

# Spatial variability and temporal periodicity of rainfall in the Etosha National Park and surrounding areas in northern Namibia

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## ABSTRACT

Because of the possibility of long - term desiccation and resulting ecological problems in southern Africa, analyses of spatial variability and temporal periodicity of rainfall are of great importance. Rainfall in the Etosha National Park and surrounding areas in northern Namibia decreases from east to west and rainfall isohyets show a nearly meridional arrangement. On the basis of a dense network of rain gauges in the Etosha National Park, evaluations of seasonal rainfall amounts show different spatial patterns for every rainy season 1983/84-1989/90. High variability of more than 40% occurs especially in the north-western part and in the area of the Adamax Pan in the Etosha National Park and characterises the reliability of rainfall. There is indication for decreasing rainfall since the beginning of the century but the succession of wet and dry spells of 10 stations in northern Namibia shows clear oscillations of 20, 16, 12, 8, 6, 4, 3, and 2 years, which are different from the 18-year oscillation identified in other regions of southern Africa.

## INTRODUCTION

The idea of decreasing seasonal rainfall and subsequently of southern Africa becoming drier has long been a subject for discussion (for example Livingstone 1857, Dove 1893, Passarge 1904, Jaeger & Waibel 1921, Tyson 1986, Buch 1993). Because of the pressure of a growing population, depletion of natural resources and related ecological problems the prominence of this theory is increasing. The first detailed studies of changing rainfall in Namibia

since the 1940s were carried out by Gellert (1955). Subsequently for the whole of southern Africa Tyson (1986) analysed rainfall since the 1970s. Today the more relevant question is not the desiccation of southern Africa but the identification of rainfall cycles with wet and dry spells to provide a base for agricultural planning.

In Namibia, farming and agriculture are the basis of the national economy. For this reason an investigation of the spatial variability and the temporal periodicity of rainfall

