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Abstract: Short-term changes in the general circulation of the atmosphere, which may lead to prolonged periods of drought, are catalysts for producing accelerated desertification. In southern Africa the northeastward thrust of desertification from the western and central arid and semi-arid areas (the Karoo) has long been recognised, but up til 1970 research failed to demonstrate a clear-cut relationship between the process of desertification and long term rainfall data. The application of sophisticated analytical techniques to regional rainfall data showed, however, that spatial and temporal variations in the Southern African rainfall pattern have a striking degree of organization. The summer rainfall region of the northeastern part of the subcontinent experiences 16–20 year fluctuations, in contrast with 10–12 year fluctuations in the all-season rainfall region along the southern Cape coast. Concentrating on regionally averaged data for the summer rainfall region, the author used Fourier analysis to confirm the persistence of the quasi 20-year fluctuations since 1840. The wet spell of the late 1970s is expected to die out by 1982 and may be followed by a dry spell running from 1983 to 1992. Policy and management practices should be geared to prevent further desertification during this period.

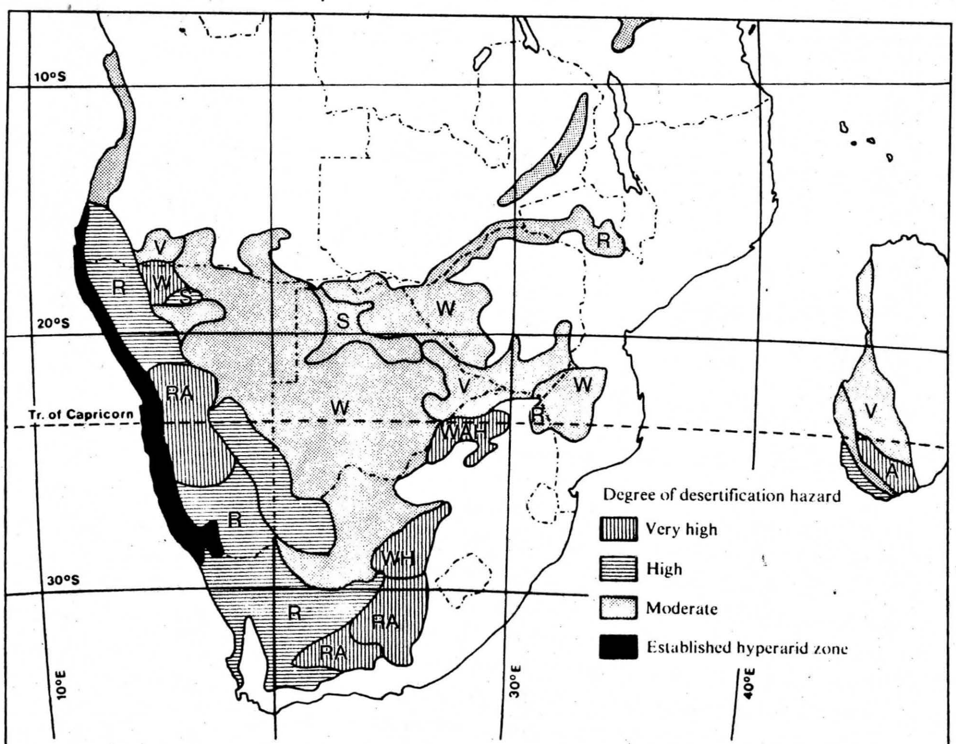
Introduction

Desertification and the attendant problems of declining biological productivity, deterioration of the physical environment and increasing hazards for human settlement and life affect much of Africa in general and southern Africa in particular. The process of desertification is well defined as 'the impoverishment of arid, semi-arid and some subhumid ecosystems by the combined impact of man's activities and drought' (Dregne 1977). Using the three factors: climate, land vulnerability and pressure of human land use, the regional degree of world desertification has been assessed (UNCOD 1977*). Of the world's arid lands 84 % experience a high or very high degree of desertification hazard; of the semi-arid lands only 26 % experience this degree of hazard, but nearly 70 % experience a moderately high degree of hazard.

