3. DROUGHT, FOOD STRESS, AND THE FLOOD AND RAINFALL RECORD FOR RED SEA PROVINCE. Roy Cole

Summary

In this paper the flood record for 9 watersheds in Red Sea Province, 1 watershed in Kassala Province, and the records of 19 rainfall gauging stations in and around Red Sea Province were examined. The purpose of the study was:

1. To obtain a more precise understanding of the extent and nature of the drought of the early 1980s and during other periods in Eastern Region.

2. To compare information obtained from the flood record with information obtained from rainfall gauging stations around Eastern Province to see what differences and commonalities exist between the two measures of precipitation.

3. To compare qualitative estimations about drought and food stress in the past with the flood and rainfall record.

4. To make available to policymakers, government, and other researchers the historical record for the study area.

The findings of the study indicate that prior to the 1980s, severe drought was a local phenomenon in Red Sea Province but that in the early 1980s (generally from 1983 to 1984), severe drought became general. However, precipitation and flood data show no general downward trend over time for the area of study.

It was found that the well-known famine of 1948 was not related to severe drought; it was related to economic factors. Severe drought impacts of the early 1970s were felt along the coast and mountain areas that receive winter rainfall. It is notable that the interior watersheds of record had above average flooding during the same period. The interior of the province and the central Red Sea coast experienced the greatest drought impacts in 1983 and 1984, when floods as well as rains failed.

Introduction

We do not have a clear understanding about the extent and the severity of the drought experienced in the Eastern Region of the Sudan during the early 1980s, nor do we have much information concerning previous drought in the area. A drought is generally held to have occurred simultaneously over the Red Sea Province, Kassala Province (together the Eastern Region), Eritrea, and Ethiopia sometime in the early 1980s and a widespread famine is reported to have occurred in 1985. The Eritrean and Ethiopian drought, complicated by a long civil war, is well known. The present study was conducted to examine the distribution in time and space of the less well known drought in the Eastern Region of the Sudan that occurred in the early 1980s and other droughts that have occurred in the past.

The flood and rainfall record forms the basis for the present examination of the distribution of drought in the Eastern Region.

In this paper the flood record for 9 watersheds in Red Sea Province, 1 watershed in Kassala Province, and the records of 19 rainfall gauging stations in and around Red Sea Province will be examined. The study has four purposes:

1. To obtain a more precise understanding of the extent of the drought of the early 1980s in the Eastern Region as well as the droughts that preceded the 1980s.

2. To compare information obtained from the flood record with information obtained from rainfall gauging stations around Eastern Province.

3. To compare qualitative estimations about drought and food stress in the past with the flood and rainfall record.

4. To make available to policymakers, government, and other researchers the historical record for the study area.

Although purposes one and two are important and form much of the discussion of the present paper, it is purpose four that is most important to the author. It is in the endeavour to contribute to the growing database on Red Sea Province that the present paper was written.

In the following discussion of the flood and rainfall records, first a general discussion of precipitation patterns in and around Red Sea Province will be presented. A definition of drought will then be formulated and discussed. After this discussion, a section on the flood record will be presented followed by a section on the rainfall record. A specific discussion of the measurement of drought impacts for each method of measurement will be found in a summary at the end of each section. A comparative discussion of the measurement of drought impacts by both methods will be reserved for the penultimate section on the measurement of drought impacts.

Precipitation in Red Sea Province

Precipitation in Red Sea Province occurs in two seasons, summer and winter. Summer rainfall (July to September) occurs as a result of the northward movement of the Inter-Tropical Convergence Zone (ITCZ). This 600 kilometre wide zone of humid air moves seasonally across the entire Sudano-Sahelian zone of Africa and is the source of the precipitation in that zone; the heaviest rainfall occurs in the southern parts of the Sudano-Sahel and the least in the southern Sahara. Precipitation during this season falls throughout the interior of the province to approximately the central ridge of the Red Sea Hills from the southern districts of Red Sea Province to central Halaib District in the north.

Coastal Red Sea Province, generally dry throughout the summer season, receives rainfall in the winter months from November to February and heavy dew up until the end of April. This season of precipitation is caused by the northeast Trade Winds (called the harmattan in West and Central Africa). They are dry winds that transport water vapour from the Red Sea and deposit it in the form of rain and dew along the coast and mountain areas of Red Sea Province. These winds blow all year long but achieve their maximum during the winter months. Consequently, rain or dew may occur at any time of the year along the coast in Red Sea Province.

The effect of the Red Sea Hills on precipitation in both seasons is important. The Hills increase the precipitation during the summer season by forcing moist air into cooler, upper elevations where it condenses and falls as rainfall or is deposited on the ground as dew. Regarding the coastal zone, it is doubtful whether there would be any precipitation during the winter season without the lifting effect of the mountains. Areas located in a central position along the north-south axis of the Red Sea Hills as well as the khors flowing to the coast or interior fed by these hills benefit from two rainy seasons. In the summer season heating by the sun can cause local instabilities (thermal convection), uplift of air parcels, and rainfall (see El-Tom 1989).

Mahdi Amin El-Tom (1975) distinguishes five precipitation zones in Red Sea Province. Two periods of rainfall can be distinguished: November to January and July to September.

Table 3.1. El-Tom's rainfall zones for Red Sea Province.

Area	Rainy Season
Coastal Eritrea to Khor Arba'at delta	November to January
Coastal Khor Arba'at delta to Halaib	October
Mountain and coastal northern Red Sea Hills	November
Mountain northwest	July to August
Interior southwest	July to September

Flood and Rainfall Records: Problems and Possibilities

The rainfall record in most third world countries is incomplete. Piecing together a complete picture of precipitation is further complicated by the uneven distribution of rainfall in arid and semi-arid areas and the thin distribution of rainfall gauging stations. Rainfall gauging stations are generally located where there a major concentrations of human population, not necessarily where the rain is. If the rain is not where the gauging station is located then it is not measured. Such measurement error could mask the difference on paper between a good rainfall year and a poor one. It is common in Red Sea Province to find no rainfall at a gauging station for a year or series of years but at the same time find floods in nearby khors because of unmeasured rain falling elsewhere.

The watershed gauging station, in contrast to the rainfall gauging station, is situated on a vast collecting basin. Because the unit of measurement encompasses a large contiguous spatial unit, the catchment basin, the chances of a "miss" of information are smaller than with the rainfall gauging station, which measures phenomena at a point. A drawback of flood data, however, is that where the river bed is permeable measurable amounts of runoff can leak out of the system and remain unmeasured. This problem is minimised to a great extent by the incidence of thick clay pans in the beds of the khors and along waterlines and by the rocky nature of the terrain. In general, the khors are sealed and runoff from the mountains is close to 100%.

In the end, however, the flood record suffers from the same problem as the rainfall record: it is incomplete. Flood records should be used in conjunction with rainfall records to provide a more complete picture of precipitation history than rainfall records alone.

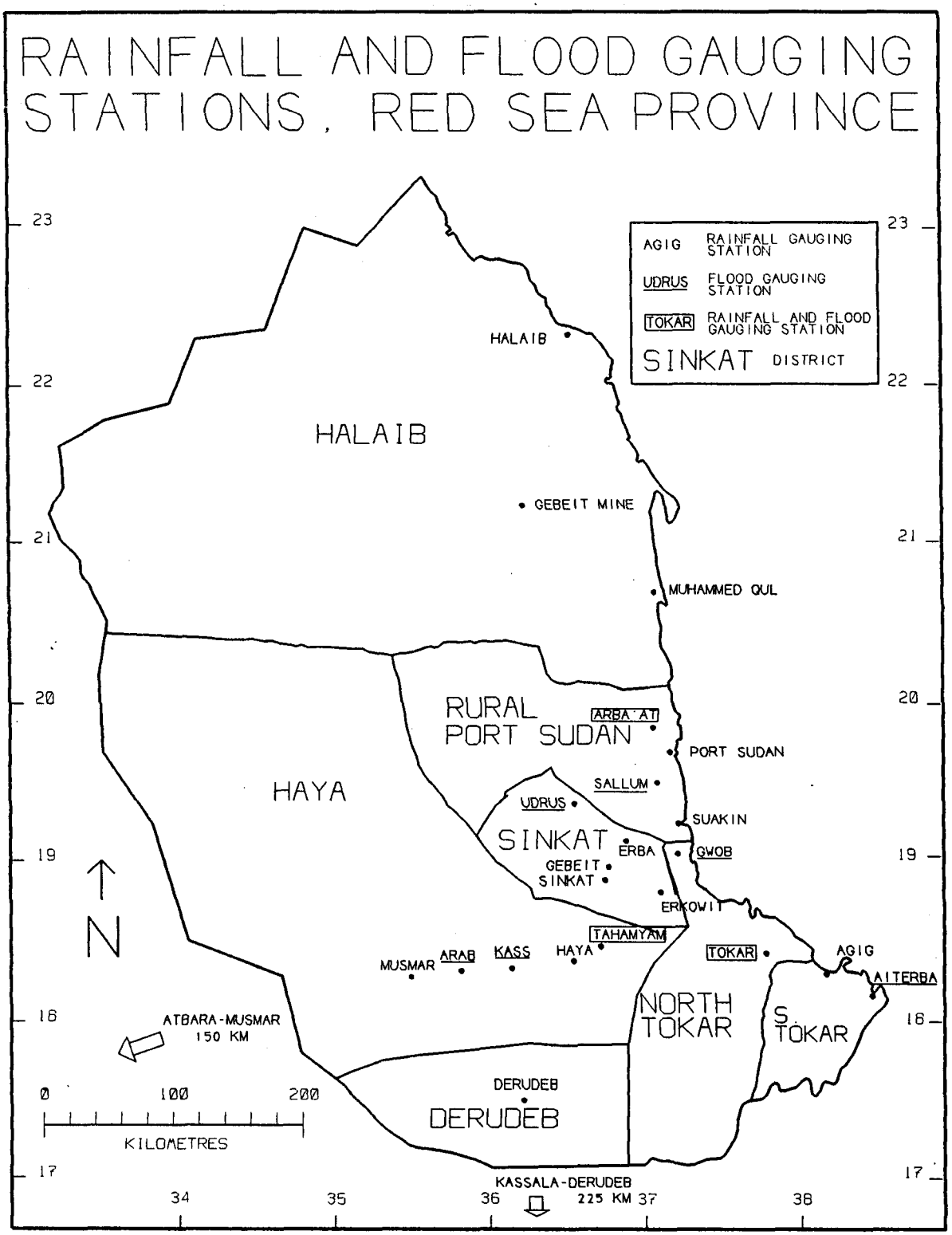
A more perplexing problem, and one which is common to both types of data, is what does one make of the results? To interpret them in a meaningful way requires that they be linked to human experience. In many areas of the world rainfall data are used to predict crop yields. In Red Sea Province this is difficult to do because rainfall is extremely low, unevenly distributed, and agriculture is dependent on floods rather than rainfall. For reasons mentioned above, rainfall and floods may not covary well. Two uses to which the flood data may be put are the prediction of annually cultivated areas and the prediction of areas of pasture production. Flood data would be more useful than rainfall data in predicting agricultural activity or rainy season pasture production in Red Sea Province because of the reliance of both activities on the flood plains, grassy or wooded alluvial fans, and khor beds. Cultivated area can be predicted from the flood using the equation $Y = mX + b$, where Y equals the dependent variable, cultivated area, X equals the flood, m is the intercept, and b is the slope. Pasture production can be treated in the same way. Historical data on cultivated area and harvested area are kept by the District Councils (Majlis) throughout Red Sea Province. The author would have liked to include as a central point in the present paper a model of agricultural and pastoral production in Red Sea Province based on that presented above. Due to circumstances beyond his control he was unable to obtain the data on cultivated areas collected by the Sudanese government.

