# Spatial and temporal analysis of the recent drought in the summer rainfall region of Southern Africa*

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### Abstract

A technique was developed to depict spatially, the extent, relative severity and location of the areas most affected by the drought in the period ending 1982/83. This form of analysis showed that large parts of the country were severely affected in the recent drought. However, it was also apparent that in many parts of the country the summer rainfall totals for this period were considerably higher than the lowest on record.

## Introduction

Much has been written in overgeneralised, semi-scientific and often emotive terms, in the popular press, concerning the severity, extent and frequency of recurrence of the drought of the early 1980's in the summer rainfall region of Southern Africa.

In order to study a phenomenon such as drought it is desirable to seek an objective definition of drought. However, to date no universally acceptable definition has been developed, partly since drought is a non-event as opposed to a distinct event such as a flood (Hershfield *et al.*, 1973). Thomas (1965) draws a distinction between 3 types of drought:

- a meteorological drought occurs when the rainfall is abnormally low;
- an hydrological drought occurs when actual water supply is less than the minimum necessary for normal operations; and
- an agricultural drought exists when soil moisture is depleted to the extent that crop yields are reduced considerably.

It is clear from the above that drought is a relative rather than an absolute phenomenon. This analysis is concerned with the phenomenon of a meteorological drought and is designed specifically to reflect *inter alia* the relative aspect of the drought phenomenon. It is essential to distinguish between drought and aridity, where both are characterized by a lack of water, but, while aridity carries the connotation of a more or less permanent climatic condition, drought is a temporary condition (Schulze, 1984).

Whatever criterion is used to assess a drought, Yevjevich (1967) states that some or all of the following aspects should be considered:

- the duration of periods, meeting non-exceedence criteria;
- the probability of occurrence;
- the severity;
- the time of occurrence within the annual cycle; and
- the areal extent.

The phenomenon of drought has been studied by many researchers in South Africa over the past few decades. Much of this research by *inter alia* Buys *et al.* (1979), Dyer (1976), Dyer (1979), Dyer and Gosnell (1978), Dyer and Tyson (1977), Louw (1980), Louw (1982), Weather Bureau (1960), Weather Bureau (1972), Whitmore (1962), Whitmore (1962b), has focussed on the apparent persistence of periods of above or below average rainfall and the duration and frequency of occurrence of such periods. In contrast, the emphasis in this paper is on the relative severity and areal extent of such dry periods.

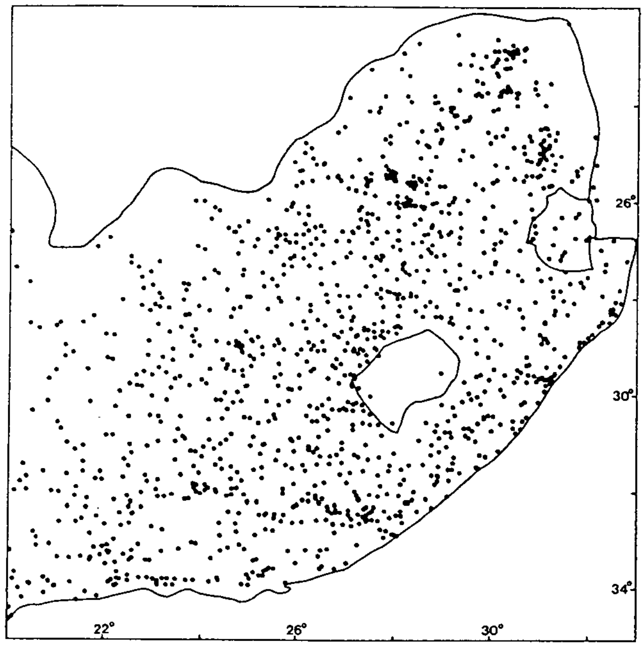


*Figure 1*
*Locations of all the stations used in the spatial depiction of the drought.*

## Methods of analysis

This paper presents an objective assessment of the rarity, severity and spatial extent of this drought from a specific meteorological (as distinct from an agricultural or hydrological) point of view by analysing summer seasonal rainfall totals for over 2 400 long-term rainfall stations, all of which had daily data processed up to the end of March 1984. Summer rainfall totals were chosen as the

