4. This pattern is most representative of rainfall in agro-ecological zones I to III. The other regions have a similar pattern but slightly more uncertain due to the erratic nature of precipitation regimes.

The peak pentad for the first wet period is around 27 November–1 December, hereafter referred to as early summer first wet spell (EFW). This is followed by a minor wet spell (ESW), which occurs around 12–16 December. These two wet spells effectively define early summer. Late summer has three pronounced wet spells, namely LSFW (with a peak around 21–25 January), LSSW (10–14 February) and LSTW (22–26 March). The LSTW effectively defines the end of the season as far as rain-fed agriculture is concerned.

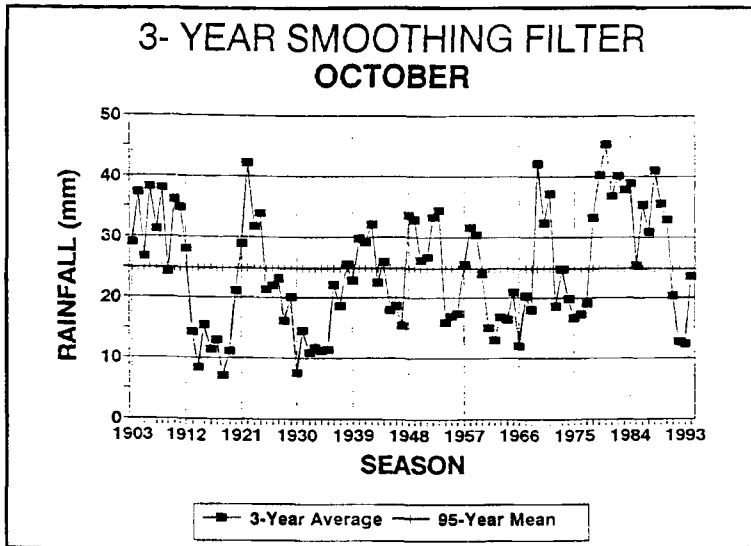
Figure 1.2 Spectral analysis of Zimbabwe seasonal rainfall



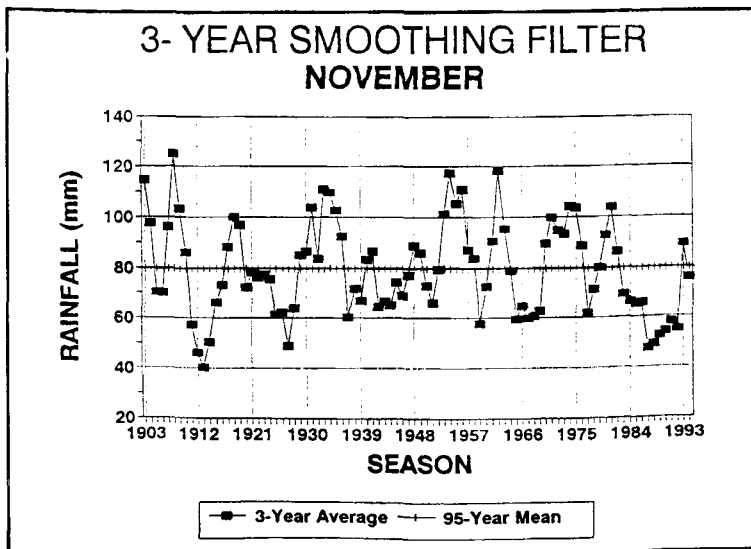
The major dry periods extend from 27 December to 11 January, the mid-summer dry spell (MSD) and from 25 February to 16 March, the late summer dry spell (LSD). The MSD marks the transition from early to late summer, and its behaviour can, single handedly, determine the onset of late summer. In other words, the incursion of the Inter-tropical Convergence Zone (ITCZ) into Zimbabwe depends upon the severity and temporal distribution of the MSD.

Figure 1.3(a-g): Areally-averaged monthly precipitation for Zimbabwe from 1901 to 1995. A 3-year smoothing filter is applied.

(a)

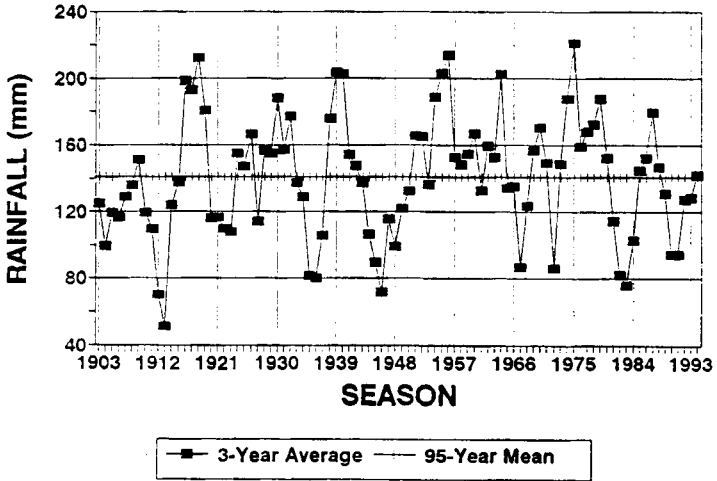


(b)