Recently, scientists and policymakers have turned to vegetation and crop greenness as an important variable to examine when assessing drought impacts. To do this they

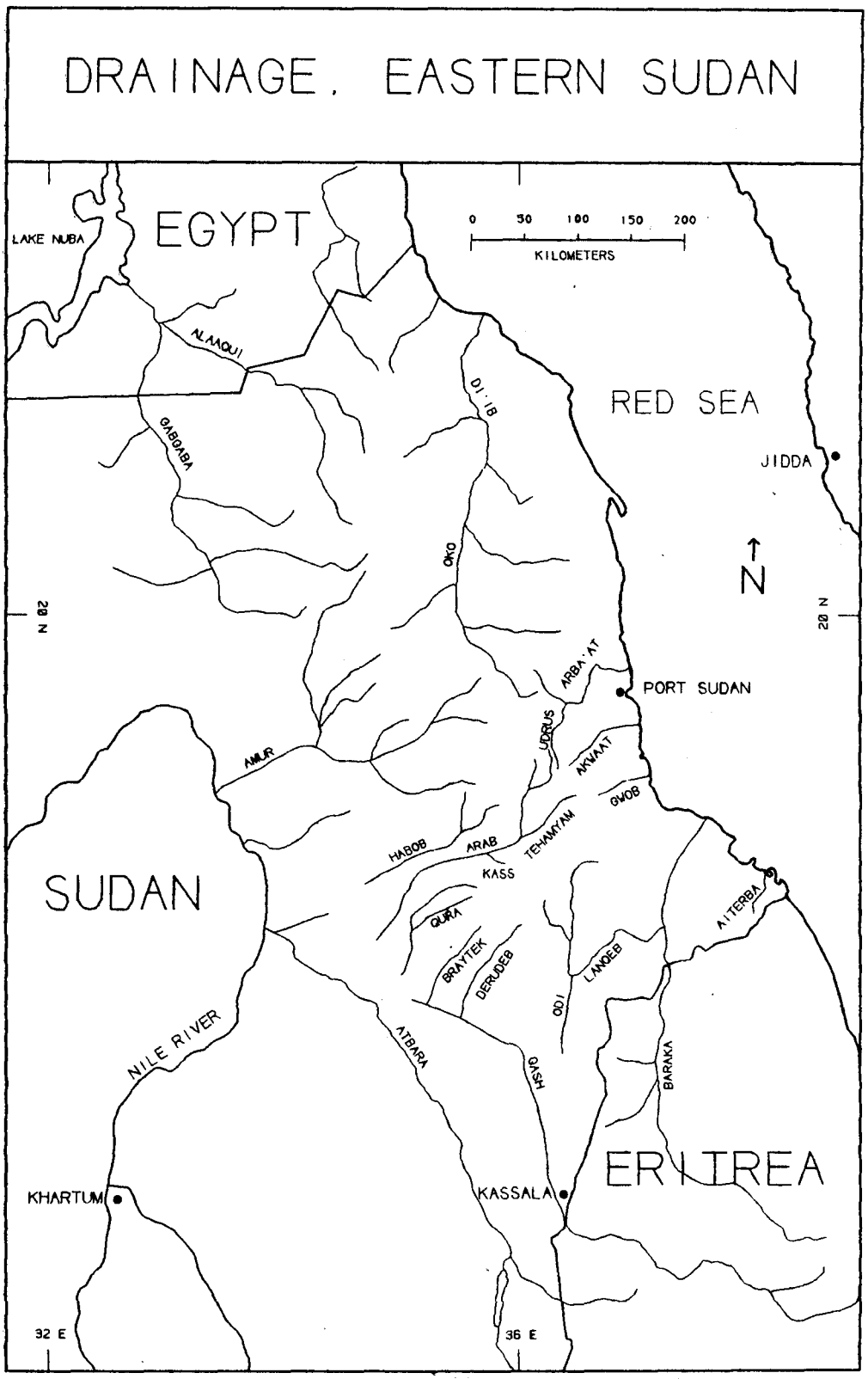
use data provided by satellites of the areas of interest. The sensors in the satellite measure the greenness or "vigour" of the vegetation on a month-by-month basis. These data are then indexed with rainfall data and mapped for publication and distribution. For a deeper discussion of NDVI see the paper, "Measuring drought impacts and food insecurity in Red Sea Province" in this collection.

Map 3.1 below presents the location of flood and rainfall gauging stations throughout Red Sea Province. Khor Sallum, named after Sallum railroad station is called Khor Akwaat on the map. This is in conformance with local usage. The major drainage of the eastern Sudan is presented in Map 3.2 below.

Map 3.1. Flood and rainfall gauging stations, Red Sea Province.



Map 3.2. Drainage, Eastern Sudan.



A Definition of Drought

Understanding drought in Red Sea Province is dependent on understanding land use and its variability from year to year. In Red Sea Province, with the exception of favoured places such as the Tokar and Gash Deltas, strict dichotomies between activities such as the division between agricultural and pastoral have little meaning. Gradations in involvement are such that continuous is a more appropriate descriptor than dichotomous. This relationship is a result of the variable nature of the environment. This variability has implications for any definition of drought in human terms. To define drought in human terms both agriculture and pastoralism must be considered not as absolutes but as options that change from year to year.

The figures below present the long-term coefficients of variation for each of the khors and rainfall gauging stations and are presented to illustrate the variability of floods and rainfall in the study area.

Figure 3.1. Coefficients of variation for nine khors.

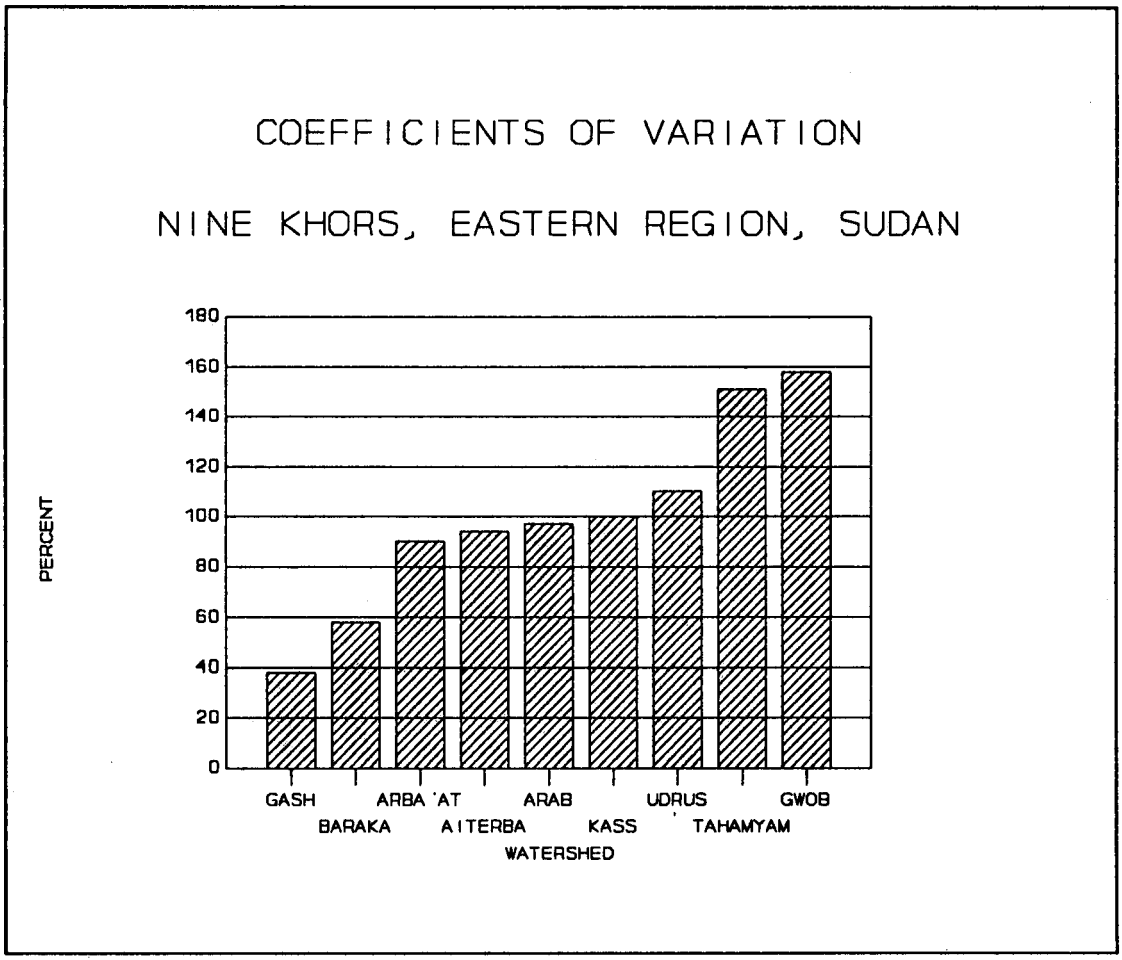
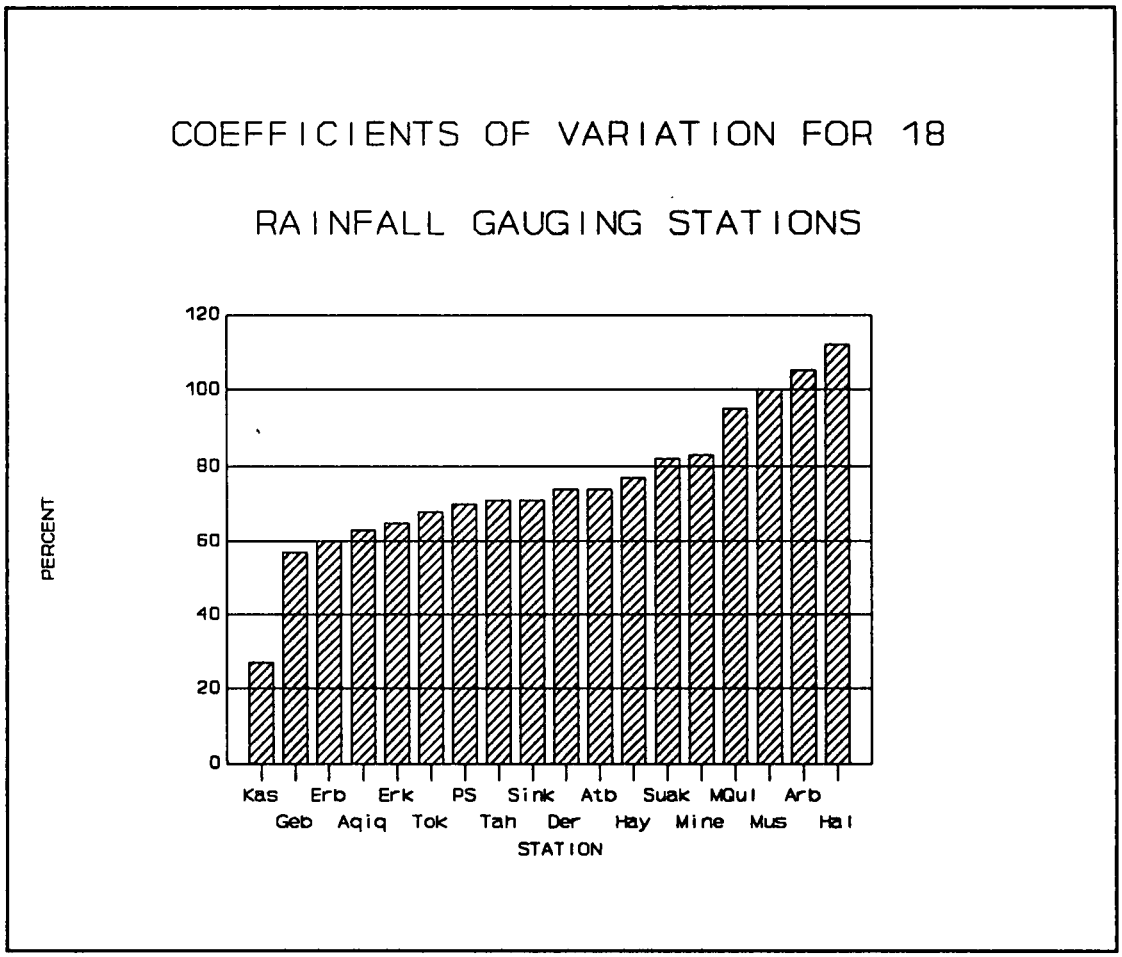
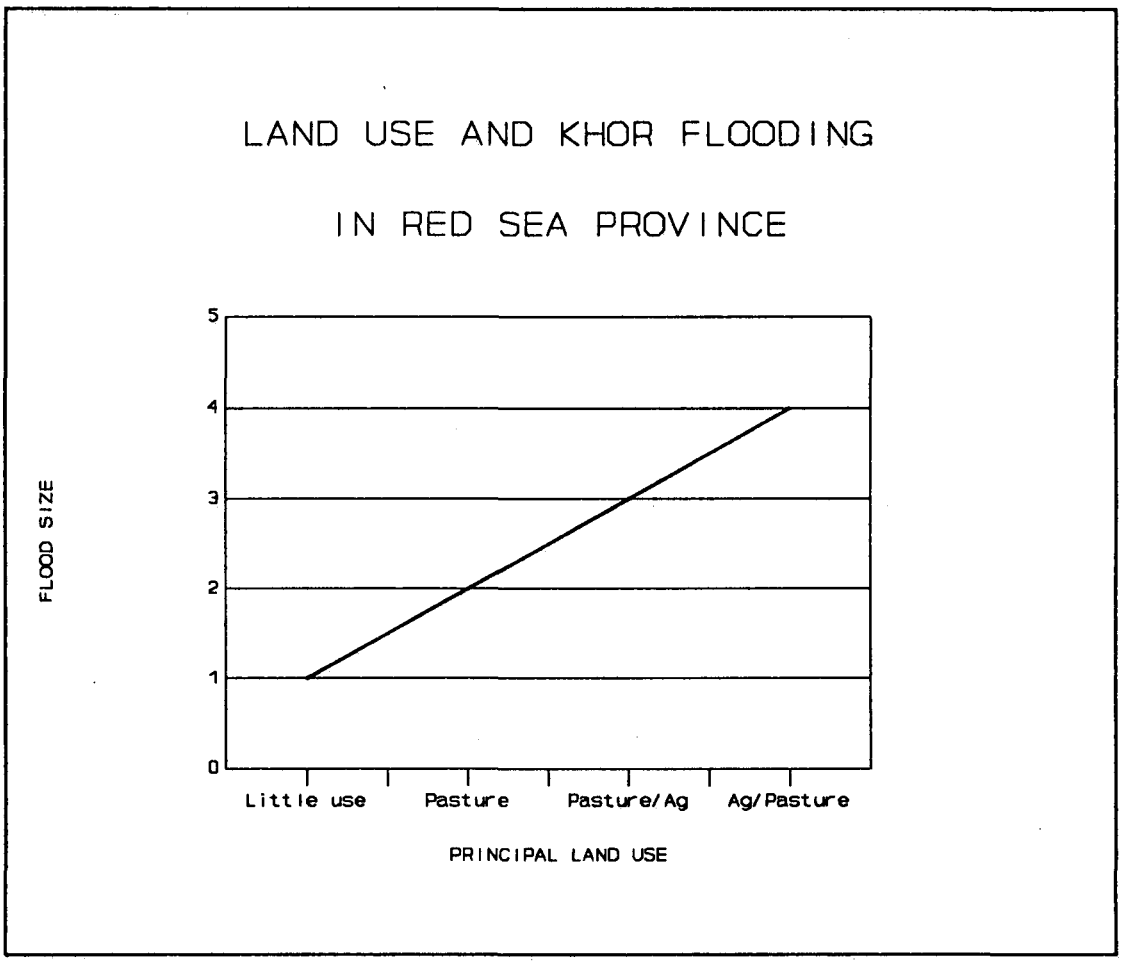


Figure 3.2. Coefficients of variation for 18 rainfall gauging stations.