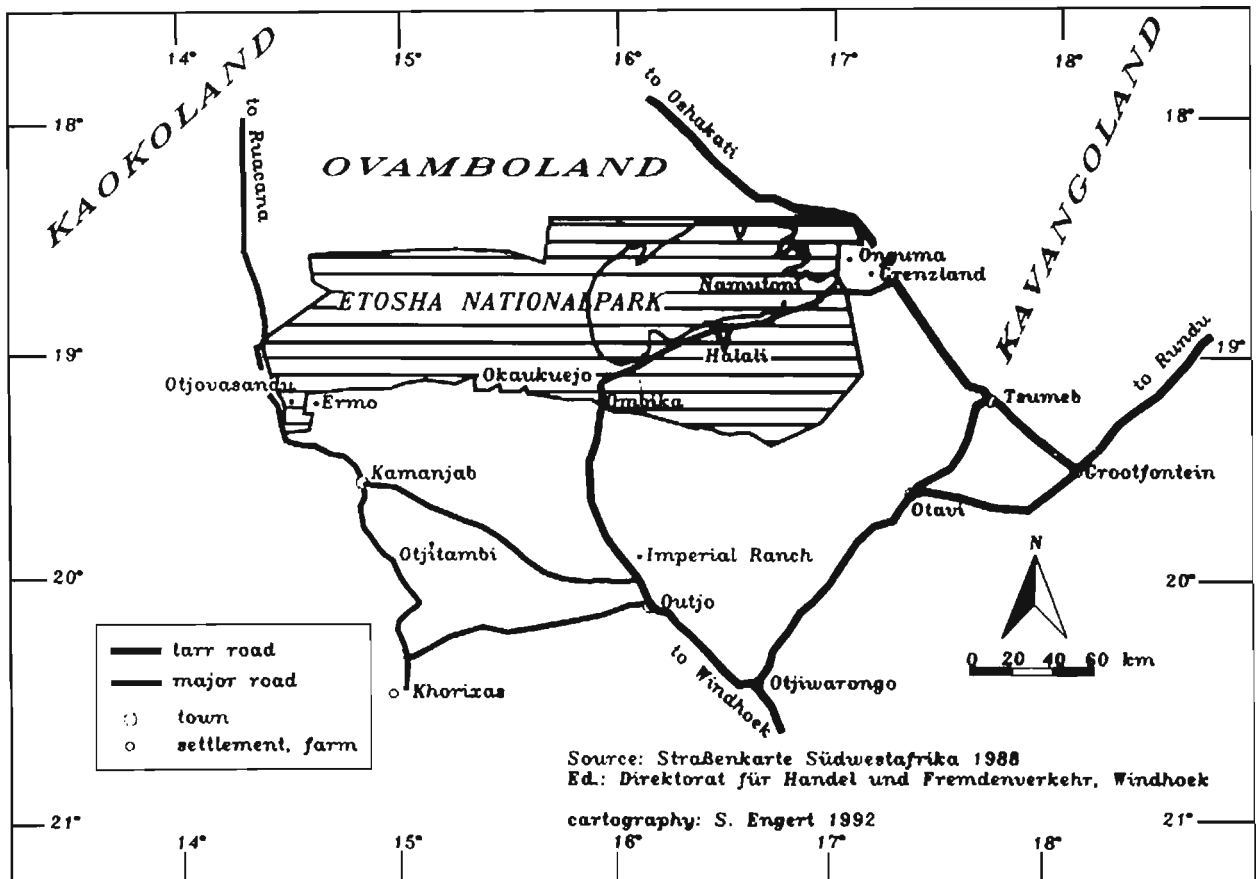


FIGURE 1: Position of stations with monthly rainfall records in the study area.

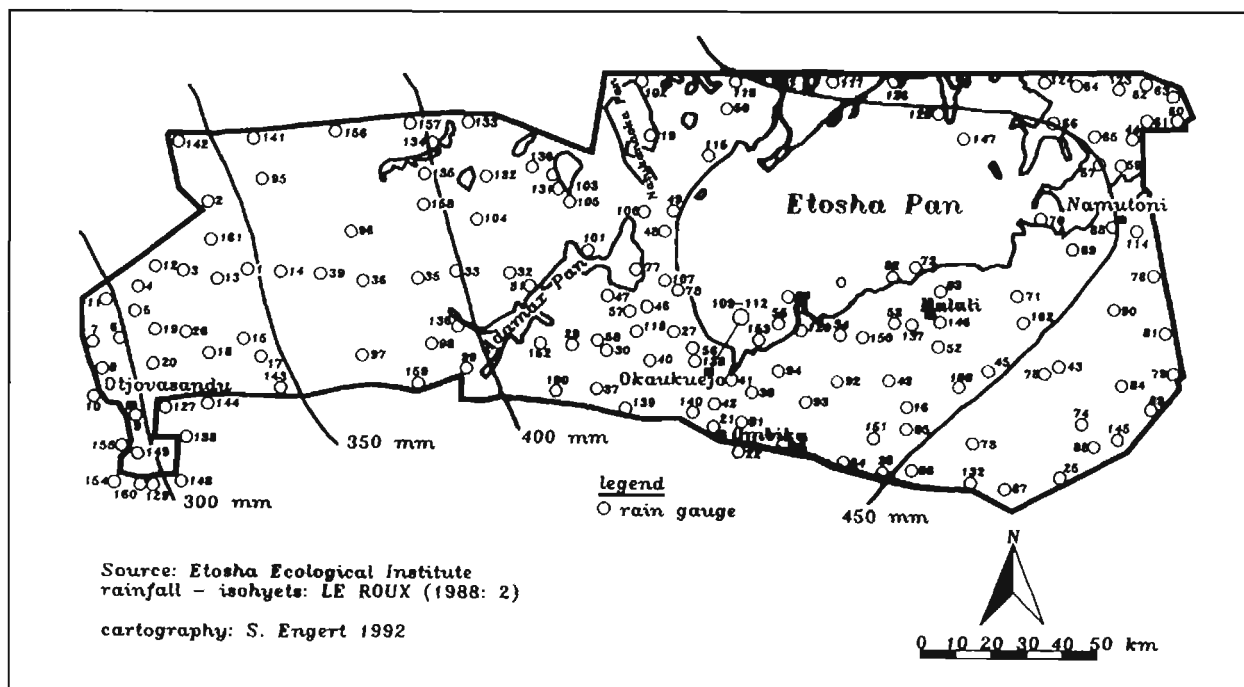


FIGURE 2: Position of 161 rain gauges in the Etosha National Park.

in an ecological model area like the Etosha National Park is of great importance because the results are transferable to the adjacent areas in northern Namibia.