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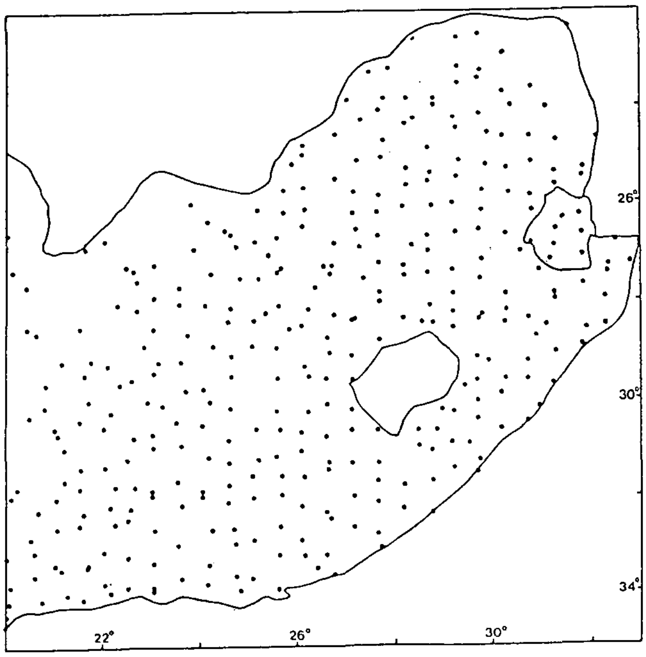


*Figure 2*
*Location of the first station encountered in each Weather Bureau sector.*

basis for an index of drought since most of the area covered by this investigation receives over 70 per cent of its rainfall in the summer months (Weather Bureau, 1960). In addition, the summer rainfall total is a good indicator of potential agronomic yield, reservoir yield and supplementary irrigation requirements of a season (Schulze, 1983).

Droughts of varying lengths have different effects on different water users. Therefore it was decided to investigate not only the one single year's summer rainfall totals but cumulative two, three and four year summer totals as well. Various indices were developed in order to provide a relatively undistorted categorisation of the drought despite disparities in spatial and temporal distribution of the available rainfall records. These indices are used to indicate which drought sequences have been the worst on record, both spatially and temporally.

The analysis was undertaken in two distinct phases. First an index was developed to identify the most severe drought periods in the record. Then having selected the most severe drought periods, by the aforementioned index, the areal extent, location and relative severity of these droughts were presented cartographically. This form of the analysis revealed that large parts of Southern Africa experienced a severe and extended drought during the summer rainfall periods ending in March 1983. However, it was also apparent that in many areas, supposedly suffering from a so-called 200 year drought, the summer rainfall totals for this period were considerably higher than the lowest on record, which at most locations extended back only 60 years.

## Data base preparation

The rainfall data used were supplied by the South African Weather Bureau. The daily data from 2 408 stations each with a longer than 30 year daily rainfall record were processed to yield monthly rainfall totals. These monthly totals were then aggregated to form totals of summer rainfall which for this study was taken as the period September through March. Thereafter single summer as well as the two, three and four consecutive summer totals were calculated for each station. In the event of a summer total being missing, the sequence of consecutive summers was broken and the summation was reset to zero and only resumed again when the summer's rainfall record continued.

The data base also included the latitudinal and longitudinal positions of each rainfall station. These data were necessary for the spatial depiction of the drought indices.

## Index of drought severity

Drought being a relative phenomenon, it is desirable that any index used to classify its severity should reflect this fact. The incorporation of such a property in the index of drought was therefore one of the criteria for this index. A further criterion was that the index should reflect the rank order position of the drought sequences at each station.

The procedure to obtain such an index was as follows:

- the mean summer rainfall at the station for the period under analysis was calculated;
- the value of each of the period totals, as a percentage of the mean for that station, was then computed;
- the period with the smallest percentage was identified;
- each of the period totals was classified into groups of 5 per cent of the mean, the smallest percentage being the starting point for this classification; and
- finally an index of 1 was assigned to each of the summer rainfall totals which were within 5 per cent of the mean above the driest and an index of 2 to those periods with summer rainfall totals from 6 to 10 per cent of the mean above the driest and so on.