The interdependencies between agriculture and pastoralism in such a variable environment are so great that it would be more proper to speak of these interdependencies as complementarities. The figure below illustrates the variable relationship between floods and principal activity in the khors of Red Sea Province. A drought, as defined below, may be considered to fall somewhere between Pastoral and Pastoral and Agricultural. Severe drought, as is defined below, falls somewhere for two years running to the right of "little". "Little" means that few resources are available for any activity but those that are available are used by livestock: there has been little annual plant production and livestock subsist on Acacia tortillis and other browse.

Figure 3.3. Land use and flood size in Red Sea Province.



Years where the flood or rainfall varies between 1 standard deviation above and below the mean are notable for their frequency and should be considered as normal variation which people expect and for which, except for the most marginal of households, they are prepared. A year of flood or rainfall greater than 1 standard deviation below the mean is equivalent to little flood or rainfall. In human terms this means the failure of one annual crop and low production of annual grasses. However, crop residues will still be produced. On Figure 3.3 above pasture is the principal land use when the flood is over 1 standard deviation below the mean and a mix of pasture and moderate agricultural production when floods are around the mean. A good crop may be harvested despite the low rainfall the closer the flood or rain is to the mean (or above it) and if the rains or floods are well spaced. The more the flood is over the

mean the more agriculture is practised. It can, as it did in 1988, become the dominant activity of the khor.

One standard deviation accounts for over two thirds of the values on either side of the mean of any distribution. Beyond one and up to two standard deviations accounts for an additional third. Beyond two and up to three standard deviations accounts for the remaining fraction. 99.7 percent of all values will be within three standard deviations of the mean. Values greater than three standard deviations from the mean are generally considered outliers and are removed from calculations of central tendency. Data collected by different measures on different scales are often compared by transforming the raw data, in this case annual floods in millions of cubic metres and annual rainfall in millimetres, into standard scores called z-scores. For example, a z-score expresses each annual observation of a flood series as a deviation from the average or mean value for the entire series of values. In this form the two types of measurement are directly comparable; that is to say, rainfall data and flood data, although they are measured in completely different units can be compared on the same scale. To calculate a z-score you must first calculate the mean and the standard deviation. The standard deviation is the square root of the deviation of each value in a data series from the mean. The formula for the standard deviation is $SQRT(\Sigma((X\text{-the mean})^2/n-1))$. To obtain a z-score the mean is subtracted from each value in the data series and the resulting value is divided by the standard deviation.

Defining drought in terms of standard deviations below the mean seems significant in human terms because harvest surpluses are stored from year to year (up to 6 years - see Cole 1989) and because pasture produced in one year can last for up to 3 to 5 years. In the western areas of Red Sea Province where interannual variation is the greatest ERGO (1989) found that pasture was usable for at least 3 years. Thesiger (1984) reported that pasture was usable 5 years after the last rain in the Empty Quarter of Saudia Arabia. Further research is needed on this topic and in modelling agricultural and pastoral production in Red Sea Province. In any case, grain storage and the use of pasture for more than one year are mechanisms (among many others) that are used to smooth environmentally-induced interannual variation in livestock and human food supplies.

The cut-off of 1 standard deviation was used for 4 khors and 17 rainfall gauging stations. The khors are: Aiterba, 'Arab, Arba'at, Baraka, and Gash. The rainfall gauging stations are: 'Agig, 'Atbara, Derudeb, Erba, Gebeit, Gebeit Mine, Haya, Kassala, Muhammed Qul, Musmar, Port Sudan, Sinkat, Suakin, Tahamyam, and Tokar.

The 1 standard deviation criterion could not be used with khors or rainfall gauging stations where the coefficient of variation was more than 100% because the lower deviation was negative. Instead of the standard deviation, any annual flood or rainfall equal to or less than 20% of the mean was considered as a drought. This was done for 4 khors and 2 rainfall gauging station. The khors are: Gwob, Kass, Tahamyam, and 'Udrus. The rainfall gauging stations are: Arba'at and Halaib.

I would like to recapitulate the definition of drought above and to extend the definition to include severe drought where animal mortality and human impacts may be said to become important.

Drought is defined as one year in which the flood is equal to or greater than 1 standard deviation below the mean, or equal to or less than 20% of the mean flood.

Severe drought is defined as two consecutive years where floods are equal to or more than 1 standard deviations below the mean, or equal to or less than 20% of the mean flood.

The Flood Record

Prior to the 1950s, no flood records were collected in Red Sea Province except inundated area in feddans in the Tokar Delta. In the late 1950s and early 1960s, the Government of Sudan began collecting precise figures on flooding in five watersheds in Red Sea Province. In the mid-1970s, three additional stations were added. The collection of data was relatively stable throughout the 1960s and 1970s. In 1988, the National Water Corporation had no budget for the monitoring of any of the watersheds except Khor Arba'at which is part of a permanent monitoring programme.

For each month in which flooding occurs, data is collected at the gauging stations on the following topics:

1. Date of each flood.

2. Duration of each flood in hours.

3. The maximum discharge of each flood in cubic meters per second.

4. The total volume of each flood in cubic meters.

Permanent flow, where it occurs, is treated separately on a month by month basis and added into the grand total for the station by month and year.

The following table lists the gauging stations, the date they began operating, the date they terminated operating, and the authority responsible for maintaining the stations. By "present" it is meant that the station is still in use.

Table 3.2. Flood gauging stations of Eastern Region.

Station	Location	Start	End	Authority
Aiterba	Coast	1977	Present	National Water Corporation
'Arab	Interior	1960	Present	National Water Corporation
Arba'at	Coast	1957	Present	National Water Corporation
Baraka	Coast	1900	Present	Tokar Delta Board
Gash	Interior	1964	Present	Gash Delta Board
Gwob	Coast	1958	Present	National Water Corporation
Kass	Interior	1974	Present	National Water Corporation
Sallum	Coast	1958	1968	National Water Corporation
Tahamyam	Interior	1976	Present	National Water Corporation
'Udrus	Mountain	1960	Present	National Water Corporation

The table below presents the means, standard deviations and coefficients of variation for all watersheds of record.

Table 3.3. Means, standard deviations and coefficients of variation for ten watersheds in Eastern Region.

Station	Mean Annual Flood (m^3)	Standard Deviation	Coefficient of Variation
Aiterba	7174940	6721840	94%
'Arab	13586209	13219465	97%
Arba'at	25123895	22512259	90%
Baraka	76322*	44137	58%
Gash	67579*	25517	38%
Gwob	4185013	6630691	158%
Kass	8346966	8347522	100%
Sallum	4880734	4896680	100%
Tahamyam	1813798	2738385	151%
'Udrus	2583461	2847960	110%

* Data available only in feddans inundated. In the Sudan, 1 feddan is equivalent to 1 acre.

Both the standard deviation and coefficient of variation for the Khor Arba'at data are much lower if the outlier flood of 1987 (190 million m^3 and 7 standard deviations above the mean) is removed from the calculation. The mean, standard deviation and coefficient of variation including the extreme value are 30630044, 37001635, and 121% respectively.

Drought and the Flood Record

One thing is immediately clear from the flood record: interannual variability of the flood is great: with the exception of Khors Baraka, and Gash interannual variability is near or over 100%; a very risky and marginal environment. The table below, taken from the data in Appendix 3.1, presents years of drought for each watershed.

Table 3.4. Drought and severe drought periods for three floodwater source areas in or near Red Sea Province.

Source Area	Drought	Severe Drought
<u>Interior RSP</u>		
'Arab		1983-84
Kass		1983-84
Tahamyam	1974, 1987	1980-85
<u>Mountain RSP</u>		
Aiterba	1985	
Arba'at	1986	
Gwob	1958, 1960, 1963, 1969, 1977	1970-71, 1980-81 1983-87
'Udrus	1961, 1965, 1970, 1983, 1985	
<u>Mountain Eritrea</u>		
Baraka	1936, 1955, 1957 1960	1962-63
Gash	1983	

In the interior of the province and for Khors Baraka and Gash, which have their source in Eritrea, the 1970s were a decade of above average flooding. The major drought-affected area during the early 1980s was the interior of the province where Khor 'Arab, the agricultural and pastoral focus of many individuals for part of the year, failed to flood for two consecutive years. Khors Kass and Tahamyam, tributaries of Khor 'Arab, present the same pattern.

The flood deficit in the Interior of Red Sea Province before and after the two years of complete drought created a calamity for which people were unprepared and informants in the area recalled no other similar period in their recent history except 1948, a year mentioned by many people as one of major famine and one for which we have no flood data. In addition, the Gash delta, a redoubt of pastoralism and one of the major agricultural areas for Red Sea Province, experienced a drought in 1983. Stern in

1985 estimated that there were 25000 people in camps in the Districts of Derudeb, Haya, and Sinkat. This figure represents between 6 and 9 percent of the rural population of Red Sea Province depending on which figures are used in estimating rural population in Red Sea Province (see Population and Human Geography in the Introduction). The Khor 'Arab basin drains much of two of the three districts mentioned in Stern's report.

The Rainfall Record

Data is available for 19 gauging stations around Red Sea Province: 17 within the boundaries of Red Sea Province itself and 2 near the province (Refer to the Map 3.1 of the flood and rainfall gauging stations). The record, as the table below indicates, is far from complete. Only nine of the 19 stations are still functioning today. The remainder stopped collecting data in the early 1980s, probably as a result of budgetary problems with the then Numeiry government.

Table 3.5. Location and years of record for 19 rainfall gauging stations in and around Red Sea Province.

Station	Lat.	Long.	Elev.	Location	Years of Record
'Agig	18 14	38 11	5	Coast	1921-38, 1944-88
Arba'at	19 49	37 20	120	Mountain	1943-62, 1964-68, 1973-87
'Atbara	17 39	33 58	348	Interior	1907-88
Delay	17 23	36 05	500	Interior	1975-84
Derudeb	17 35	36 06	510	Interior	1944-77
Erba	19 04	36 48	680	Mountain	1943-72, 1975-81
Erkowit	18 46	37 06	1095	Mountain	1943-52, 1965-72, 1977-78, 1981-1983
Gebeit	18 57	36 51	795	Mountain	1908-24, 1928-80
Gebeit Mine	21 03	36 20	640	Mountain	1944-78, 1980-81
Halaib	22 13	36 39	12	Coast	1953-88
Haya	18 20	36 22	640	Interior	1940-81
Kassala	15 28	36 25	NA	Interior	1901-39, 1942-88
Mohammed Qul	20 54	37 06	5	Coast	1953-75, 1978-80
Musmar	18 13	35 38	495	Interior	1948-76, 1980-82
Port Sudan	19 37	37 13	5	Coast	1941-88
Sinkat	18 50	36 50	870	Mountain	1920-82
Suakin	19 07	37 20	5	Coast	1890-1988
Tahamyam	18 20	36 32	690	Interior	1909-40, 1942-50, 1952, 1956-72, 1974-80
Tokar	18 26	37 44	20	Coast	1913-18, 1920-36, 1939-88

Table 3.6 below presents the mean annual rainfall, coefficients of variation for the eight gauging stations with complete records. Only two stations have coefficients of variation that are greater than 100 percent. As a general rule for reasons mentioned above in the section concerning rainfall and the movement of the Inter-Tropical Convergence Zone, the more southerly the location of the gauging station, the lower the coefficient of variation.

Table 3.6. Years of record, mean annual rainfall, standard deviations, and coefficients of variation for eight rainfall gauging stations in and near Eastern Region, Sudan.

Station	Years of Record	Mean Annual Rainfall	Standard Deviation (mm)	Coefficient of Variation
'Agig	63	136	85	63
Arba'at	40	39	51	105
'Atbara	82	68	50	74
Halaib	36	33	37	112
Kassala	86	307	84	27
Port Sudan	48	90	63	70
Suakin	99	157	127	81
Tokar	73	73	50	68

Table 3.7 below presents the decadal means for the eight gauging stations for which we have complete records. A general downward trend in the data is not clear. For three of the stations, Kassala, Port Sudan, and Suakin, a downward trend is evident. For the others the trend is upward or not clear.

Table 3.7. Decadal means from 1988 to the earliest complete decade for eight gauging stations in and around Red Sea Province.

Station	Decade								
	1988-79	78-69	68-59	58-49	48-39	38-29	28-19	18-09	08-99
'Agig	109	157	117	166	134	139	128	na	na
Arba'at	40	31	35	19	87	na	na	na	na
'Atbara	62	60	60	87	59	69	82	65	na
Halaib	28	6	57	48	na	na	na	na	na
Kassala	240	264	279	367	314	328	319	347	na
Port Sudan	53	66	115	103	116	na	na	na	na
Suakin	49	97	300	113	128	145	155	170	172
Tokar	64	55	98	77	83	45	70	91	na

These data are presented in the following figures to clarify trends. Figure 3.4 illustrates the downward trend of three stations while Figure 3.5 presents the upward or indeterminate trends of five stations.