## DATA BASE

The data of this paper, which represents a summary of Engert (1992) are monthly rainfall data from 13 stations in the Etosha National Park and surrounding areas in northern Namibia from the beginning of the 20th century until today (Fig. 1). Additionally, seasonal rainfall data (July to June of the following year) from 161 rain gauges in the Etosha National Park from 1983 to 1992 were used (Fig. 2). Furthermore daily data for wind direction and windspeed, evaporation and minimum and maximum temperature at Okaukuejo for the period 1982 - 1990 were used to calculate monthly means.

## CLIMATE

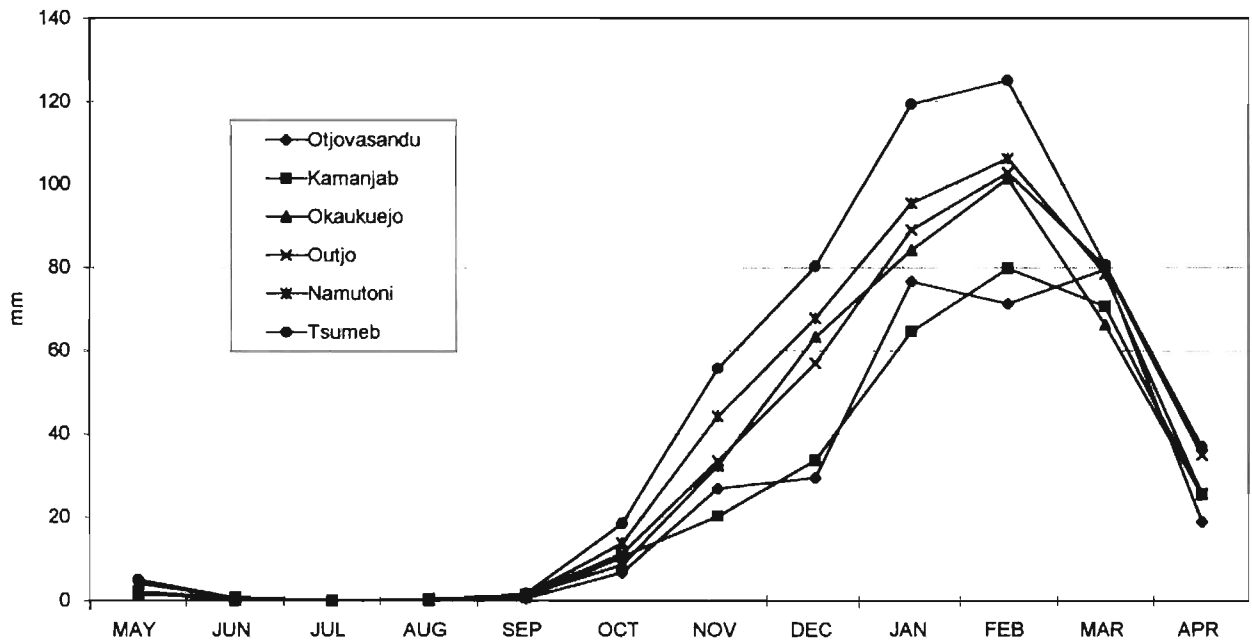
In general, the climate of Namibia is influenced by the subtropical high pressure cells in the South Atlantic and South Indian Ocean and the position of the intertropical convergence zone (ITCZ). At about 20°S, three near-surface air-streams flow together and form as a part of the ITCZ the "Zaire Air Boundary" (ZAB), namely from the south-east mainly dry air masses, from the north-west equatorial moist air masses and from north-east also moist unstable air masses (Nieuwolt 1977, Tyson 1986, Buch 1993). Disturbances in the area of the ZAB are mainly responsible for the convective rainfall, especially in the central and northern parts of Namibia. According to the position of the ZAB, rainfall fluctuates from year to year and day to day. The position of the ZAB itself is the result of a complex interaction of different subsystems of the general circulation of the atmosphere (Buch 1993). Rainfall in the study area decreases from 500 - 600 mm/a in Tsumeb to the east of the Park to below 300 mm/a in

Otjovasandu in the extreme western part of the Park. The long-term rainfall isohyets show a nearly meridional arrangement from north-northeast to south-southwest (Leser 1982, Van der Merwe 1983). In accordance with the Koeppen system of climate classification the study area is located in the zone of BShgw climate (B: dry regions with deficiency in rainfall, S: Steppe or semi-desert, h: annual temperature mean above 18°C, g: month with a temperature maximum in summer, w: rainfall during summer) (Van der Merwe 1983). The area of Tsumeb with average rainfall of 500 - 600 mm/a is described as "sub-humid", the area to the west with average rainfall of 300 - 500 mm/a as "semi-arid". The variability increases from 25 - 30 % at Tsumeb in the west of the study area up to 40 - 50 % at Kamanjab in the east (Van der Merwe 1983).