The so-called march of the desert is probably as old as settled communities and history is replete with examples of how aridification has led to the abandonment of settlement. The best recent example of desert encroachment occurred with the Sahelian drought between 1968 and 1974, when climatically and ecologically it was as if the Sahara had extended its limit southwards by 5 degrees of latitude (Mabbutt 1978). Such desert encroachment is seldom uniform and progressive. Instead it takes place through the coalescence of islands of degradation, as fragile dryland ecosystems are allowed to degenerate through misapplied technology, bad management or other human controls. That man is one of the main agents of desertification is beyond dispute (UNCOD 1977). That long-termed shifts in the climatic zones of atmospheric subsidence are responsible is not conclusively proved. However, short-term changes in the general circulation of the atmosphere that produce prolonged periods of drought are almost always the catalysts for producing accelerated desertification.

* United Nations Conference on Desertification, Nairobi, 29 Aug. – 9 Sept., 1977.

Fig 2 Degree of desertification hazard for southern Africa (after UNCOND 1977)



Desertification map for Southern Africa prepared for UNCOD. Desertification is here defined as 'the intensification or extension of desert conditions; it is a process leading to reduced biological activity, with consequent reduction in plant biomass, in the land's carrying capacity for livestock, in crop yields and human well-being.' Legend: W, surfaces subject to sand movement; R, stony or rocky surfaces subject to aerial stripping by deflation or sheet wash; V, alluvial or residual surfaces subject to stripping of topsoil and accelerated runoff, gully erosion on slopes and/or sheet erosion or deposition on flat lands: S, surfaces subject to salinization or alkalinization; H, subject to human pressure; A, subject to animal pressure.

in 1970 that the pronounced degree of temporal and spatial organization of South African rainfall was first pointed out (Tyson 1970, 1971). The fallacy of the notion of uniform progressive desiccation has been pointed out (Tyson et al. 1975) and shown to be untenable in regionally-aggregated data (Dyer 1976a). Using a variety of different analytical techniques ranging from simple sorting and averaging to sophisticated spectral and principal components analyses, the regional nature and oscillatory character of rainfall changes over the period of meteorological record have been firmly established (Tyson et al. 1975; Dyer 1975, 1976a; Tyson and Dyer 1975; Tyson 1978; Tyson 1980); estimates of future conditions have been attempted (Dyer and Tyson 1977, Tyson and Dyer 1978) and links with the general circulation have been sought (Dyer 1976b, Dyer and Tyson 1978; Tyson 1981).

By mapping the variance associated with different peaks in rainfall variance spectra, a striking degree of spatial dependence and correlation between regions of influence of specific oscillations and climatic regions is evidenced (Tyson et al. 1975). Thus a quasi 20-year fluctuation has its most pronounced expression in the summer rainfall region of South Africa, Swaziland, Lesotho, Botswana and Namibia. By contrast a 10–12-year fluctuation is confined almost entirely to the all-season rainfall belt of the southern Cape coast of South Africa. A 3–4-year fluctuation is ubiquitous, whereas a quasi-biennial oscillation shows its most pronounced expression in the central Cape (Fig 3). The quasi 20-year fluctuation is the predominant one throughout the sub-continent except in the southern Cape where it accounts for slightly less variance than the 10–12-year oscillation.

Taking the region in which the quasi 20-year oscillation is most pronounced and submitting regionally-averaged data for 62 stations in north-eastern South Africa to a 5-term binomial filter and then Fourier analysis, it is possible to define the extended wet and dry periods and extend them back in time to the start of meteorological records, viz. 1841. By taking averages over the suggested wet and dry periods it is possible to assess the extent to which the quasi 20-year oscillation has persisted in time and manifested itself in space (Fig 4).

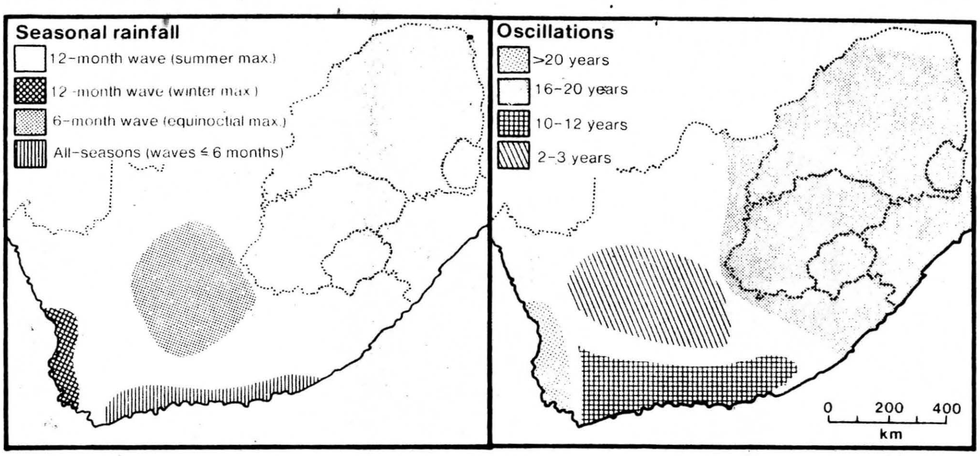


Fig 3 Core areas of seasonal rainfall regimes and regions of predominant oscillations (after Tyson et al. 1975)