Figure 3.4. Decadal rainfall means exhibiting a downward trend for three rainfall gauging stations in or near Red Sea Province.

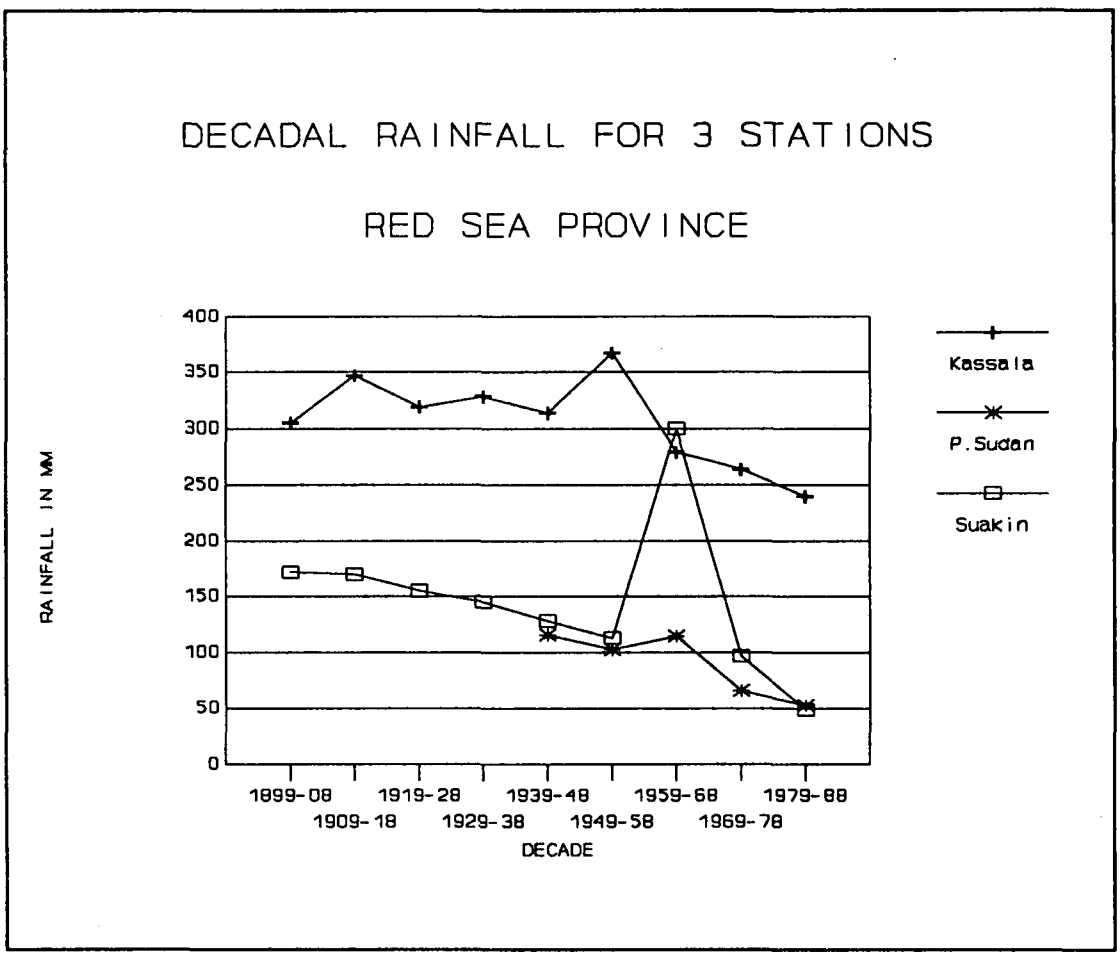
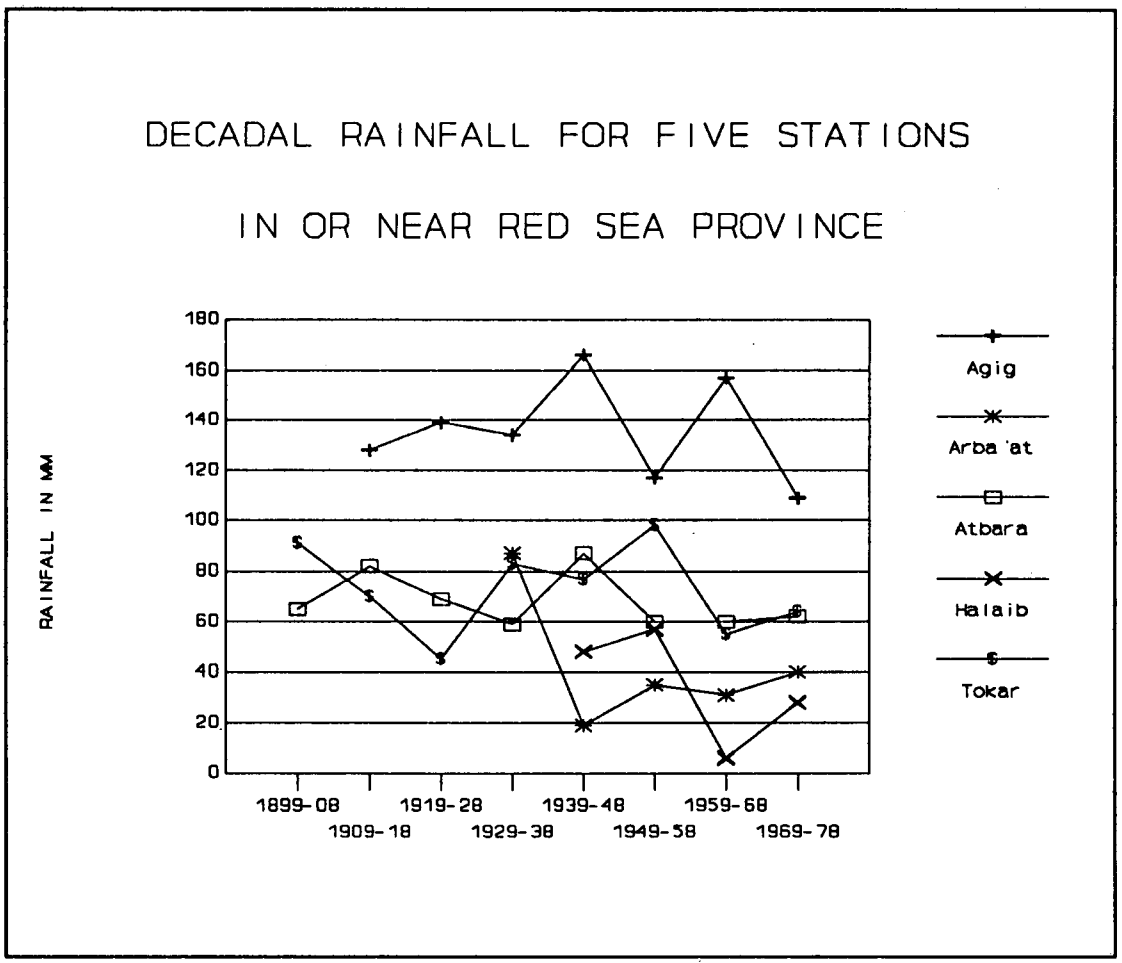


Figure 3.5. Decadal rainfall means exhibiting an upward or indeterminate trend for five rainfall gauging stations in or near Red Sea Province.



Drought and the Rainfall Record

The same criteria used for defining drought for the khors is used in defining drought for rainfall. To reiterate, a **drought** is defined as one year in which the rainfall is equal to or greater than 1 standard deviation below the mean, or equal to or less than 20% of the mean rainfall. **Severe drought**, in contrast, is defined as two consecutive years where rainfall is equal to or more than 1 standard deviation below the mean, or equal to or less than 20% of the mean rainfall.

The rainfall record for all of the stations for which we have data in and around Red Sea Province are presented in Appendices 3 and 4. The table below presents

drought and severe drought periods for the rainfall gauging stations for which we have data.

Table 3.8. Drought and severe drought periods based on rainfall data for three geographic areas in Red Sea Province.

Area	Drought	Severe Drought
Coast		
'Agig	1945, 1960, 1964, 1986	
Halaib	1958, 1969, 1982, 1984, 1988	
Muhammed Qul*	1959	1971-73
Port Sudan	1949, 1973	1980-83, 1987-88
Suakin	1977, 1981, 1983, 1987	
Tokar	1939, 1949, 1960, 1977, 1983	
Interior		
'Atbara	1914, 1918, 1926, 1935, 1941, 1948, 1963, 1966, 1969, 1971, 1973	1912-13, 1982-84
Derudeb*	1948, 1963, 1973	1983-84
Haya*	1941, 1970, 1973, 1975	1980-81
Musmar*	1948, 1960, 1973, 1980, 1982	
Kassala	1902, 1926, 1930, 1958, 1963, 1966, 1970, 1980, 1982	1943-44, 1984-85
Tahamyam*	1919, 1948, 1971, 1980	
Mountain		
Arba'at	1948, 1951, 1969, 1974, 1977, 1987	1953-57, 1980-81, 1983-84
Erba*	1951, 1958, 1969, 1980	
Gebeit*	1944, 1948, 1980	1971-74
Gebeit Mine*	1949, 1980	
Sinkat*	1941, 1943, 1947, 1970, 1980	1977-78

* Incomplete record

Although the early 1970s were a period of deficit rainfall throughout sub-Saharan Africa, it is interesting that it was not registered as severe drought at the gauging stations in the Interior of Red Sea Province. There was, however, serious drought in the Mountain and Coastal zones during that time. Another interesting fact derived from the table is that there was no severe drought in the late 1940s, a recognised period of famine. This famine had little to do with drought. It was, rather, the result of war taxation of the colonies from 1939 to 1945, cereal price inflation associated with the war, and decline in the terms of trade of livestock to cereals which weakened the people of the province such that they were not able to cope with the normal variation of their environment. The same phenomenon happened in Mali in West Africa where the author did research on drought in the mid-1980s. In the Sudan, the Second World War was a boom period and a period of high commodity price inflation. Imports rose from

8,060,849 Egyptian Pounds (£E) to £E 41,966,091 from 1941 to 1951. Exports rose from £E 8,895157 to £E 62,177,529 over the same period (Holt and Daly 1979). Serious problems accompanied these increases. Durra prices doubled from 1939 to 1945 and tripled from 1946 to 1948. Most northern (Nile valley) farmers benefited from the increase in farmgate prices, however, nonfarmers or those only peripherally involved in farming may have experienced a situation not unlike that experienced by many in Red Sea Province in the early 1980s.

Conclusion

In areas like Red Sea Province where almost all economic activity is confined to watercourses, it is good practice to use rainfall data in conjunction with the flood record to obtain a better picture of the extent and severity of drought. In addition to this obvious statement, there are five statements we can make about drought in and around Red Sea Province according to the available flood and rainfall records.

1. Floods and rainfall in and around Red Sea Province are highly variable: floods being more variable than rainfall.

2. There is no general downward trend in the rainfall or flood data, however, there are local downward trends.

3. Up to the early 1980s drought was a localised phenomenon in Red Sea Province.

4. There was no severe drought in the interior areas of the province in the early 1970s according to the flood record. There was, instead, above average flooding.

5. Severe drought was felt during the early 1970s in the Red Sea Hills, an area of predominantly winter rainfall.

6. The famine of 1948 was related to war taxation, cereals price inflation, and change in the terms of trade of livestock and only peripherally related to drought.

7. The area that has experienced the greatest drought impacts in the recent past in the area of study has been the Khor 'Arab basin and its immediate neighbours in 1983 and 1984 and the coastal around Port Sudan since the early 1980s.

Discussion

Despite the variability of precipitation in Red Sea Province, pastoralists and agropastoralists have relied on certain characteristics of the terrain in the province as insurance mechanisms. The principal insurance mechanism are the khors themselves, the focus of almost all rural economic activity. Just as it was said above that without the influence of the Red Sea Hills there would be no winter rainfall, it can be said that without the khors there would be no life in Red Sea Province.

Agriculture is not found outside the stream beds or alluvial fans and pastoralism is reliant on perennial and annual vegetation produced and maintained by annual inundations of the khors. The watershed acts as an enormous catchment that makes the most of spatially dispersed rainfall by channelling it to human users near the central course of the khors. As Evanari (1979) found in his study of ancient and modern water harvesting in the Negev, 10 mm of annual rainfall is enough to grow tropical fruit trees if the catchment area is 30 times greater than the area of cultivation. This is the principal behind land use in Red Sea Province. Furthermore, the vegetation in some large khors (and some small khors, particularly in the mountains) in Red Sea Province does not experience annual drought; the trees (and sometimes the grass) are always green because of subsurface water supplies.

Only in years of extreme and persistent drought or where there are other intervening variables does the insurance system break down, as it did in the Khor 'Arab basin in 1983-84, the place where destitute people were found crowding along the Port-Sudan Khartoum road begging for food in 1985, or in the coastal (and presumably, mountain) areas around Suakin and Port Sudan. Destitute people from these areas settled in Suakin, Port Sudan, and around Tokar town.

Although drought cannot be held responsible for the entire burden of misery shouldered by many people in Red Sea Province during the middle 1980s, it is a causal factor. Other factors which played a significant role in extending the misery during the early 1980s were principally economic inflation and, to a lesser extent, lack of economic diversification, and isolation. Of primary importance during the famine of 1984-85 was inflation of cereal prices and the turning of the terms of trade of livestock to cereals against livestock. This inflation might have been meaningless if, with the exception of the Tokar Delta, local production in interior and coastal Red Sea Province had not collapsed for two years running. This was exacerbated by low production elsewhere in the Sudan. The economic impact of these factors in conjunction with drought are first felt by people who have a reason for being poor: single parent households (divorced or widowed women), families with unemployed or aged heads of household, refugees, and the incompetent.