TABLE 1: Arithmetic mean, standard deviation and coefficient of variation.

	Arithmetic mean (mm)	standard deviation (mm)	coefficient of variation (%)
Tsumeb	513.0	165.1	32.2
Grenzland	499.6	149.0	29.8
Onguma	487.6	147.6	30.3
Namutoni	434.8	144.7	33.2
Halali	410.5	150.0	36.0
Imperial Ranch	419.8	136.9	32.6
Outjo	410.5	144.2	35.1
Ombika	430.9	139.5	32.4
Okaukuejo	382.8	122.5	34.2
Otjitambi	335.5	130.5	38.9
Kamanjab	312.3	119.3	38.2
Otjovasandu	304.8	124.1	41.3
Ermo	315.6	125.8	39.9

Rainfall in the Etosha National Park starts in September with the minor rainy season, reaching a maximum in January or February and ending in April. Figure 3 shows the average seasonal rainfall progress for selected stations. At most stations, except Otjovasandu, February is



Source: Etosha Ecological Institute, Weather Office Windhoek

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FIGURE 3: Average monthly rainfall for selected stations in the Etosha National Park and surrounding areas.

the month with the highest amount of rainfall. 50% of the seasonal rainfall occurs by the end of January. The average of the total seasonal amount of rainfall decreases from a long-term seasonal mean of 513,0 mm in Tsumeb in the eastern part of the study area to 315,6 mm at Ermo in the western part (Table 1).

The mean potential evaporation for the rainy season at Okaukuejo is 2 600 - 2 800 mm which exceeds seasonal rainfall multiple times. Temperature minimum at Okaukuejo is in June/July with a mean of 16°C, temperature maximum occurs in December/January with a mean of more than 26°C. Likewise December is the month with highest evaporation (Engert 1992). The range of temperature is highest in the late winter (June, July, August) with a difference between mean monthly maximum and minimum of up to 20°C. Late summer (February, March) has a range of 14°C. The prevailing wind direction throughout the year at Okaukuejo is northeast, followed by north and east. During the day wind changes from southwest-erly/southeasterly direction in the morning to northeast at midday and back to the morning conditions in the evening (Berry 1980). Highest windspeeds occur in winter with peaks about 22 m/sec. This fact also explains the high rate of aeolian erosion during the dry season (Engert 1992).

**SPATIAL VARIABILITY OF RAINFALL**

Standard deviation and arithmetic mean of rainfall in the study area decreases from east to west, also increases the coefficient of variation (Table 1) (Engert 1992).

An index for the reliability of rainfall is the coefficient of variation (CV) of Pearson (Bahrenberg, Giese & Nipper 1990) which is defined as

$$cv = \frac{s}{|x|} \cdot 100$$

s = standard deviation, |x| = arithmetical mean

For an interpretation of the amount of rainfall for different stations, the coefficient of variation gives a better basis for comparison than the standard deviation. High values of the coefficient of variation imply high variability and therefore low reliability of rainfall.

Table 1 presents the coefficients of variation for 13 stations in the study area with long records. The north-east with high average precipitation is characterised by the lowest CV values and the west with the lowest average precipitation by the highest CV values. Accordingly the rainfall in the east is more reliable than in the west, as outlined above.

A more precise picture of the spatial variability is given by the evaluation of the seasonal rainfall data (July to June of the next year) of 161 rain gauges located in the Etosha National Park for the period 1983/84 to 1989/90 (Table 2, Fig. 4, 5). The above outlined trend of generally higher rainfall in the east and lower rainfall in the west is supported by the Etosha rain gauge data, but it is also apparent that rainfall is very locally. Neighbouring rain gauges may show very different amount of precipitation.