Early records are few and sometimes of doubtful reliability; only from 1910 onwards has it proved possible to work with a number of stations exceeding 150. Notwithstanding there is some evidence to suggest that the quasi 20-year oscillation was prevalent in the data from the 1840s onwards. Backward extrapolation suggests that 1844–52 should have been dry. The only station recording during that period showed a mean deviation of –9 %. The period 1853–61 should have been wet; the three stations recording in that period all show positive deviations. All six stations for the period 1862–70 recorded the expected below-normal rainfall. Alternating wet and dry spells continued up to 1905, with the period 1888–96 being the wettest complete spell on record. The regular rhythm of change faltered just after the turn of the century. Thus 1906–15 instead of being wet continued to experience below-normal rainfall over large areas. However, the rhythm was immediately re-established and has continued uninterruptedly from 1906 to the present. Since the turn of the century, over the summer rainfall region of north-eastern South Africa (i.e. north of approximately 29°S), the most consistently dry spell has been that of 1944–53 when the regionally-averaged rainfall for every year was below normal. The driest spell on average was that of 1963–72. The lowest space mean regional rainfall was recorded in 1945; the highest in 1943. The most persistently wet spell has been the present one with five consecutive years with above-normal rainfall. In general, the dry spells have been more persistently dry than the wet spells have been wet. In addition, the dry spells have had a greater areal extent and homogeneity than the wet. With each successive wet spell since the turn of the century the areal extent of the excess-rain areas has increased. Departures for the latest incomplete wet spell are much higher than those of the 1888–96 wet period.

Individual rainfall spectra show the quasi 20-year peak clearly, as spectra for Warmbaths in the Transvaal, Dundee in Natal, Bloemfontein in the Orange Free State, Graaff-Reinet in the Cape Province and others in South Africa illustrate (Fig 5). All the quasi 20-year peaks illustrated are significant at least at the 5 % level. In the spectrum of regionally-averaged data for the summer rainfall region as defined in Fig 3, the quasi 20-year fluctuation is present at 18 years and significant at the 1 % level (Fig 6). Other important peaks in the regional spectrum are that at about 3.5 years (significant at $<$5 %) and that of the biennial oscillation at 2.3 years (significant at $<$5 %).

Using the 62-station, regionally-averaged data for 1910–67 and the Fourier model mentioned previously (Tyson and Dyer 1978), it proved possible to estimate the run of wet years the north-eastern summer rainfall region experienced after 1972 (Fig 7). Reference to Fig 4 reveals the extent to which the sub-continent as a whole experienced the wet spell. The model suggests that the run of wet years may continue with diminishing annual totals until about 1982. Thereafter, providing the pattern of events since 1906 continues to repeat itself, it is quite likely that a dry spell may succeed from about 1983 to about 1992. Whereas the model appears able to estimate the duration of the wet and dry spells, it is unable to predict amplitudes. Since it is predicated on the use of filtered data it is unable to estimate annual rainfall totals; it will only suggest a broad pattern. In the past random forcing has ensured that on average 2 to 3 years in any 9 or 10 of a spell have been wet in a dry spell or vice versa. In the future the same may apply. Notwithstanding the crude estimates, and though they only refer to a region and never to an individual locality, they may have implications for desertification. In the absence of any physio-mathematical models of the general circulation of the atmosphere that will give better results, the estimates given here need to be given attention. Certainly the possibility that the mid- to late-eighties may experience droughts in runs of dry years cannot be ignored.