The late mid to late 1980s brought a more promising outlook to Red Sea Province. It is unfortunate that no data are available from the National Water Corporation for 1988, a year of unprecedented rainfall and flooding. The National Water Corporation was not able to field their watershed monitoring teams because of the financial crisis in the Sudan. It is clear that flooding was probably two or three standard deviations above the mean throughout the province in 1988. The rainfall for the 'Atbara

station, located at the confluence of the Nile and 'Atbara rivers, was almost 3 standard deviations above the mean and Kassala's was one standard deviation above the mean.

Limitations of the Study

A major limitation to what we can say about drought in Red Sea Province is presented by the use of annual averages in the present study rather than monthly averages. The method used in the present study was insensitive to years in which floods were few but high in volume. This could have masked what technically should have been classed as drought. Caution needs to be exercised with the flood data obtained from the Tokar and Gash Deltas. Change in the number of feddans inundated over time may have been due to deteriorating infrastructure rather than drought. This is probably more of a problem in the Gash than in Tokar because of the canal system employed in the Gash.

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Appendix 3.1. Annual floods for nine khors in Red Sea Province and Khor Gash in Kassala Province.

Table 3.9. Annual floods in cubic metres, Khors Aiterba, 'Arab and Arba'at.

Khor Aiterba		Khor 'Arab		Khor Arba'at			
Year	Volume*	Year	Volume	Year	Flood Volume	Flow** Volume	Floods and Flow
1977	6679425	1960	3883203	1957	14701480	2811170	17512650
1978	6266306	1961	14377191	1958	9846225	1347844	11194069
1979	5181696	1962	4640592	1959	47125198	999570	48124768
1980	6668739	1963	3647072	1960	10164516	0	10164516
1981	22745285	1964	33397056	1961	10835120	6410958	17246078
1982	7132806	1965		1962	10016618	5146416	15163034
1983	1585458	1966	6216335	1963	7264706		7264706
1984	948006	1967	40502232	1964	5216727		5216727
1985	0	1968	7397496	1965			
1986	17952165	1969	13633582	1966	9146808		9146808
1987	3764457	1970	0	1967	13527184		13527184
		1971	3194103	1968			
		1972	3453205	1969	521370	5907946	6429316
		1973	16706136	1970	9309064	4398372	13707436
		1974	17018364	1971	3778713	4229998	8008711
		1975	21010873	1972	20019218	3825381	23844599
		1976	31580204	1973	67608120	5154562	72762682
		1977	8788883	1974	0	3867995	3867995
		1978	51993344	1975	7158744	3561140	10719884
		1979	25212744	1976	18105828	3998287	22104115
		1980	2230092	1977	3918489	4281730	8200219
		1981	7186457	1978	72601850	3847592	76449442
		1982	5415246	1979	72317441	8300635	80618076
		1983	0	1980	20496884	10109752	30606636
		1984	0	1981	23504123	8536980	32041103
		1985	4161672	1982	25856239	5596138	31452377
		1986	23182884	1983	18060302	4339600	31452377
		1987	17998695	1984	15493752	4520110	20013862
				1985	26862210	2863584	29725794
				1986	0	2315799	2315799
				1987	1.88E+08	1992834	1.9E+08
				1988	66974256	2737736	69711992

* All records are in cubic meters except Khors Baraka and Gash which are in feddans inundated.

** Permanent flow.

Table 3.10. Annual floods, Khors Baraka, Gash, and Gwob.

Khor Baraka

Year	Flooded Area	Year	Flooded Area	Year	Flooded Area	Year	Flooded Area
1900	19068	1922	42000	1944	86000	1966	27000
1901	13369	1923	49863	1945	114000	1967	112000
1902	14611	1924	35000	1946	96000	1968	111000
1903	18465	1925	31000	1947	65210	1969	28000
1904	39671	1926	33900	1948	26000	1970	110000
1905	33492	1927	60000	1949	56250	1971	40000
1906	36332	1928	75000	1950	168000	1972	82525
1907	50647	1929	125000	1951	38167	1973	88546
1908	27658	1930	100000	1952	50000	1974	124641
1909	45324	1931	85000	1953	134949	1975	167000
1910	51287	1932	99000	1954	27455	1976	56000
1911	43923	1933	70000	1955	2602	1977	118000
1912	53495	1934	66000	1956	177873	1978	128000
1913	30061	1935	25000	1957	22165	1979	35953
1914	76598	1936	82000	1958	71787	1980	61213
1915	38154	1937	43000	1959	117721	1981	55680
1916	122661	1938	85000	1960	23485	1982	63535
1917	43190	1939	54000	1961	214838	1983	78315
1918	42670	1940	50000	1962	12491	1984	35000
1919	47797	1941	64000	1963	22685	1985	95000
1920	135977	1942	76000	1964	117435	1986	88358
1921	54914	1943	71480	1965	29000		

Khor Gash

Year	Flooded Area	Year	Flooded Area
1963	37802	1976	61892
1964	70852	1977	64593
1965	49185	1978	65278
1966	60593	1979	54446
1967	103948	1980	54951
1968	45333	1981	
1969	80353	1982	50184
1970	80557	1983	38358
1971	86970	1984	51531
1972	74101	1985	55371
1973	72174	1986	46579
1974	100007	1987	47000
1975	159441	1988	78000

Khor Gwob

Year	Volume	Year	Volume
1958	530855	1973	2756056
1959	27916104	1974	5499146
1960	0	1975	5503613
1961	18829481	1976	14543618
1962	16609946	1977	0
1963	835452	1978	5760882
1964	610101	1979	4083526
1965	4877111	1980	0
1966	7861405	1981	821619
1967	1319211	1982	2773504
1968	441017	1983	0
1969	1930961	1984	0
1970	0	1985	0
1971	0	1986	0
1972	2047338	1987	0

Table 3.11. Annual floods, Khors Kass, Sallum, Tahamyam, and 'Udrus.

Khor Kass		Khor Sallum		Khor 'Udrus	
Year	Volume	Year	Volume	Year	Volume
1974	24939468	1958	1382260	1960	842657
1975	3264158	1959	3920478	1961	9005
1976	7560343	1960	346285	1962	1792596
1977	4122927	1961	1196811	1963	4000417
1978	13073481	1962	1433899	1964	3579394
1979	27907570	1963	17542606	1965	447556
1980	3136285	1964	8411399	1966	12732343
1981	4607328	1965	9647082	1967	2449567
1982	3755871	1966	3754362	1968	1747935
1983	0	1967	3706716	1969	
1984	0	1968	2346186	1970	0
1985	2432349			1971	3055169
1986	10878012			1972	983214
1987	11179737			1973	7973056
				1974	1049670
				1975	1071787
Khor Tahamyam				1976	1260379
				1977	1080071
Year	Volume			1978	1356198
				1979	
1974	182719			1980	
1975	4076658			1981	2996280
1976	9472397			1982	3457701
1977	769429			1983	0
1978	5158257			1984	6480234
1979	2151159			1985	0
1980	0			1986	1986624
1981	0			1987	4234689
1982	0				
1983	0				
1984	0				
1985	0				
1986	3582558				
1987	0				

Appendix 3.2. Annual flood z scores for nine khors in Red Sea Province and Khor Gash in Kassala Province.

Figure 3.6. Annual flood z scores, Khor Aiterba, 1977 to 1987.

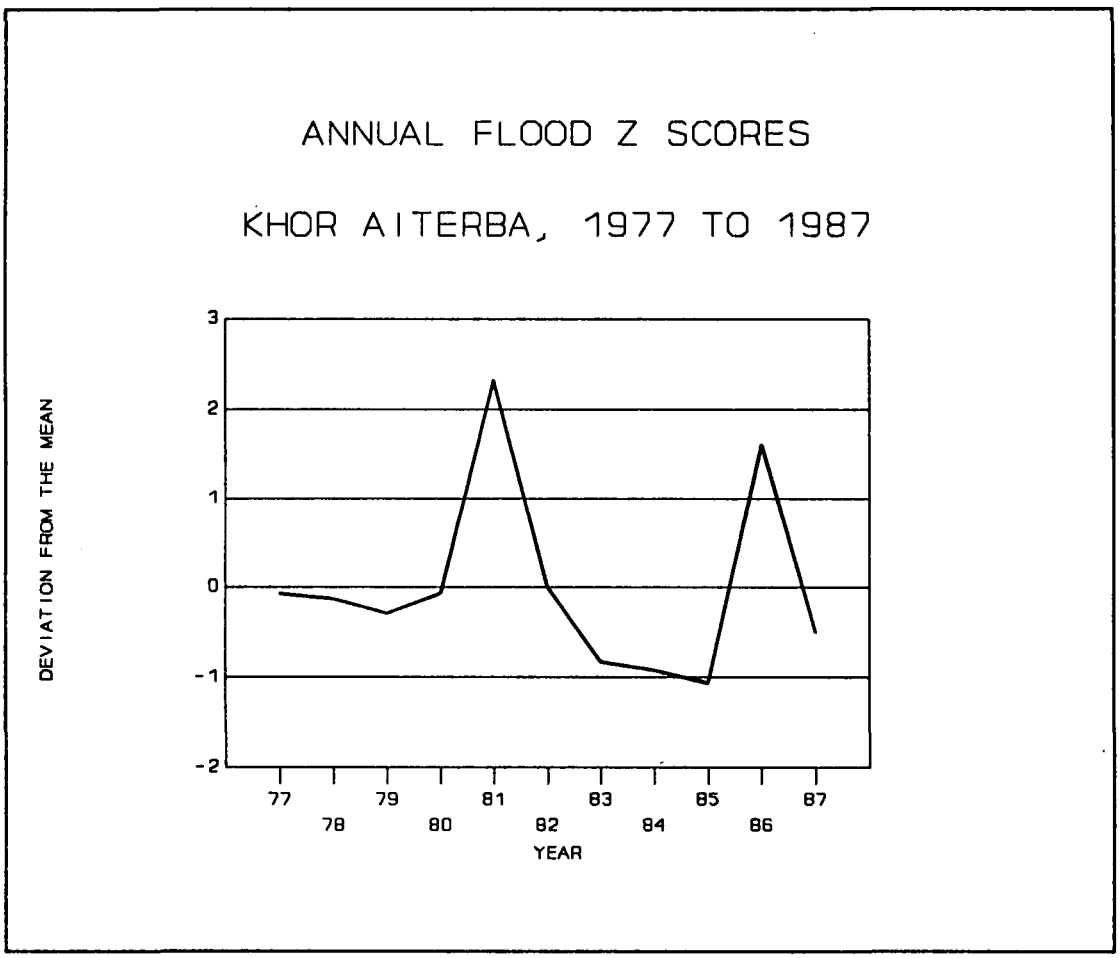


Figure 3.7. Annual flood z scores, Khor 'Arab, 1960 to 1987.

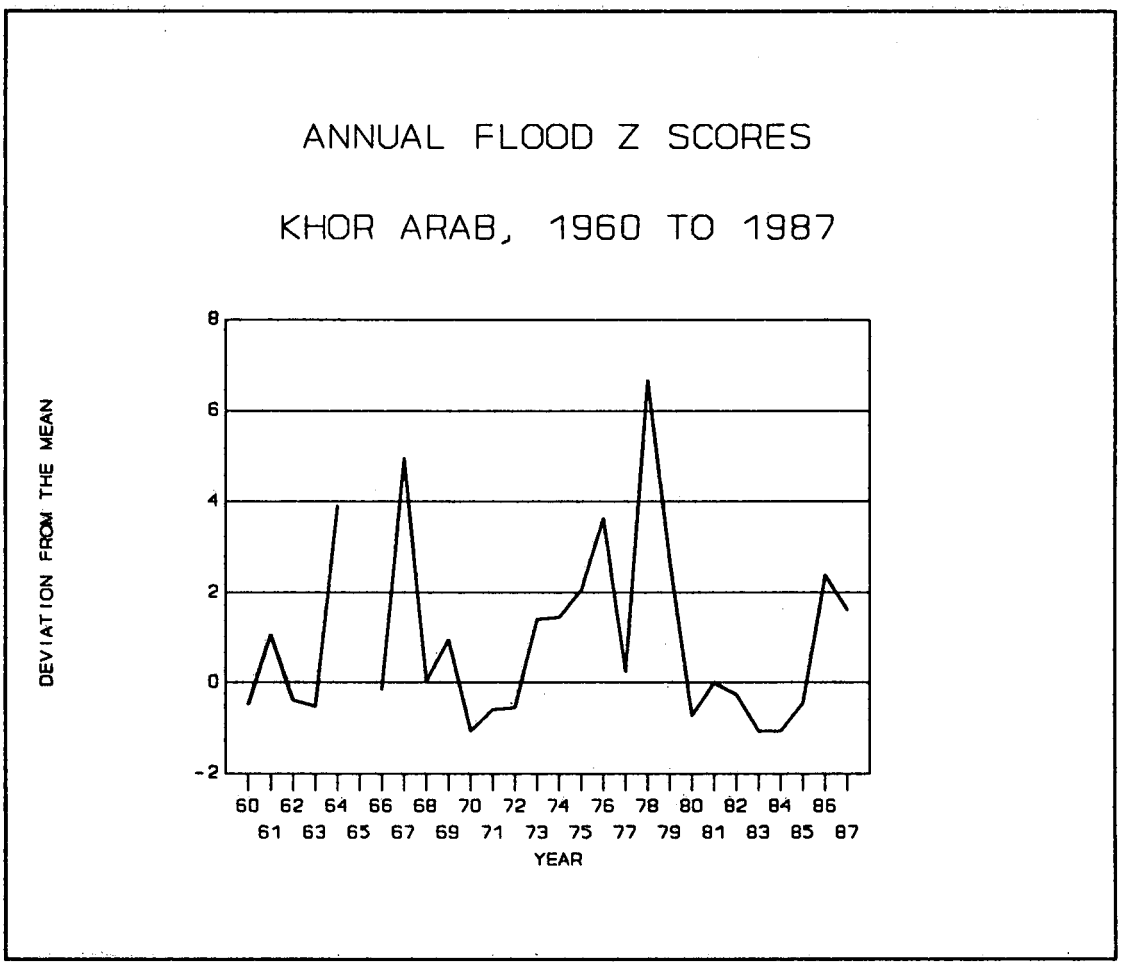


Figure 3.8. Annual flood z scores, Khor Arba'at, 1957 to 1987.