The resultant indices were grouped into categories and then used as the basis for the maps (Figures 3 to 9) which depict the spatial distribution of the relative drought severity. This form of analysis was also applied to the data for the identification of the most severe drought periods on record. However, additional routines were also applied to the data which were used for this latter purpose.

### Index to identify the most severe drought

The index to reveal the most severe drought was developed as follows:

- the "rank order" index, described earlier, was calculated for each station in the data base;
- thereafter the mean "rank order" index for the entire study area was computed for each analysis period; and
- the period with the lowest mean "rank order" index was identified as the most severe drought period for the region as a whole.

This form of analysis did, however, introduce serious spatial and temporal distortions due to the non-uniformity of distributions

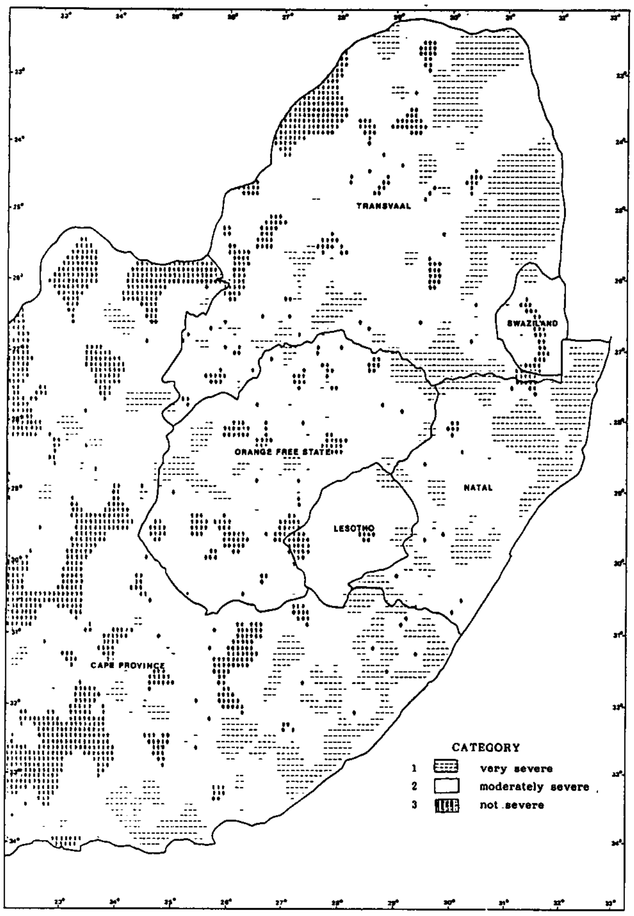


*Figure 3*
*Categorised spatial depiction of the 1 summer (1982/1983) drought.*

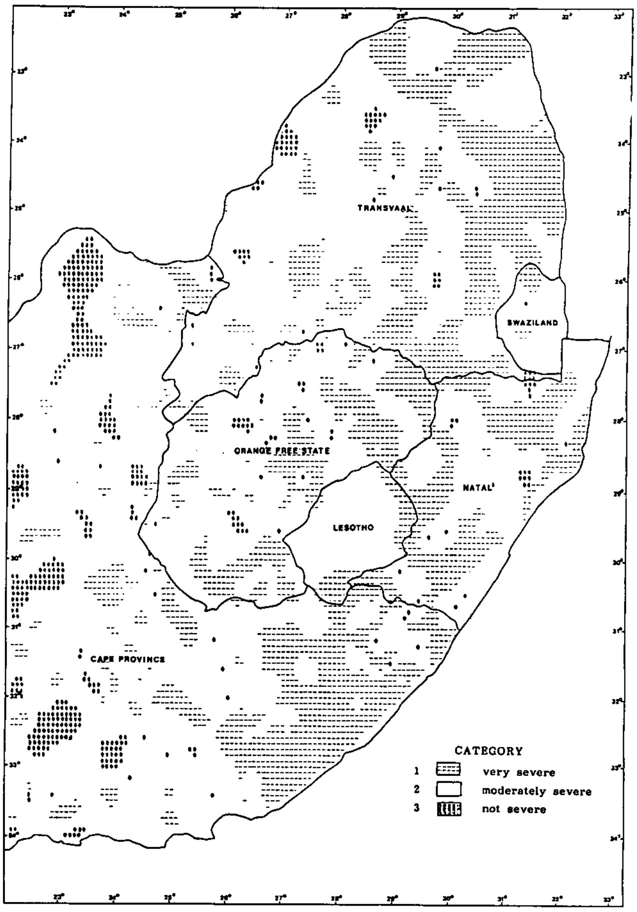


*Figure 4*
*Categorised spatial depiction of the 2 summer (1981/82 – 1982/83) drought.*

of the data, both spatially and temporally. In order to rectify this distortion the index was calculated using the mean summer rainfall totals for each Weather Bureau sector in place of the totals for each station. The distribution of stations used in the spatial depiction and the development of the most severe drought index are shown in Figure 1 and Figure 2 respectively. In Figure 2 only the first station which was encountered in each Weather Bureau sector was plotted. The distribution of stations in Figure 2 shows that very little spatial distortion remains in this index. The contribution of each area of the country is thereby weighted equally in the analysis. Ninety three per cent of the Weather Bureau sectors within the study area were represented in this index; 89 per cent of the sectors represented had merged records which covered the period 1925 – 1984.

On the basis of this index the six most severe drought periods for the single and the two, three and four consecutive summers were identified. These periods are presented in Table 1.

According to this index, the drought of the early 1930's is not revealed to be among the most severe on record. The recent drought of 1981 – 1983 was the most severe on record if one considers the one and two year drought sequences. However, from this it appears that the drought of the late 1960's was the most severe in terms of the 3 and 4 year periods. Such a drought would have a pronounced effect on water resources and dam levels in particular.