Implications for Desertification

Even if they do not ultimately lead to large scale desertification, droughts have enormous effects on national economies in southern Africa. In 1969, a year when the

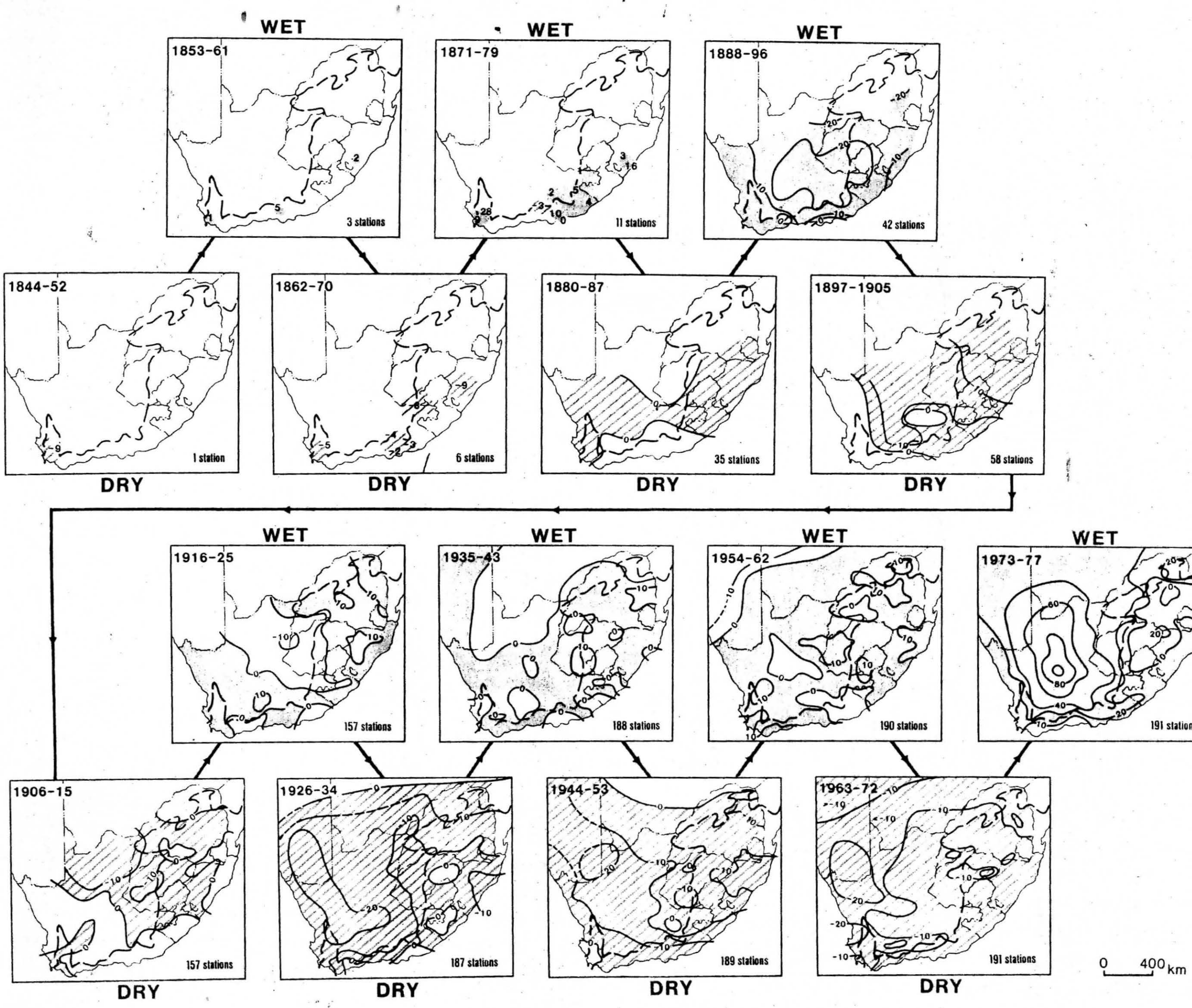


Fig 4 Mean percentage rainfall deviations during alternating wet and dry spells over S Africa from 1844 onwards. Raw data have been used and deviations have been taken from entire-series means except for pre-1880 conditions when the means of Hutchins (1889) were used. Isopleths have been included when two or more stations showed deviations of like sign. The percentages of single isolated stations in zone of unlike sign from 1880 onwards are: 1888–96 nil; 1897–05 5 %; 1906–15 5 %; 1926–34 3 %; 1935–43 2 %; 1944–53 8 %; 1954–62 6 %; 1963–72 4 %; 1973–77 3 %. Over Botswana and Namibia interpolation prior to 1935 may be uncertain owing to paucity of data. The same applies everywhere before 1906. For the period 1906–15, 1910–15 data had to suffice for some stations north of about latitude 29° S

regional average rainfall was slightly below normal during the 1963–72 dry spell, South Africa suffered an estimated R116 million loss in agricultural production due to weather alone (Theron et al. 1973). Of this loss 57 % was due to drought-related causes. The next single most important contributor to the total weather-induced loss was hail damage (9 %). In 1970 50,000 ha of farm land (13 %) in Lesotho suffered complete crop failure (Lesotho 1970). Drought accounted for 78 % of the losses (Wilken 1978).