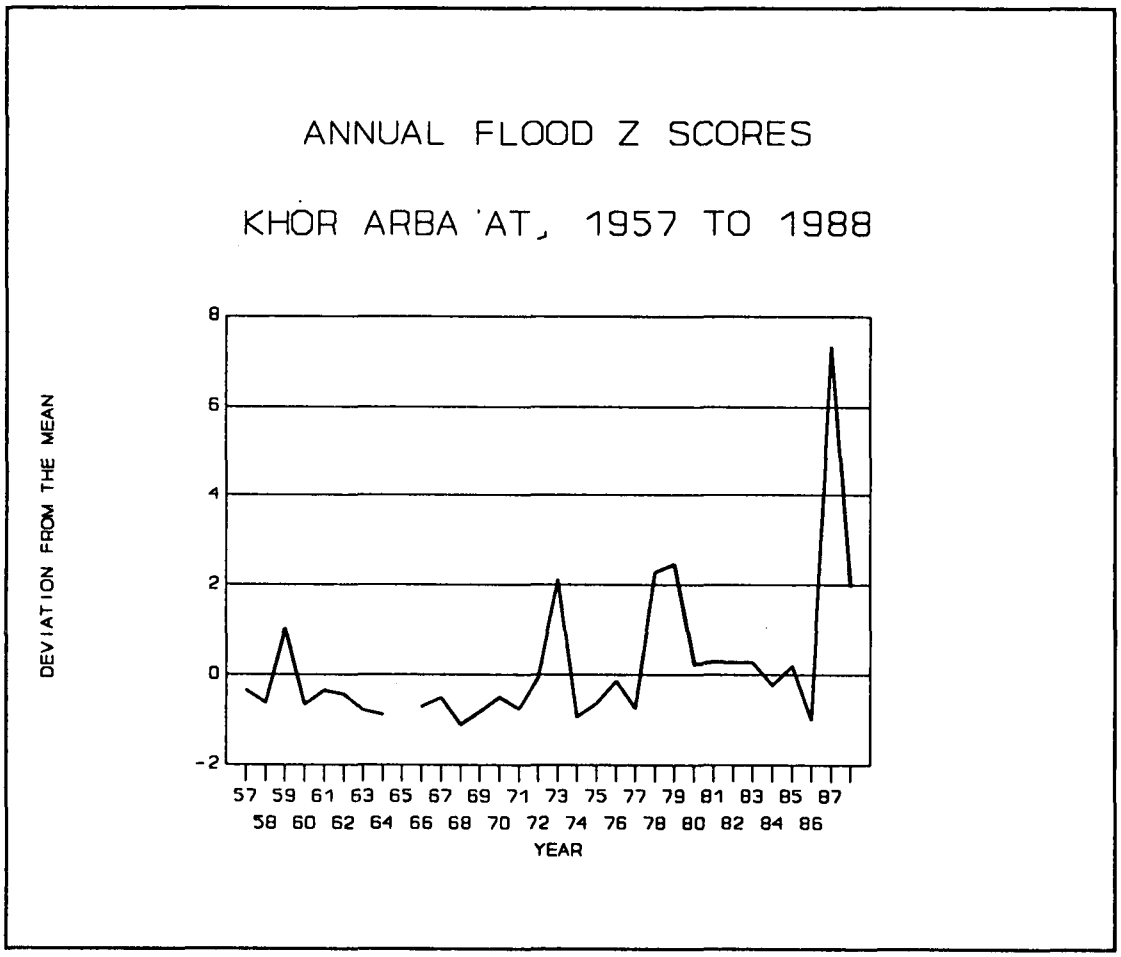


Figure 3.9. Annual flood z scores, Khor Baraka, 1900 to 1986.

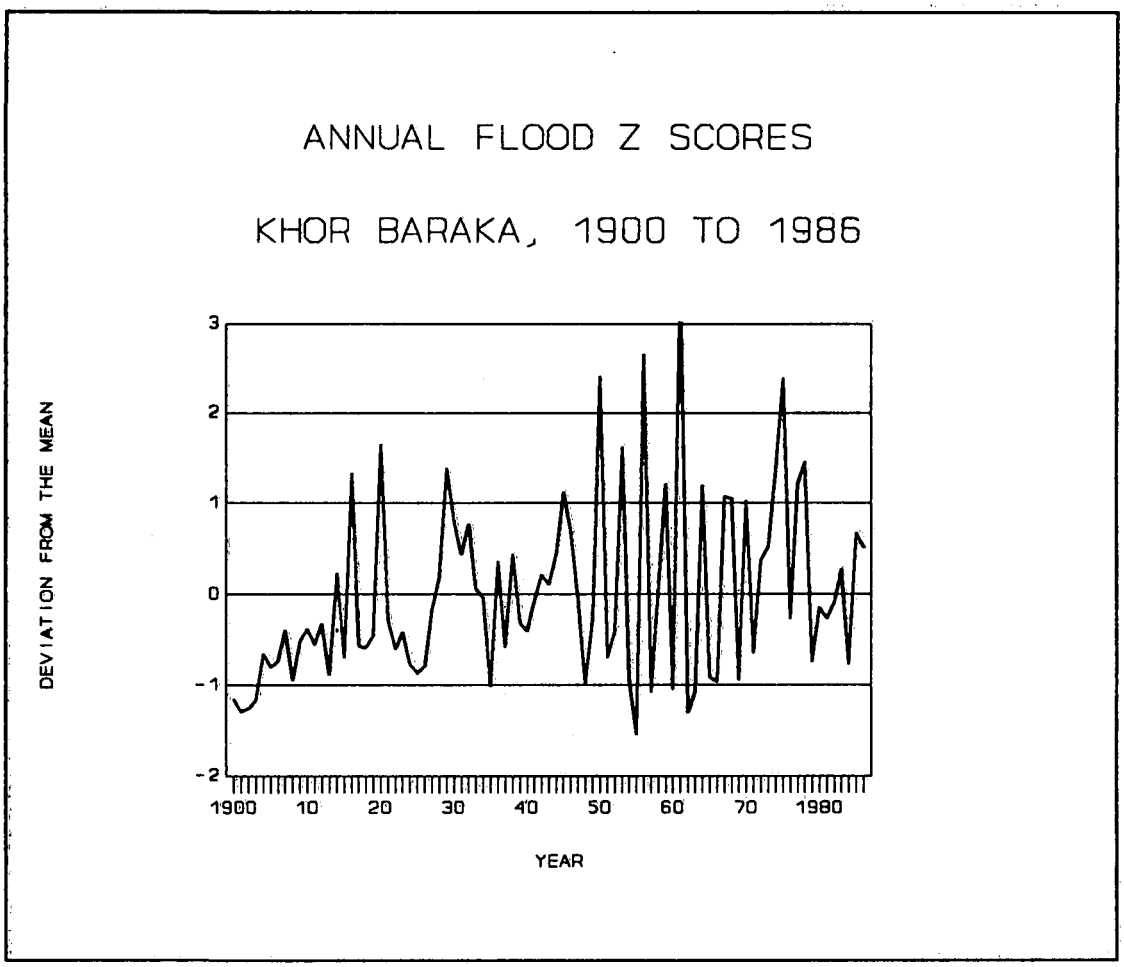


Figure 3.10. Annual flood z scores, Khor Gash, 1964 to 1988.

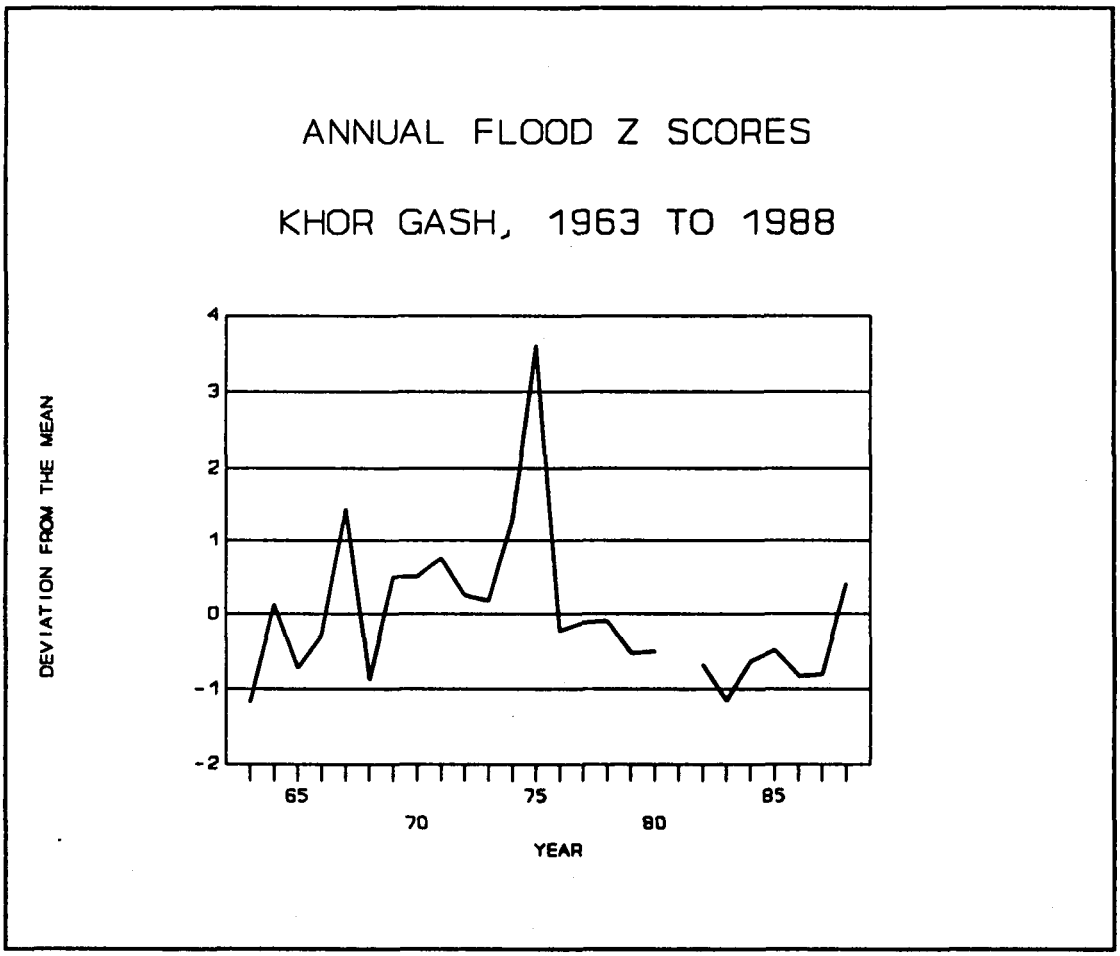


Figure 3.11. Annual flood z scores, Khor Gwob, 1958 to 1987.