TABLE 2: Seasonal rainfall distribution for the 161 raingauges (July to June of the next year)

	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	1989/90
0-150 mm	3.3	0.0	0.0	1.6	4.1	0.0	0.0
-200 mm	7.8	5.0	0.8	9.6	18.0	2.5	0.0
-250 mm	8.9	14.9	2.3	32.0	29.5	9.9	3.7
-300 mm	18.9	22.3	12.4	16.0	20.5	13.2	13.4
-350 mm	16.7	19.8	16.3	16.8	13.1	23.1	36.6
-400 mm	14.4	14.0	27.9	15.2	4.1	19.0	31.7
-450 mm	15.5	15.7	19.4	4.8	4.9	5.8	6.1
-500 mm	11.1	7.4	13.2	2.4	4.9	5.8	7.3
>500 mm	3.3	0.8	7.7	1.6	0.8	20.7	1.2

Fig. 4 presents the precipitation for the rainy season 1985/86 (July 1985 to June 1986) and 1986/87 (July 1986 to June 1987) within a dry spell. During 1985/86 (upper panel) the central and eastern parts received more than

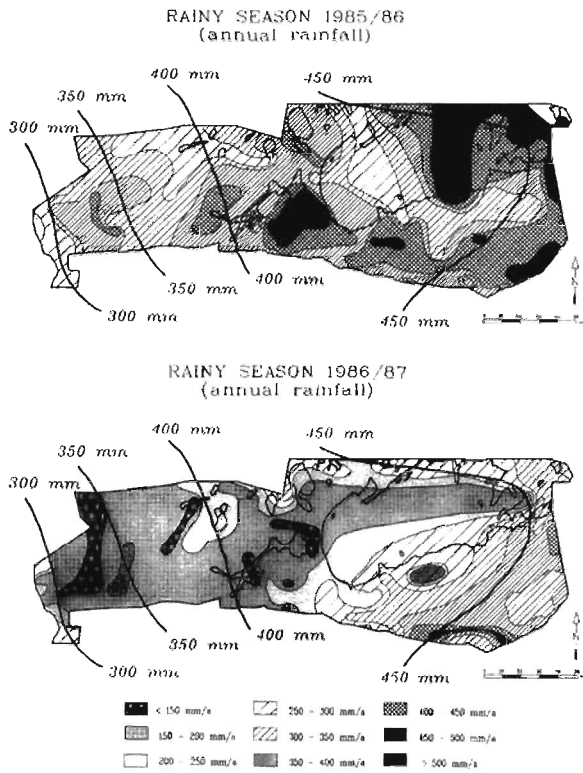


FIGURE 4: Etosha National Park: seasonal rainfall 1985/86 and 1986/87.

350 mm of rainfall as well as a small part in west. Only at Otjovasandu at the western boundary of the Park less than 300 mm of precipitation were observed. The area of Adamax Pan west of Etosha Pan received an amount of more than 500 mm as well as small parts in the north-east and south-east of the Etosha National Park (Engert 1992).

As an example of a season with extremely low rainfall the situation for 1986/87 is shown (Fig. 4, bottom panel). Only a very small area in the east of the National Park received a precipitation of more than 400 mm. Around the area of the Etosha Pan rainfall was 300 mm or less. A precipitation of less than 200 mm was recorded in the central and western parts and the region of Adamax Pan. Small areas in the west received less than 150 mm (Engert 1992).

Comparing these two rainy seasons the wet year shows areas of more than 200 mm greater than the dry year. It is also apparent that the distribution of areas with different amount of rainfall is more patchy during a wet season than during a dry season. Both seasons show clearly the influence of the Etosha Pan as a huge area without any vegetation on the rainfall. The same picture is obvious with the long term rainfall isohyets where the 450 mm isohyete makes a curve around the eastern edge of the Pan.

The calculation of coefficients of variation of the rain gauges in the Etosha National Park (Fig. 5) confirms an increase of variability and thus less reliability in a westerly direction. The area of Adamax Pan at the western edge of the Etosha Pan is characterized by a coefficient of

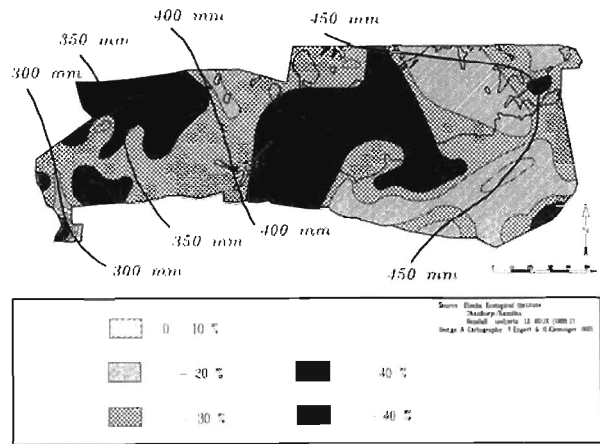


FIGURE 5: Etosha National Park: variability of rainfall.

variation of more than 40%, as well as the north-western region and a small area in the south-west. Values between 31% and 40% occur in most areas of the Etosha National Park. Variability of less than 20% occurs in the eastern parts and in a small area of the west (Engert 1992; Buch 1993).