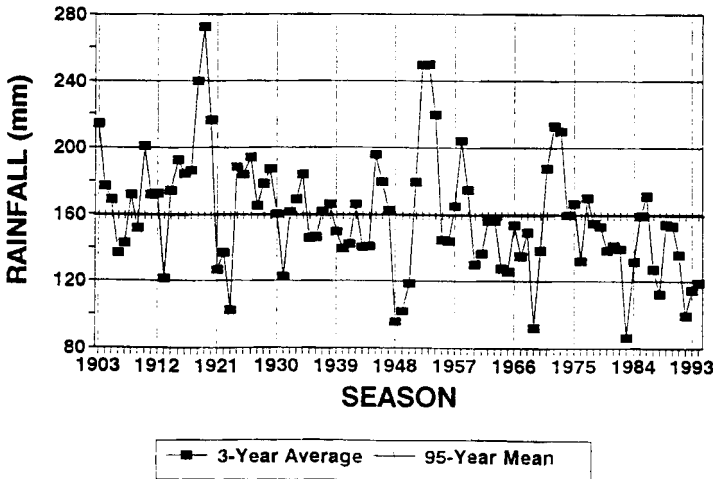
(c)

3- YEAR SMOOTHING FILTER DECEMBER

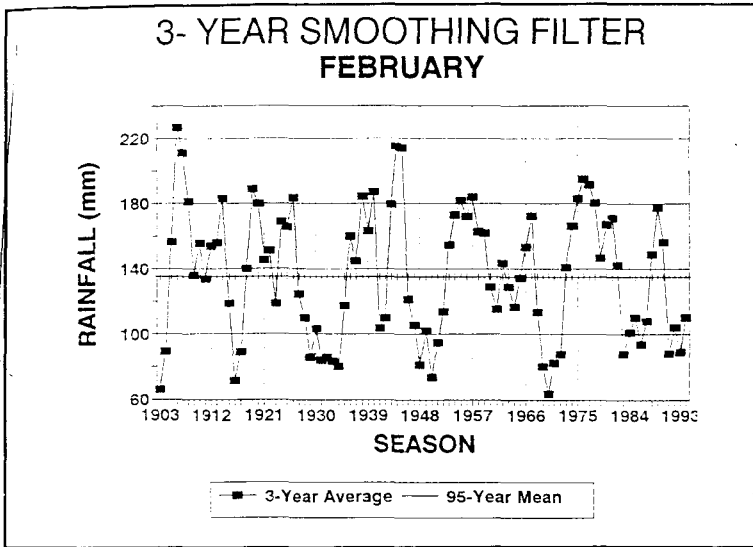


(d)

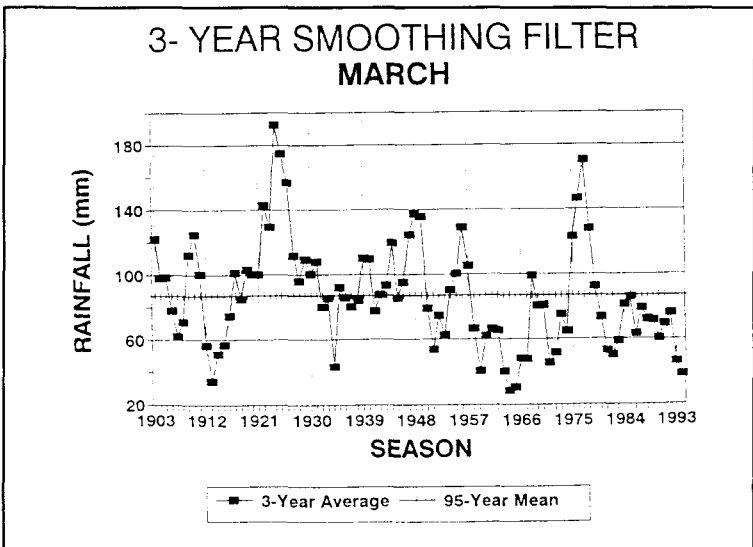
3- YEAR SMOOTHING FILTER JANUARY



(e)