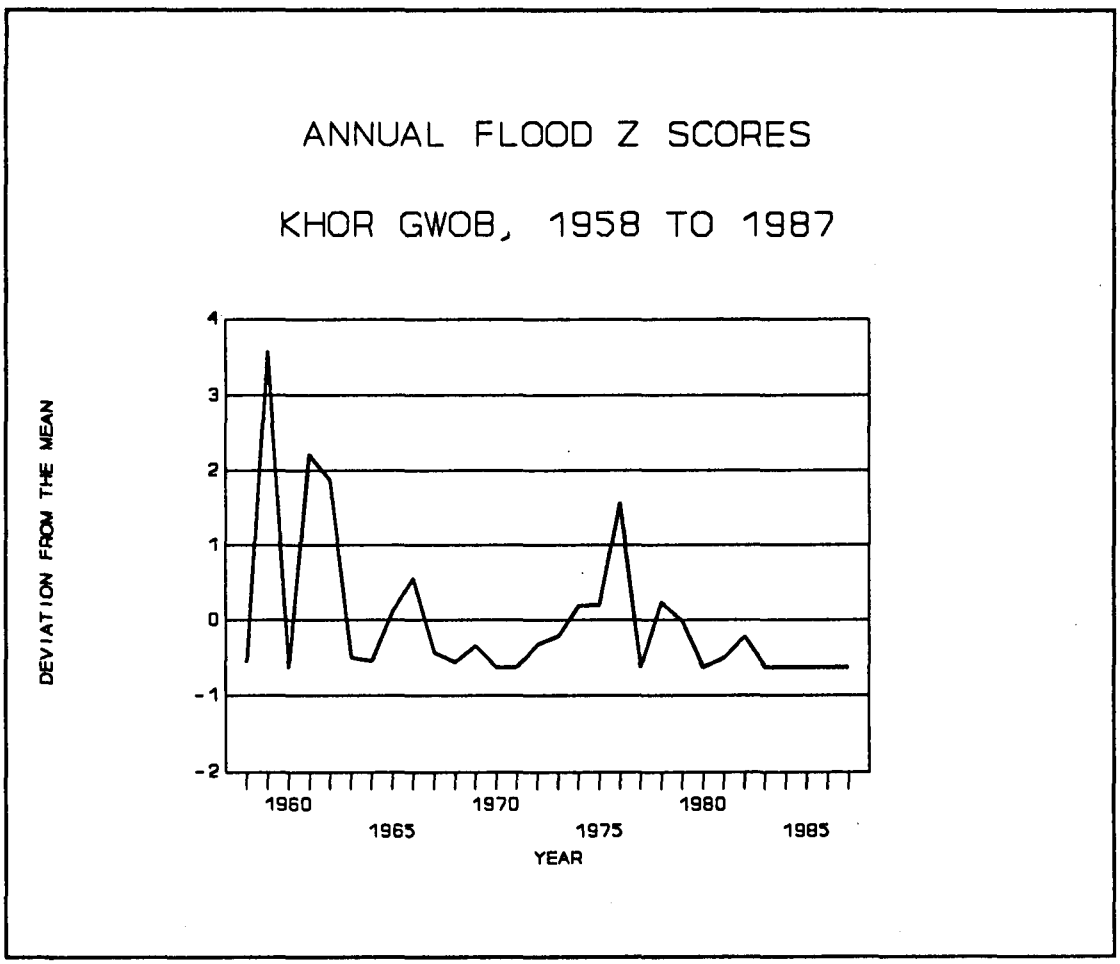


Figure 3.12. Annual flood z scores, Khor Kass, 1979 to 1987.

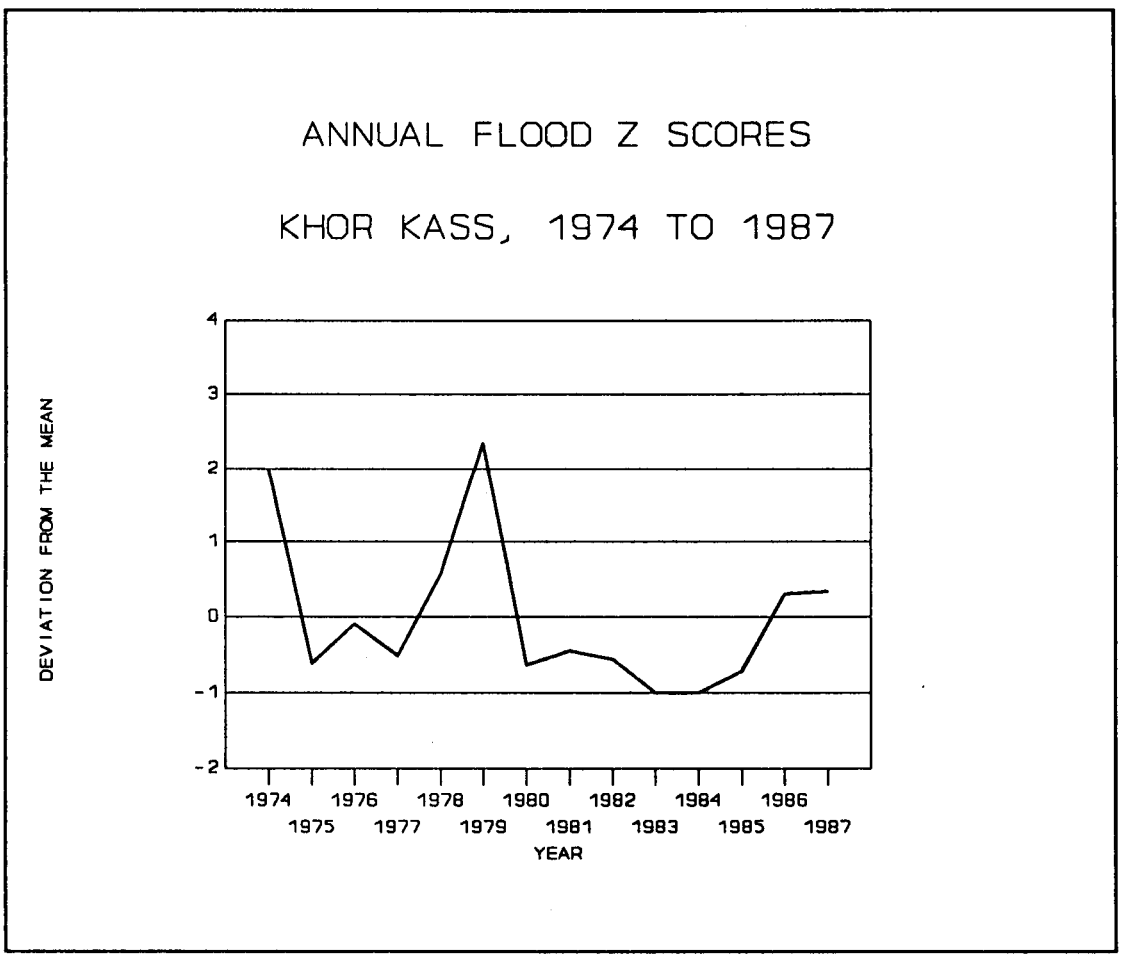


Figure 3.13. Annual flood z scores, Khor Sallum, 1958 to 1968.

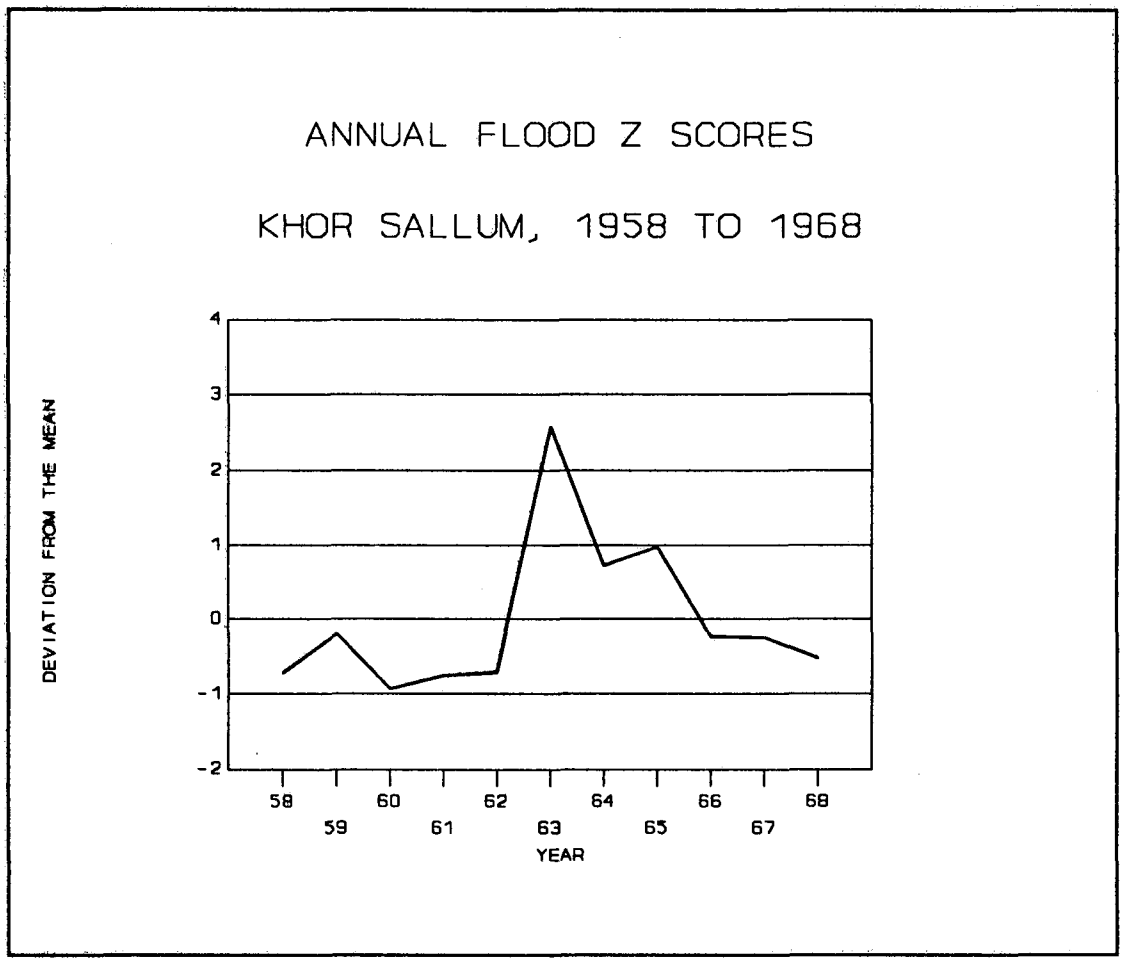


Figure 3.14. Annual flood z scores, Khor Tahamyam, 1974 to 1987.

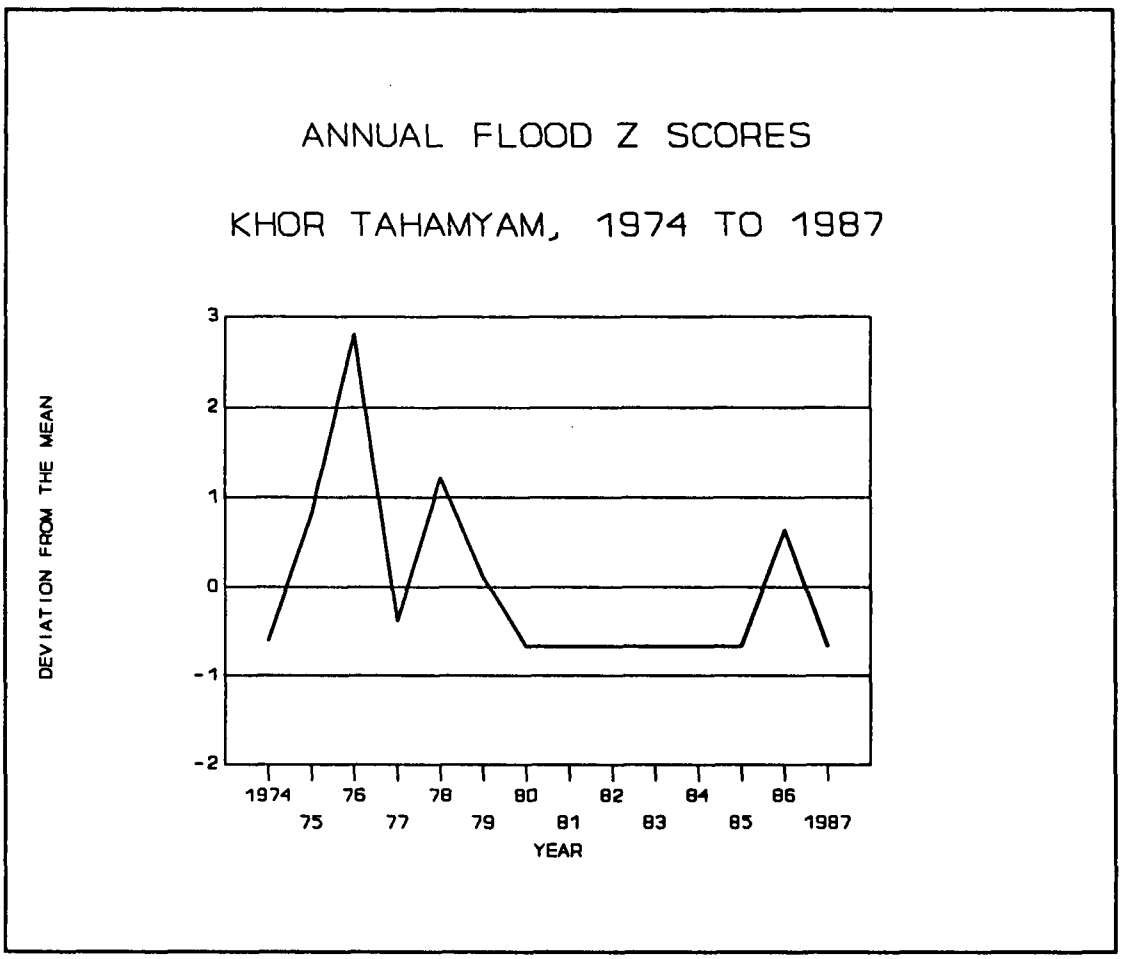
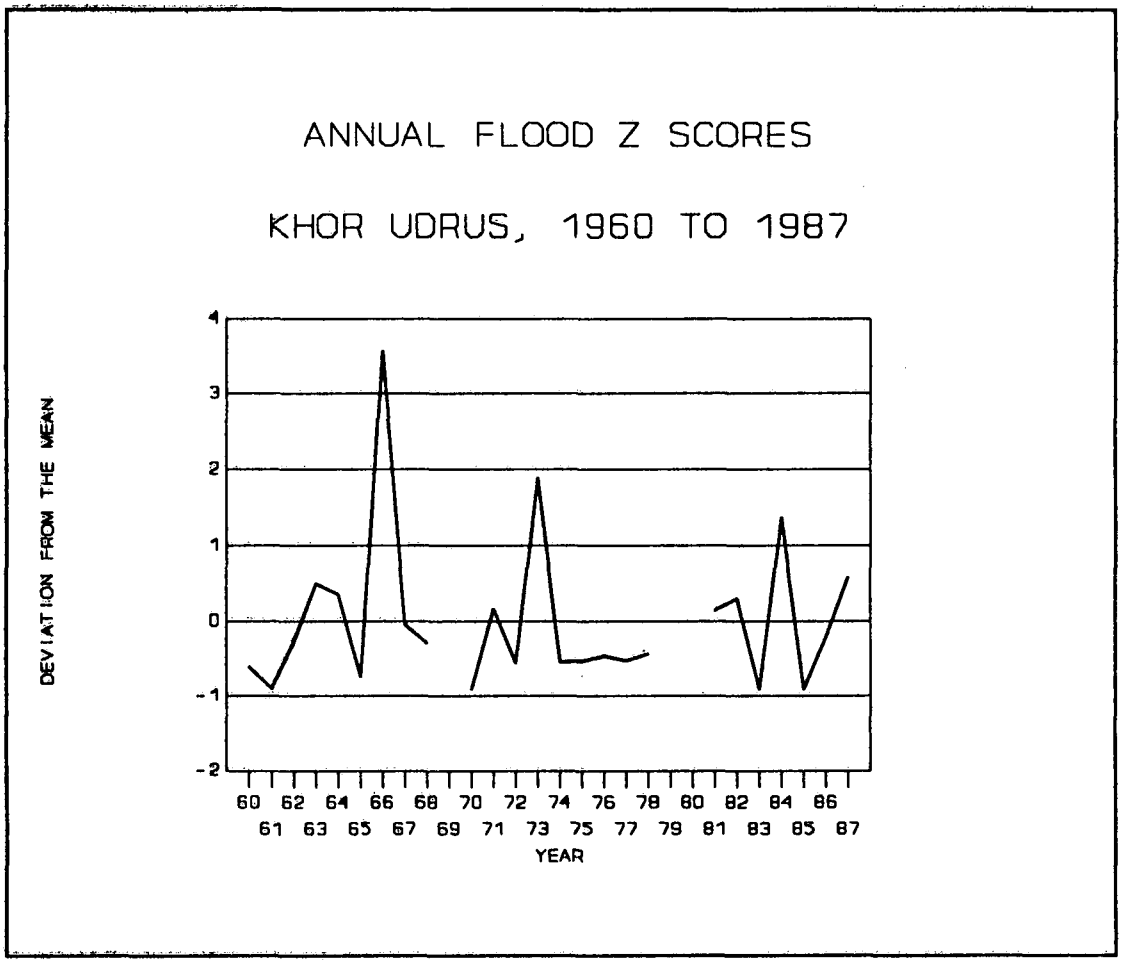