## Spatial depiction of the drought indices

In an analysis of this nature it is not only desirable to evaluate the relative severity and overall extent of a drought but it is also essential to establish the location of the drought areas particularly when comparing the one versus two, three or four year drought, or when comparing the current drought with historical ones. The position of these areas in relation to the catchments of large dams such as Vaal Dam and Midmar Dam supplying water to important irrigation schemes or metropolitan areas is vital to our appreciation of what occurred in these areas during the drought.

Initially a single digit, the drought index was printed at the location of the rainfall station. The result was a random scatter of points, as may be appreciated from Figure 1. The intention was then to interpolate, manually, in order to establish three levels of drought severity. However, this exercise did not prove to be satisfactory as the extent of the area of influence of each drought index point was in considerable doubt. It was therefore desirable that a more objective approach be sought.

Polynomial spline interpolation routines were therefore applied to the scatter of station drought indices. Interpolation was performed onto a square grid at 5 min of a degree intervals. The gridded data of interpolated values were then classified into the three categories of drought severity, namely:

| | | |
|---|---|---|
| Category 1: | $<10$ per cent | of the mean above the |
| Category 2: | 11 – 35 per cent | driest summer period |
| Category 3: | $>35$ per cent | on record. |

The picture which emerged when these classified data were plotted was a bold one. Figures 3, 4, 5, 6, 7, 8 and 9 depict the spatial patterns. This technique of interpolation, classification and matrix printing proved to be very fast and effective.

## Discussion of the spatial patterns of relative drought severity

The analysis shows that the summer rainfall region of Southern Africa suffered from a very extensive and severe drought for the one, two, three and four year periods ending in March 1983. The two year drought was particularly extensive. It is estimated that during this period 35 per cent of the study area suffered a drought which was classed Category 1, i.e. the most severe of the categories. As far as the one, two, three and four year drought periods were concerned it is evident that the eastern part of Southern Africa was more severely affected than the central and western part.

What is of particular interest is the intrusion of areas which received moderate amounts of rainfall, i.e. Category 3 droughts, into otherwise severe drought stricken areas. It may be deduced from this that the extensive, frontal rains occurred with rarity in these periods. However, isolated and in some cases, substantial thunderstorms must have occurred.