During extended dry periods livestock and land may suffer grievously. In the 1960s drought in Botswana cattle numbers dropped from about 1.35 million in the pre-drought conditions of 1960 to about 0.9 million in the dry years of 1964–67. With the drought the carrying capacity of the land dropped steadily, overstocking increased and land deterioration progressed rapidly. Cattle died by the tens of thousands. Today, after a succession of wet years and good veld recovery, 3.5 million cattle are back on the land in Botswana. Unless careful forethought is exercised and sound animal husbandry practices implemented, the potential for a repetition of the 1960s disaster is high in the eighties of the possible droughts materialise.

The pressure of increasing population and the concomitant need for increasing production of food crops often leads to the expansion of cultivated areas during good

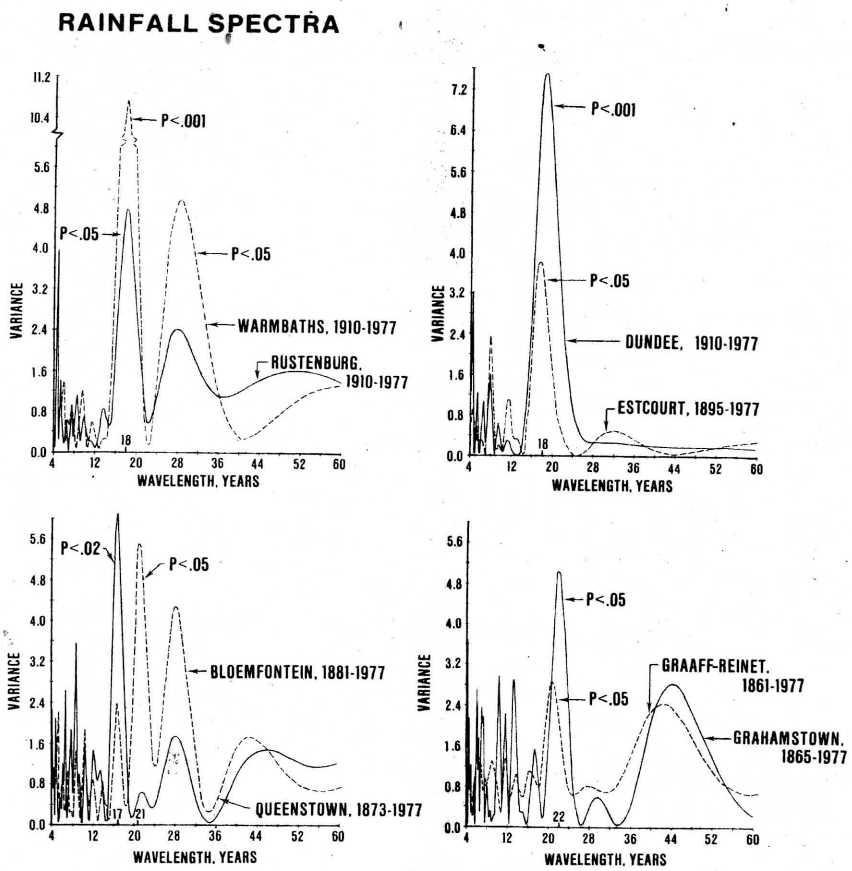


Fig 5 Rainfall spectra for some stations in South Africa. Raw stationary data have been used and analysis has been according to the method of Jenkinson (1976). Significant levels for significant peaks are included

rainfall years into areas not completely suited to supporting such activities. With declining rainfall or drought the ensuing ecological imbalance may result in the collapse of dry-farming systems and the acceleration of conditions leading to land degradation and ultimately desertification.