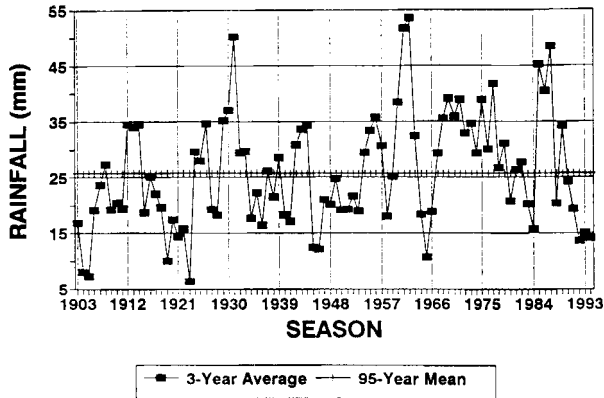


(f)



(g)

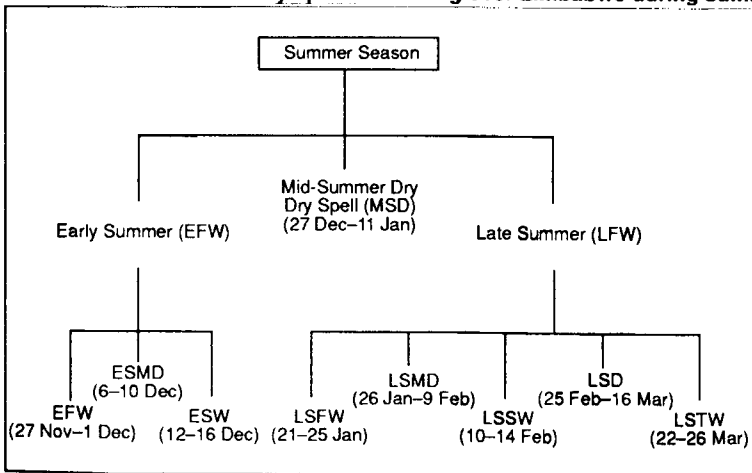
3- YEAR SMOOTHING FILTER APRIL



The LSD is also vital, like the MSD, and enables the atmosphere to maintain equilibrium. In addition, there are two minor dry periods of 1–2 pentad’s duration just after EFW and LSFW.

It is also apparent that, in the long-term, approximately 30 days lapse between the last peak of early summer (ESW) and the first peak of late summer (LSFW). A similar period also exists between the LSSW and LSTW (in other words between the February and March wet spells).

Figure 1.4 Observed wet and dry spells occurring over Zimbabwe during summer



The above climatic patterns have useful applications for agriculture. Crop planning requires accurate definition of the growing season, knowledge of critical stages of crop development and the timely occurrence of such critical stages like germination, flowering and grain filling. Crop success or failure is largely dependent upon adjustment of the life cycle of the crop to the sequence of seasonal climatic conditions. The growing season is not the same every year. It is governed by the onset and cessation dates of each summer season. The crop requirements vary throughout the growing season and for annual crops like maize which take three to four months to reach maturity, the most critical stages are defined largely by presence, absence and timing of the wet spells in November, January and March.

Dry spells are also necessary for agriculture as they facilitate opportunities for cultivating, spraying and weeding, in addition to providing the heating degree days necessary during different phases of crop phenology.

As mentioned earlier, the average rainfalls in November, January and March have been on the decrease. These are crucial months in terms of agriculture. Considering that the effective growing season with respect to rain-fed agriculture is traditionally from November to March, there is therefore an inevitable need to review the crop calendar and staple crop type as well as water harvesting and water conservation techniques. The summer season from a rainfall perspective is not continuous, but multi-modal, weather bearing systems in early and late summer are different. There is need to supplement water through irrigation every other month.

TEMPERATURE PATTERNS

Temperature fluctuations are, like rainfall, vital for agriculture. How they influence crop growth is not the subject of this chapter. Generally these play a role in photosynthesis, heating and cooling degree days, evapotranspiration, evaporation, radiation, vapour pressure as well as relative humidity. Figures 1.5 and 1.6 are really averaged annual temperature graphs for Zimbabwe from July 1933 to June 1995, inclusive.