In order to provide some facts of topical interest, three areas were selected for more detailed assessment. These areas were the Vaal Dam catchment, Midmar Dam catchment and the Umfolozi catchment. Table 2 gives a breakdown of the area covered by the droughts of each category in these regions.

The drought for all four time periods in the catchment area of the Vaal Dam fell into Categories 1 and 2, i.e. very and moderately severe. However, the combined flow into the Vaal and Grootdraai Dams was far lower relative to the flow during previous drought periods (Alexander, 1984), than is suggested by the rainfall. A possible explanation for this anomaly is that the agronomic practices in the catchment have improved and hence a higher percentage of the rainfall is being retained on the land. Increases in the number of farm dams (Maaren, 1985) and also in upstream usage could also be additional contributary factors.

It is interesting to note that prior to cyclone Domoina in January 1984 the Umfolozi catchment was in the grip of a very severe long-term drought. The Midmar Dam catchment, which was of particular interest to inhabitants of Durban and Pietermaritzburg, was affected more by the two, three and four consecutive year rather than the single season drought. Despite stringent water restrictions the level of Midmar Dam dropped to 14 per cent of its capacity during this drought period.

By way of comparison with the 1980's drought Figure 7 shows the drought pattern for the three consecutive summers' rainfall ending in March 1933. It is evident that this much publicised drought of the early 1930's occurred predominantly in the Orange Free State, Transvaal and in the Northern Natal. Perhaps the fact that this drought of 50 years ago was experienced in the most densely populated region of South Africa namely the Southern Transvaal and also that it occurred concurrently with a major world-wide economic depression accounts for the fact that it is still referred to as the big drought. Figures 8 and 9 show the extensive area covered by, and the severity, of the late 1960's early 1970's drought for the three and four consecutive summer periods which ended in March 1970 and March 1971 respectively. Unlike the drought of the 1980's this drought was not concen-

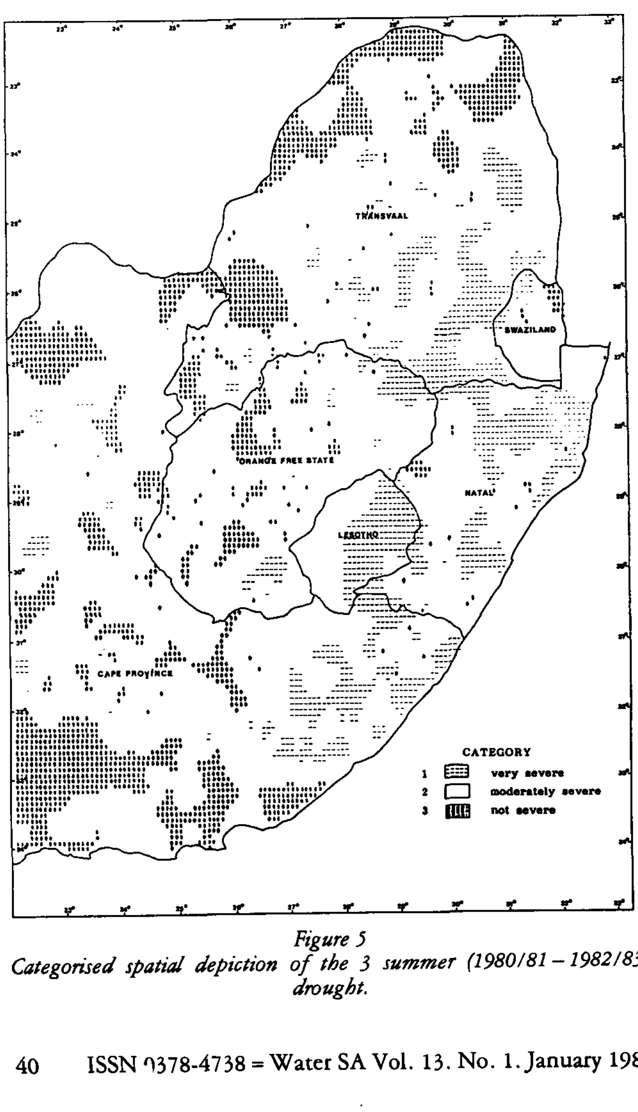


*Figure 5*
*Categorised spatial depiction of the 3 summer (1980/81 – 1982/83) drought.*