It has been shown that south of about 18°S the areas vulnerable to desertification occur in the central and western parts of the sub-continent (Fig 2). The eastern boundary of the zone of vulnerability has been included on the maps showing the alternating wet and dry periods during the nineteenth and twentieth centuries (Fig 4). It is clear how the desertification-prone areas of South Africa have experienced alternating extended wet and dry periods since at least 1880. Given the regularity of the climate-induced impetus towards desertification and the bad farm management reported so frequently for the first half of this century and latter half of the last, it is not surprising that Karoo encroachment has occurred over the last ten decades or more. That, if given the chance, the recovery of threatened or even severely damaged ecosystems is possible once climate ameliorates, has been frequently shown, as for example in the case of the dust-bowl areas of Oklahoma after the 1930s (Hare 1977). It is crucial that the land must be allowed to recover. In South Africa this has not always happened and after each successive dry period veld recovery has been insufficient to reverse the long-term trend towards desertification in central parts of the country. Present practices of veld reclamation, soil conservation and farm management have, however, improved the situation since mid-century. For instance hydrologists report a reduction in run-off of up to 60 % in the Karoo since the fifties (Alexander 1978). Whether the advance of Karoid vegetation into the grasslands of the north and east has been checked as a result remains to be seen.

Conclusion

Desertification occurs for a variety of reasons. Whereas man is most commonly the main cause of the process, drought is usually the catalytic triggering mechanism. Periods of drought in areas of land vulnerability and desertification hazard are thus times when great care must be exercised in order to halt and reverse environmental degradation. Over southern Africa the possibility that the eighties may be drier than normal and that drought conditions may prevail over large areas is one that it would be wise not to ignore, notwithstanding the crude nature of the estimates of future climatic conditions.

Acknowledgements

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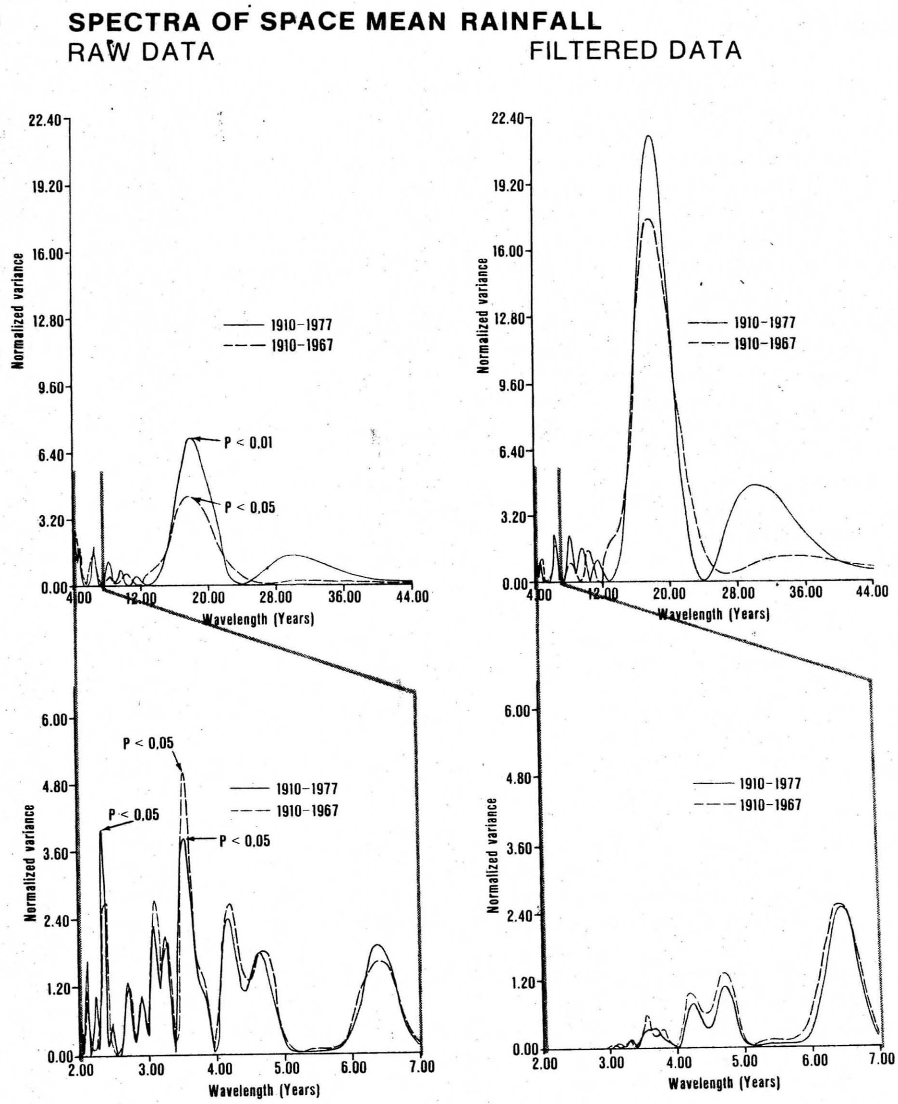