Reference to the figures shows a general increase in the temperatures. It is apparent that the maximum temperatures have shown the greatest increases, more rapidly since 1973. A trend analysis of the data gives the following linear regression equations:

$$T_{\max} = 26.5 + 0.01 * Y \quad (\text{for Figure 1.5})$$

$$T_{\min} = 13.7 + 0.0005 * Y \quad (\text{for Figure 1.6})$$

where T_{\max} and T_{\min} are the mean annual maximum and minimum temperatures and Y are the number of years after 1933. The equation suggests, barring other

ZIMBABWE MEAN ANNUAL TEMPERATURE Maximum temperature: 1933-1994

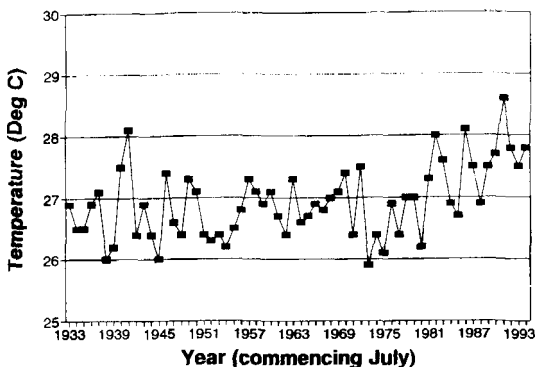


Figure 1.5 Time series of mean annual maximum temperatures for Zimbabwe between 1933 and 1995.

ZIMBABWE MEAN ANNUAL TEMPERATURE Minimum temperature: 1933-1994

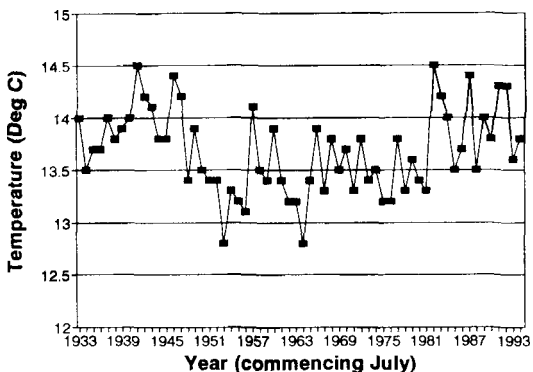


Figure 1.6 Time series of mean annual minimum temperatures for Zimbabwe between 1933 and 1995.

factors, the mean annual temperature in the year 2000 would be above 28°C, an increase of almost 2°C since 1933. While the long term mean minimum temperature indicates a little change since 1933, it is also evident that the night time temperatures have shown a steady increase from 1963.

PROSPECTS FOR FUTURE CLIMATE CHANGE

The climate of Zimbabwe has become more variable and extreme. There have been relatively frequent droughts with only rare excursions in the other extreme (floods) since the mid-1970s. The persistent warm phase of the El Niño/

Southern Oscillation phenomenon from 1990 to mid-1995 has been unusual since instrumental records began (over 120 years ago). Climate records are neither consistent nor long enough for one to ascertain whether the decline in the country's seasonal rainfall is temporary or here to stay. If the declining trend persists (as is the indication), then the demand for mitigation measures is even greater and more urgent. Less rainy days in November, January and March imply that irrigation will soon be part and parcel of farming everywhere in Zimbabwe, including in agro-ecological regions I, II and III. Careful planning is required by water resource managers with regard to dam construction. The dams should not be built without feasibility studies on downstream water table levels and landuse practices, otherwise the hydrological cycle would be severely affected.

Globally, the mean surface temperature has increased by between 0.3 and 0.6°C, most significantly since the mid-1970s. The general tendency is toward a reduced diurnal temperature range over land mainly because nights have warmed more than days. The increases in the eighties and early nineties have been among the warmest in the period of instrument record (over 130 years). Climate models project an increase in global mean surface temperatures of about 2°C by 2100. This is the "best estimate" value of climate sensitivity which takes into consideration forecast increases in aerosols. For Southern Africa, some models are projecting an increase of up to 7°C. With Zimbabwe's temperatures already up by between 1.5 and 2°C, this simulation may not be far from correct. More research is needed to carry out sensitivity analysis programmes and potential impact assessments like climate versus agricultural vulnerability.

It must be emphasised also that many factors still inhibit our ability to unambiguously detect the degree of future climate change. Inadequacies still exist in our understanding of the physics and dynamics of the atmosphere, particularly in the estimation of greenhouse gas emissions and their biogeochemical cycling, in estimating feedbacks associated with clouds, vegetation and oceans as well as systematic collection of instrumental and proxy observations of climate system variables. In addition, future unexpected, large and rapid climatic changes should not be ruled out. These are, however, extremely difficult to predict.

CONCLUDING REMARKS

The popular dictum that "the past is a key to the future" is no longer applicable. It should be "What will happen in the future is not necessarily limited to what has happened in the past". This is mainly because anthropogenic effects from activities like industrialisation, urbanisation and deforestation have increased and will dominate in charting the shape of future climate. For agriculture, these are occurring at a time when the seasonal rainfall is becoming more uncertain,

extreme events are becoming more severe and droughts are becoming more frequent and prolonged. Now is the time to seriously research on new hybrids and educate the public on the need for water harvesting and harnessing.

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