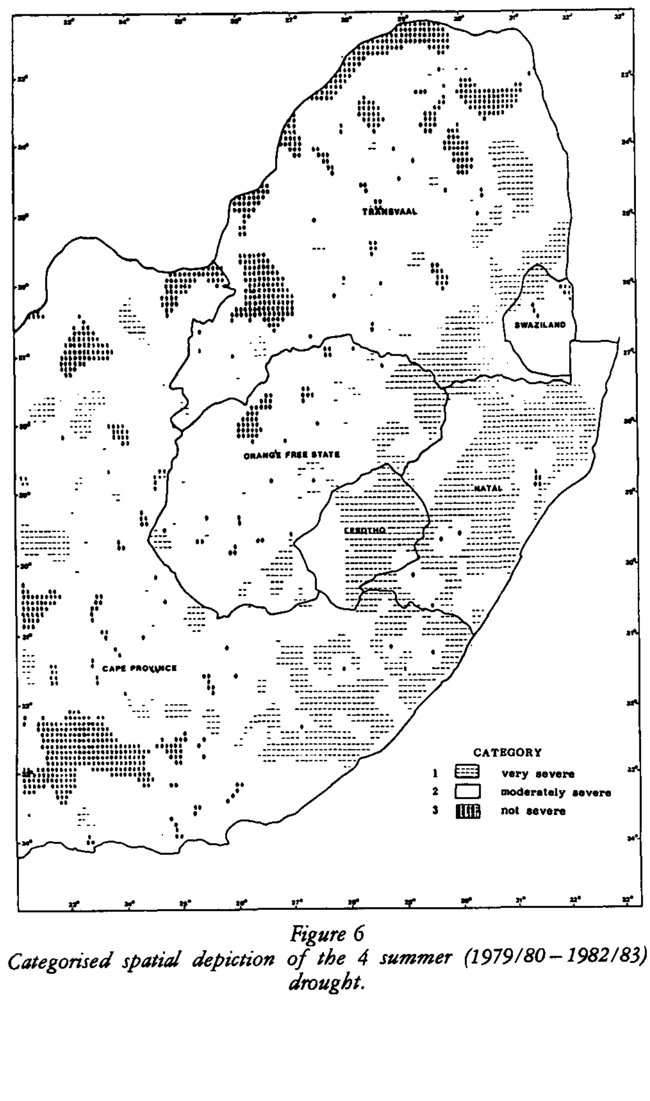


*Figure 6*
*Categorised spatial depiction of the 4 summer (1979/80 – 1982/83) drought.*

trated primarily along the eastern seaboard of Southern Africa. The central and western parts of the summer rainfall region of South Africa were more severely affected by the drought of the late 1960's.

## Conclusion

This study has shown that the drought of the early 1980's was the most severe drought overall on record in the summer rainfall region of Southern Africa according to the indices defined previously. However, it has also been shown very clearly that in many areas the summer rainfalls for this period were substantially higher than the lowest on record. The scattered distribution of the Category 1 drought (i.e. very severe) is clear from the maps. This phenomenon is also apparent when one considers that during the drought some towns were curbing water usage by up to 50 per cent of their previous normal levels whilst at the same time nearby farms were recording average crop yields. The drought was more severe in the eastern parts of Southern Africa. The central and western areas were not affected to the same extent according to the drought definition used.

It is evident from this study that substantial summer thunder showers must have occurred in parts. Neighbouring stations' records had ranked indices of 1 and 9 (or larger) respectively. What appears not to have been present in this period were the long duration widespread rains which often occur.

Another point to emerge was that it is necessary to have a comprehensive distribution of rainfall stations in order to assess the spatial extent of a drought properly. Large-scale extrapolation from a small and scattered base of stations can lead to gross errors in the spatial assessment. Of particular concern in this regard is the analysis which precedes the allocation of drought aid to agriculture (Booysen and Rowsell, 1983). Such aid running into millions of Rand, is often decided on the strength of investigations which are at best large-scale extrapolations from limited data.