Fig 6 Spectra of space mean rainfall series for 62 stations in the summer rainfall region (as defined in Fig 2). In each case the spectrum in the range 2–7 years has been enlarged. Significant peaks are indicated in the spectrum of raw data. Filtering has been effected using a 5-term binomial filter

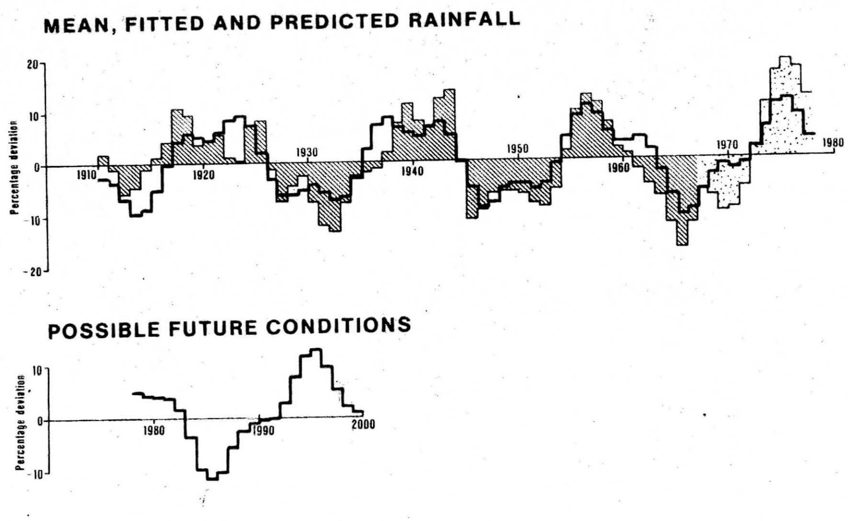

Fig 7 The smoothed summer rainfall area regional averaged series for 1910–67 (cross-hatched) and the fitted curve extrapolated to 1977 using the model of Tyson and Dyer (1978). The comparison between predicted and observed rainfall for the period 1968–77 is shown (dotted shading). In the lower part of the figure an estimate of possible future regional rainfall averages is suggested (based on extrapolation of the 1910–77 model)

References

Acocks, J.P.H.: Veld types of South Africa. Mem. Bot. Surv. S. Afr. 28, 1–192 (1953)

Agric. J. Union S.A.: Is South Africa drying up? 4, 662–666; 6, 693–694, 1027–1029; 7, 47–60, 113–114, 150–154, 256–261, 243–424, 523–538, 732–739, 894–898; 8, 107–113, 262–265 (1912–1914)

Alexander, W.J.R.: Personal communication. (1978)

Barber, F.H.: Is South Africa drying up? Agric. J. Cape H.G. 86, 167–170 (1910)

Bayer, A.W.: The ecology of grasslands. In: Meredith, D.: The grasses and pastures of South Africa. pp. 539–550. Central News Agency, Johannesburg 1955.

Donaldson, C.H., Kelk, D.M.: An investigation of the veld problems of the Molopo area: 1 Early findings. Proc. Grassl. Soc. S. Afr. 5, 50–57 (1970)

Dregne, H.E.: Status of desertification in the hot arid lands. United Nations Conference on Desertification, Nairobi, Kenya: A/Conf. 74/31, pp. 4–6, 1977.

Dyer, T.G.J.: The assignment of rainfall stations into homogeneous groups: an application of principal components analysis. Quart. J. R. Met. Soc. 101, 1005–1013 (1975)

Dyer, T.G.J.: On the components of time series: the removal of spatial dependence. Quart. J. R. Met. Soc. 102, 157–165 (1976a)

Dyer, T.G.J.: Meridional interactions between rainfall and surface pressure. Nature 264, 48–49 (1976b)

Dyer, T.G.J., Tyson, P.D.: Extended forecasts of above- and below-normal rainfall over South Africa. Jour. Appl. Meteorol. 16, 145–147 (1977)

Dyer, T.G.J., Tyson, P.D.: Inter-hemispheric associations in the year-to-year variation of major components of the general circulation of the atmosphere. S. A. J. Sc. 74, 325–328 (1978)

Hare, F.K.: Climate and desertification. U.N.C.O.D. A/Conf. 74/5, pp. 140, 1977.

Hutchins, D.E.: Cycles of drought and good seasons in South Africa. Times Office, Wynberg 1888.