PERIODICITY OF RAINFALL

In areas with unstable and unreliable rainfall, possible periodicities of rainfall are of great interest to any kind of forecasting. For southern Africa, Tyson (1980, 1986) identifies periods with systematically temporal variations of 10, 16 and 20 years by smoothing the records of 157 stations for the period 1910 to 1972 using a 5 term binomial filter. The existence of an 18-year oscillation, a succession of 9 years with above average rainfall and 9 years with below average rainfall was furthermore identified by spectral analysis (Tyson & Dyer 1975, 1978, Jenkinson 1976, Tyson 1986).

Dyer & Marker (1978) used maximum entropy spectral analysis for the evaluation of records of 17 stations in southern and central Namibia for the period 1934 to 1965. They found peaks at 9.34, 14.14, 19.80 and 22.00 years. The stations in the northern and eastern parts of their investigation area show oscillations of 19.80 to 22.00 years, while stations in the central of Namibia east of the Great Escarpment show oscillations of 16.50 years. West of the Great Escarpment oscillations of 9.43 and 14.14 years were identified. In the south Dyer & Marker (1978) found oscillations of 18.00 and 24.75 years.

Figure 6 shows the standardised rainfall departures for Okaukuejo and Namutoni. Both figures indicate that a periodicity - if it exists at all - is very complex (Engert 1992). By using a 5-term low-pass filter the data of 10 stations in northern Namibia were smoothed. Figure 7 shows the wet and dry spells for these 10 stations in the Etosha National Park and surrounding areas. Only records longer than 25 years were used. Okaukuejo shows oscillations of 20, 16, 12, 8, 4 and 2 years compared to oscillations of 20, 8, 6, 4, 3 and 2 years identified for Namutoni, as outlined by Buch (1993). In the study area regional patterns are not evident but the oscillations seem to be similar to oscillations identified by Dyer & Marker

(1978) for the northern and eastern parts of their study area. Further investigations especially in areas north of the Etosha National Park are necessary.

With these periodicities a period of above average rainfall should have started at the beginning of the 1990s (Buch 1993). Up to now, however, the contrary seems to be true, and it is possible that two dry spells occurred successively. A similar phenomenon is described for the beginning of the century for South Africa (Tyson 1986). If the continuing dry spell does persist it may continue till the end of the early 21st century (Engert 1992, Buch 1993), with significant consequences for the Etosha National Park and adjacent parts in northern Namibia. Especially in relation to the phenomenon of "future climatic change" further research on this problem is necessary.

In contrast to the often mentioned opinion of decreasing rainfall since the beginning of the century statistical analysis shows a clear periodicity of rainfall with a

succession of wet and dry spells. The 18-years oscillation in South Africa identified by Tyson and colleagues (Tyson 1986) is replaced in northern Namibia by oscillation of 20, 16, 12, 8, 6, 4, 3 and 2 years. That is the result of the obviously more complicated atmospheric circulation in this region (Buch 1993). Further investigations on the above mentioned problems are in progress.