Finally it must be stressed that it is by no means certain that the drought of the 1980's has been finally broken by the relatively good rains which fell over parts of the summer rainfall region in the summer of 1984/5, as many studies of the apparent periodicities of rainfalls in South Africa have shown, occasional wet years do occur in the so-called dry phase of the cycle (Tyson, 1977).

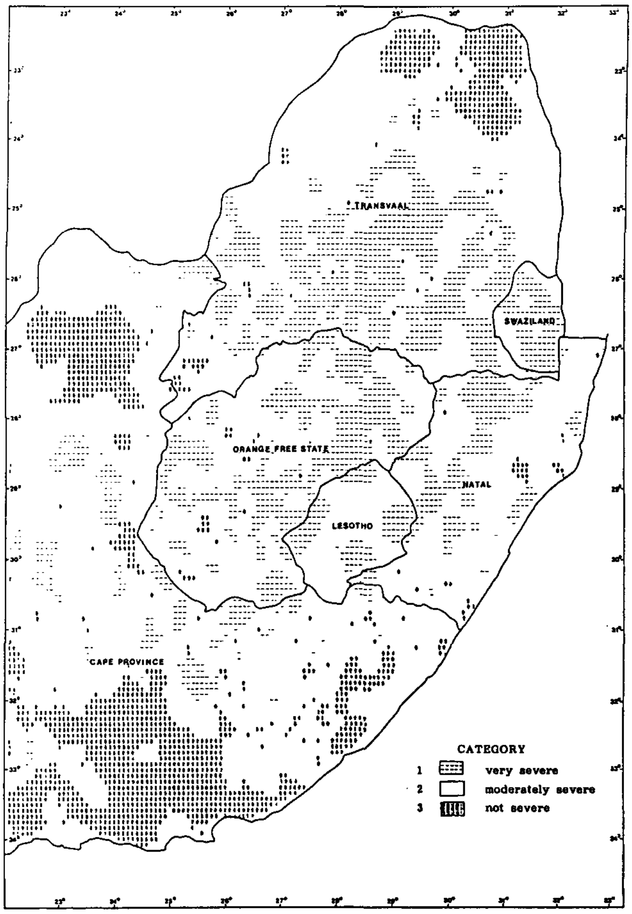


*Figure 7*
*Categorised spatial depiction of the 3 summer (1930/31 – 1932/33) drought.*

## Acknowledgement

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**TABLE 1**
**RANK ORDER OF THE SIX DRIEST PERIODS ON RECORD FROM 1925 – 1984**

| | Single Summer | 2 Consecutive Summers | 3 Consecutive Summers | 4 Consecutive Summers |
|---|---|---|---|---|
| driest | 1982/83 | 1981/82 – 1982/83 | 1967/68 – 1969/70 | 1967/68 – 1970/71 |
| 2nd driest | 1969/70 | 1968/69 – 1969/70 | 1981/82 – 1983/84 | 1966/67 – 1969/70 |
| 3rd driest | 1967/68 | 1967/68 – 1968/69 | 1944/45 – 1946/47 | 1964/65 – 1967/68 |
| 4th driest | 1948/49 | 1945/46 – 1946/47 | 1963/64 – 1965/66 | 1965/66 – 1968/69 |
| 5th driest | 1972/73 | 1982/83 – 1983/84 | 1968/69 – 1970/71 | 1948/49 – 1951/52 |
| 6th driest | 1951/52 | 1964/65 – 1965/66 | 1930/31 – 1932/33 | 1969/70 – 1972/73 |

**TABLE 2**
**PERCENTAGE OF AREA COVERED BY EACH DROUGHT CATEGORY**

| | Single Summer | | | 2 Consecutive Summers | | | 3 Consecutive Summers | | | 4 Consecutive Summers | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Category | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| Catchment | | | | | | | | | | | | |
| Vaal Dam | 25 | 70 | 5 | 70 | 30 | 0 | 40 | 60 | 0 | 60 | 40 | 0 |
| Midmar Dam | 20 | 80 | 0 | 50 | 50 | 0 | 50 | 50 | 0 | 50 | 45 | 5 |
| Umfolozi | 80 | 20 | 0 | 80 | 20 | 0 | 70 | 30 | 0 | 80 | 20 | 0 |