Jenkinson, A.F.: A powerful elementary method of spectral analysis for use with monthly, seasonal, or annual meteorological time series. Met. 0 13, Branch Memo. No. 57, Bracknell (1976)

Kokot, D.F.: An investigation into the evidence bearing on the recent climatic changes over Southern Africa. Union of S.A., Irrigation Dept. Memoir. Govt. Printer, Pretoria 1948

Mabbutt, J.A.: Desertification of Australia in its global context. Search 9, 252–256 (1978)

Lesotho: 1970 Census of Agriculture Report. Bureau of Statistics, Maseru, pp. 77–78 (1970)

Phillips, J.: Deterioration in the vegetation of the Union of South Africa, and how this may be controlled. S. Afr. J. Sc. 35, 476–484 (1938)

Schwarz, E.H.L.: The progressive desiccation of Africa: the cause and the remedy. S. Afr. J. Sc. 15, 139–190 (1919)

Schwarz, E.H.L.: Kalahari scheme as the solution of the South African drought problem. S. Afr. J. Sc. 20, 208–222 (1923)

Shantz, H.L., Turner, B.L.: Photographic documentation of vegetational changes in Africa over a third of a century. Univ. of Arizona 1958.

South Africa (Union of): Desert encroachment committee. Report. Government Printer, Pretoria, U.G. 59 of 1951, 27 pp., chairman C.R. van der Merwe 1951.

South Africa (Republic of): Commission of enquiry into Agriculture Reports. Interim Report, R.P. 61 of 1968, 100 pp., chairman M.D. Marais; second report, R.P. 84 of 1970, 234 pp., chairman M.D. Marais; third (final) report, R.P. 19 of 1972, 221 pp., chairman S.J. du Plessis 1968–1972.

Talbot, W.J.: Land utilization in the arid regions of Southern Africa. Part I: South Africa. Arid Zone Res. 17, 299–331 (1961)

Theron, M.J., Mathews, V.L., Neethling, P.J.: The economic importance of the weather and weather services to the South African agricultural sector – a Delphi survey. C.S.I.R. Research Report 321, 134 pp., 1973.

Tidmarsh, C.E.M.: Pasture research in South Africa. Proc. Grassl. Soc. S. Afr. 1, 21–26 (1966)

Tyson, P.D.: Rainfall fluctuations over South Africa during the period of meteorological record. Paper presented to the International Convention: Water for the future. Pretoria 1970.

Tyson, P.D.: Spatial variation of rainfall spectra in South Africa. Ann. Ass. Am. Geog. 61, 711–720 (1971)

Tyson, P.D.: Rainfall changes over South Africa during the period of meteorological record. In Biography and Ecology of Southern Africa. M.J.A. Werger (Ed.). W. Junk, The Hague, pp. 55–69, 1978.

Tyson, P.D.: Temporal and spatial variation of rainfall anomalies in Africa south of latitude 22° during the period of meteorological record. Climatic Change 2, 363–371 (1980)

Tyson, P.D.: Atmospheric circulation changes and the occurrence of extended wet and dry spells over southern Africa. J. Climatol. 1 (in press) (1981)

Tyson, P.D., Dyer, T.G.J.: Mean fluctuations of precipitation in summer rainfall region of South Africa. S. Afr. Geog. J. 57, 104–110 (1975)

Tyson, P.D., Dyer, T.G.J.: The predicted above-normal rains of the seventies and the likelihood of drought in the eighties. S.A.J. Sc. 74, 372–377 (1978)

Tyson, P.D., Dyer, T.G.J., Mametse, M.N.: Secular changes in South African rainfall: 1880–1972. Quart. J. R. Met. Soc. 101, 817–833 (1975)

UNCOD: Report of the UN Conference on Desertification, Nairobi, Kenya: A/Conf. 74/31 pp. 4–6, 1977.

Vorster, J.H.: Trends in long range rainfall records in South Africa. S. Afr. Geog. J. 39, 61–66 (1957)

Werger, M.J.A.: Phytosociology of the Upper Orange River valley. V & R. Pretoria, 222 pp., 1973.

Wilcocks, J.R.N.: Desert encroachment in South Africa. Unpublished M. A. dissertation, University of the Witwatersrand, Johannesburg, 347 pp., 1977.

Wilken, G.C.: Agroclimatic hazards and risk perception in Lesotho: a preliminary view. Paper presented at the I.G.U. Regional Conference, Ibadan, Nigeria July 1978, 4 pp. (mimeo), 1978.