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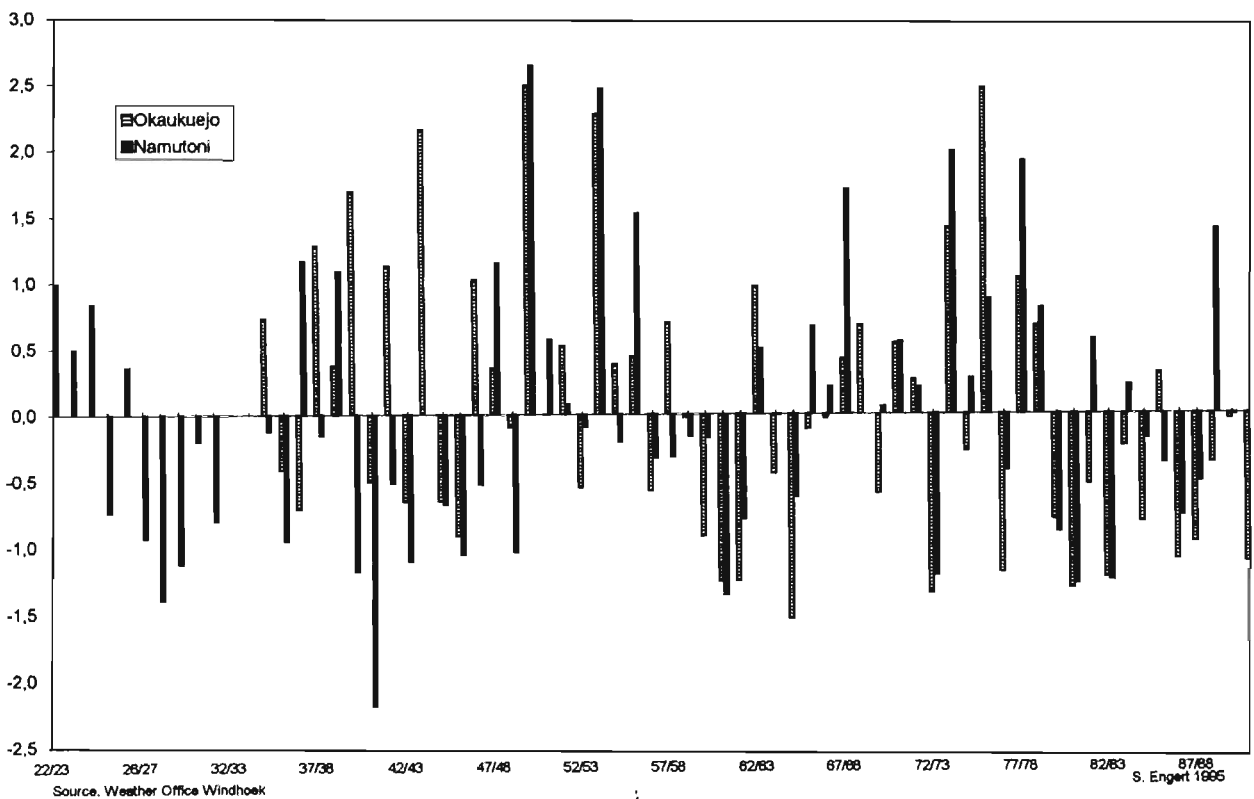


FIGURE 6: Okaukuejo and Namutoni: standardised rainfall departures

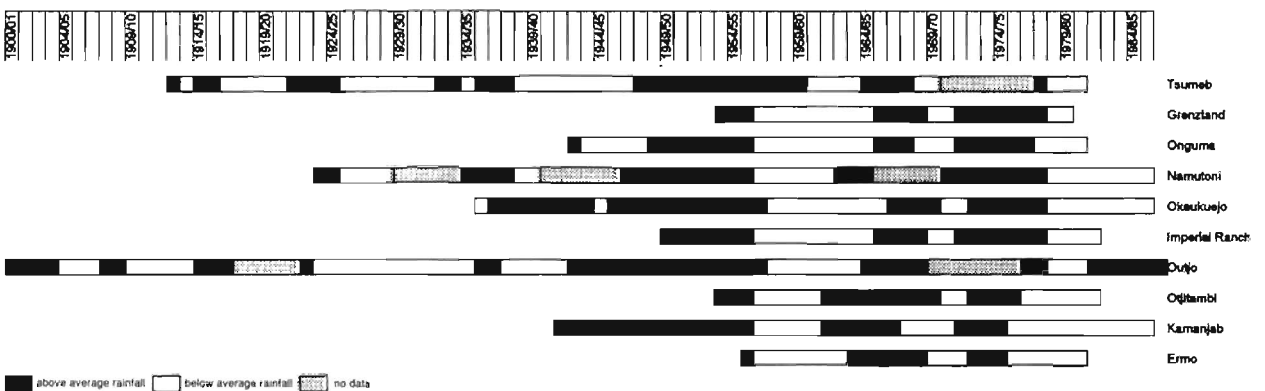


FIGURE 7: Wet and dry spells of rainfall of 10 stations in the Etosha National Park and surrounding areas.

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