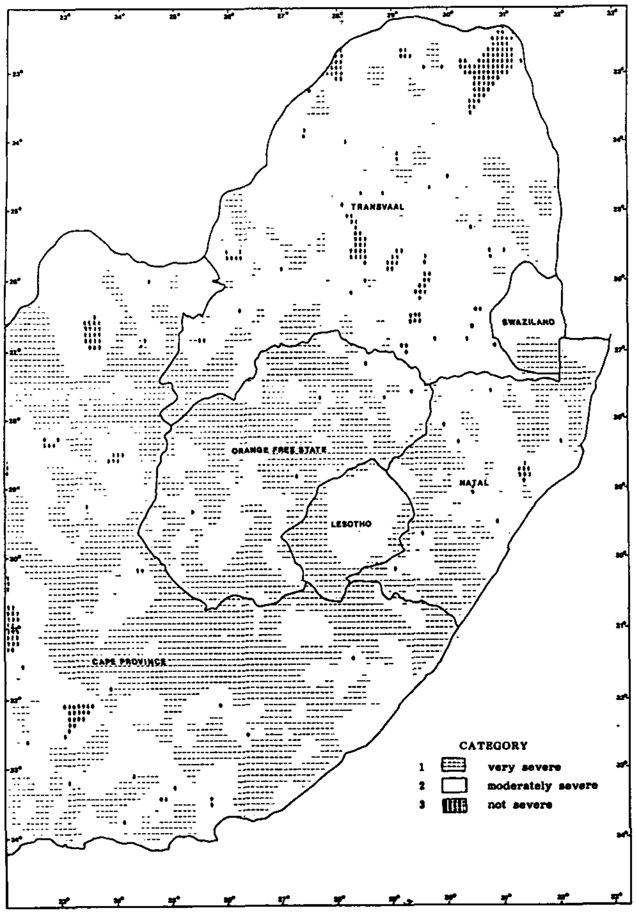


*Figure 8*
*Categorised spatial depiction of the 3 summer (1967/68 – 1969/70) drought.*

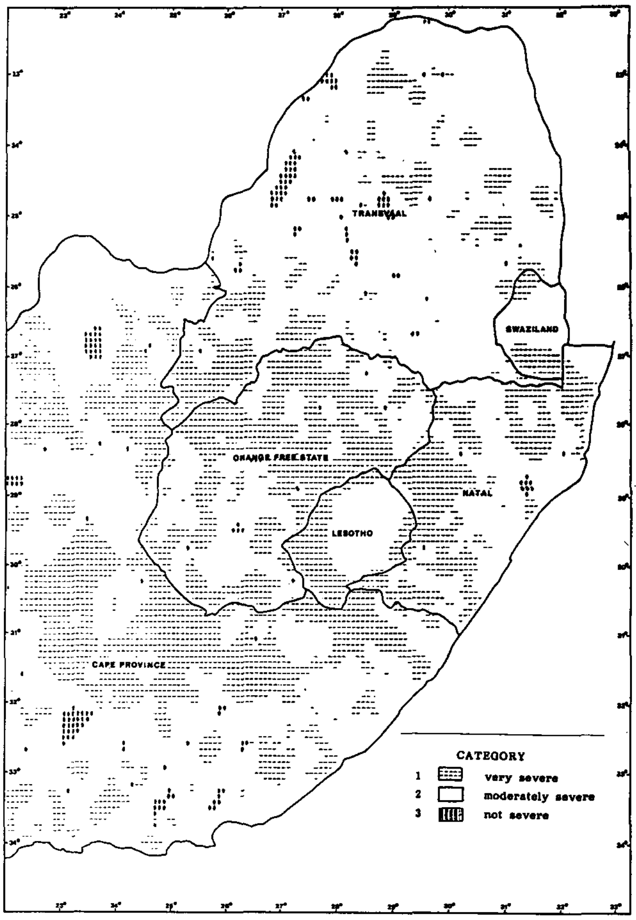


*Figure 9*
*Categorised spatial depiction of the 4 summer (1967/68 – 1970/71) drought.*

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