Figure 3.15. Annual flood z scores, Khor 'Udrus, 1960 to 1987.



Appendix 3.3. Annual rainfall in millimetres for 19 gauging stations in Eastern Region, Sudan.

Table 3.12. Annual rainfall in millimetres, 'Agig and Arba'at stations.

'Agig				Arba'at	
1943	112.4	1960	35	1944	82.6
1921	125	1961	340	1945	103
1922	170	1962	80	1946	119
1923	70	1963	78	1947	99
1924	320	1964	25	1948	4
1925	125	1965	110	1949	74
1926	85	1966	60	1950	33
1927	60	1967	225	1951	4
1928	65	1968	80	1952	54
1929	27	1969	145	1953	0
1930	101	1970	100	1954	0
1931	248	1971	143	1955	0
1932	65	1972	180	1956	0
1933	68	1973	170	1957	4
1934	135	1974	100	1958	20
1935	320	1975	306	1959	21
1936	200	1976	142	1960	32.6
1937	120	1977	115.4	1961	40
1938	110	1978	168	1962	88
1939		1979	135.7	1963	
1940		1980	84	1964	26
1941		1981	68.2	1965	24
1942		1982	108.7	1966	61
1943		1983	67.1	1967	14
1944	170	1984	326.8	1968	7
1945	40	1985	71.8	1969	
1946	195	1986	41.9	1970	
1947	105	1987	125	1971	
1948	160	1988	62.8	1972	
1949	320			1973	16.9
1950	65			1974	2.3
1951	390			1975	11.5
1952	60			1976	89.4
1953	120			1977	6.6
1954	190			1978	60.7
1955	70			1979	65.5
1956	125			1980	2.7
1957	175			1981	7.4
1958	145			1982	152.2
1959	140			1983	0.2
				1984	0.1
				1985	42.6
				1986	84.3
				1987	1.5

Table 3.13. Annual rainfall in millimetres, 'Atbara and Delai stations.

'Atbara				Delai	
1907	100.1	1950	166.1	1944	110
1908	63.9	1951	67.3	1975	114.5
1909	79.8	1952	115.3	1976	42
1910	241.6	1953	106.6	1977	47
1911	141.3	1954	57.3	1978	63
1912	17.3	1955	25.9	1979	93
1913	0	1956	104	1980	38
1914	80.3	1957	41.6	1981	241
1915	1.8	1958	149.3	1982	148
1916	52	1959	85.3	1983	12
1917	28.7	1960	8.4	1984	5
1918	5.2	1961	134.4		
1919	73.8	1962	53.2		
1920	67.5	1963	16.4		
1921	140.8	1964	51.1		
1922	127.2	1965	86.9		
1923	195.4	1966	16.2		
1924	77.1	1967	55.6		
1925	33	1968	96.2		
1926	12	1969	14.7		
1927	72.5	1970	93.8		
1928	21.5	1971	11.4		
1929	92.2	1972	55.2		
1930	42.5	1973	11.9		
1931	108.3	1974	51		
1932	98	1975	92.2		
1933	53.3	1976	68.8		
1934	37.8	1977	111.7		
1935	16	1978	91.9		
1936	88.7	1979	105.9		
1937	108.2	1980	63.3		
1938	48.7	1981	27		
1939	50	1982	18		
1940	69.5	1983	15.5		
1941	17.7	1984	1.1		
1942	130.6	1985	33.3		
1943	31.7	1986	41.3		
1944	64.4	1987	71		
1945	68.8	1988	238.9		
1946	93.9				
1947	55.7				
1948	10.6				
1949	39.4				

Table 3.14. Annual rainfall in millimetres, Derudeb, Erba, and Erkowit stations.

Derudeb		Erba		Erkowit	
1945	180	1942	264	1944	466.3
1946	110	1943	38.6	1945	250.2
1947	90	1944	91	1946	153.7
1948	17	1945	36	1947	87.8
1949	125	1946	115	1948	51.5
1950	440.2	1947	71	1949	134.6
1951	49	1948	64	1950	234.8
1952	178	1949	96	1951	40
1953	220.5	1950	257.5	1952	90
1954	88.6	1951	14	1953	
1955	45.7	1952	53	1954	
1956	117.3	1953	146.9	1955	
1957	84.6	1954	59	1956	
1958	147	1955	39	1957	
1959	167	1956	125	1958	
1960	31	1957	100	1959	
1961	237.7	1958	29.9	1960	
1962	82.3	1959	129	1961	
1963	9	1960	61	1962	
1964	97	1961	124	1963	
1965	81	1962	70	1964	
1966	84	1963	40	1965	156.2
1967	122	1964	147	1966	145.1
1968	153	1965	54	1967	254.4
1969	52	1966	105	1968	161.5
1970	106	1967	47	1969	43.5
1971	127	1968	112	1970	184.5
1972	33	1969	15	1971	136.6
1973	26	1970	60	1972	72.6
1974	37	1971	60	1973	
1975	67	1972	65	1974	
1976	176	1973		1975	
1977	58	1974		1976	
		1975	74	1977	50
		1976	58	1978	39.5
		1977	59	1979	
		1978	134	1980	
		1979	138	1981	221.2
		1980	32	1982	88.7
		1981	46	1983	140.1

Table 3.15. Annual rainfall in millimetres, Gebeit and Gebeit Mine stations.

Gebeit				Gebeit Mine	
1908	71.4	1950	231.1	1944	119
1909	124.1	1951	65.2	1945	28
1910	88.5	1952	189	1946	63
1911	157.3	1953	105.3	1947	28
1912	99.2	1954	103.1	1948	30
1913	128.8	1955	85	1949	5
1914	119.8	1956	168	1950	93
1915	77	1957	52.2	1951	54
1916	158.1	1958	88	1952	68
1917	153.4	1959	326	1953	88
1918	97.5	1960	66	1954	38
1919	62.4	1961	171	1955	38
1920	108.8	1962	113	1956	0
1921	301.3	1963	76.5	1957	45
1922	96.6	1964	99	1958	39
1923	176.7	1965	69	1959	98
1924	21.4	1966	107.1	1960	242
1925		1967	142	1961	41
1926		1968	229	1962	12
1927		1969	58	1963	113
1928	64.2	1970	87.7	1964	44
1929	116.5	1971	17.9	1965	41
1930	77	1972	32.6	1966	72.5
1931	206	1973	3.3	1967	37.5
1932	173	1974	44.5	1968	69
1933	106.5	1975	122	1969	56
1934	144.7	1976	86	1970	59
1935	109.5	1977	83.5	1971	15
1936	159.2	1978	165	1972	12.5
1937	101.1	1979	286	1973	22.5
1938	66.3	1980	0	1974	50
1939	232.4			1975	19
1940	82			1976	60.5
1941	92.8			1977	99.5
1942	213.6			1978	15
1943	36.5			1979	
1944	201.8			1980	0
1945	151.9			1981	33
1946	121.2				
1947	92.2				
1948	42				
1949	77.1				

Table 3.16. Annual rainfall in millimetres, Halaib and Haya stations.

Halaib		Haya	
1953	57	1940	55
1954	17	1941	10
1955	124	1942	105
1956	38	1943	52
1957	48	1944	130
1958	5	1945	91
1959	18	1946	82
1960	53	1947	21
1961	60	1948	30
1962	83	1949	58
1963	36	1950	166
1964	12	1951	52.8
1965	26	1952	175
1966	168	1953	89.7
1967	32	1954	235
1968	77	1955	47
1969	4	1956	127.1
1970	15	1957	42.4
1971	0	1958	118
1972	0	1959	139.7
1973	7	1960	33.1
1974	5	1961	160.8
1975	3.8	1962	63.2
1976	20.7	1963	37.6
1977	1.7	1964	75.3
1978	4	1965	60.9
1979	59.5	1966	97.6
1980	10.4	1967	150.7
1981	31.1	1968	25
1982	0	1969	54.5
1983	52	1970	6
1984	1	1971	31
1985	69.2	1972	73
1986	10	1973	12
1987	49.2	1974	29
1988	1	1975	10
		1976	70
		1977	24
		1978	42
		1979	53
		1980	0
		1981	0

Table 3.17. Annual rainfall in millimetres, Kassala and Muhammed Qul stations.

Kassala				Muhammed Qul	
1901	249	1948	205.6	1953	4
1902	199	1949	387.2	1954	41
1903	266	1950	440.7	1955	35
1904	320	1951	337.6	1956	5
1905	378	1952	284.7	1957	51
1906	280	1953	400.7	1958	31
1907	405.2	1954	359.3	1959	0
1908	343	1955	266.3	1960	78
1909	328.2	1956	429.4	1961	24
1910	329.8	1957	317.2	1962	101
1911	291.4	1958	451	1963	38
1912	302	1959	335.4	1964	23
1913	406.4	1960	293.3	1965	40
1914	333.8	1961	266.5	1966	171
1915	438.1	1962	285.3	1967	49
1916	487.9	1963	207.1	1968	90
1917	313.9	1964	464	1969	23
1918	236.1	1965	235.3	1970	52
1919	273.9	1966	131.1	1971	0
1920	387.7	1967	266	1972	0
1921	254.9	1968	305.5	1973	0
1922	314.6	1969	228.2	1974	45
1923	461.5	1970	220.2	1975	29
1924	330.5	1971	354.5	1976	
1925	324	1972	222.7	1977	
1926	135.3	1973	258.8	1978	50
1927	452.7	1974	334	1979	65
1928	253.4	1975	296.2	1980	7
1929	349.2	1976	243.7		
1930	219.8	1977	212.3		
1931	239.9	1978	270.1		
1932	333.2	1979	280.1		
1933	459.8	1980	194.7		
1934	454.4	1981	239.8		
1935	353.6	1982	217.2		
1936	278.6	1983	249.4		
1937	279.5	1984	98.8		
1938	310.5	1985	145.9		
1939	358.7	1986	306.9		
1940		1987	271.3		
1941		1988	393.8		
1942	452.2				
1943	214.2				
1944	212.3				
1945	350				
1946	386.6				
1947	333.9				

Table 3.18. Annual rainfall in millimetres, Musmar and Port Sudan stations.

Musmar		Port Sudan			
1948	5	1941	72.7	1980	10.9
1949	55	1942	58.3	1981	9.2
1950	161	1943	95.4	1982	80.4
1951	73	1944	149.9	1983	0.1
1952	153	1945	49.2	1984	83
1953	90	1946	164.6	1985	158.4
1954	89	1947	266.1	1986	66.6
1955	35	1948	75.6	1987	10.5
1956	82	1949	180.4	1988	13.9
1957	70	1950	212.9		
1958	118	1951	209.6		
1959	173	1952	67.1		
1960	11	1953	28.1		
1961	300	1954	14.8		
1962	113	1955	45.2		
1963	25	1956	44.6		
1964	87	1957	144.7		
1965	35	1958	84.8		
1966	18	1959	68.9		
1967	69	1960	132.7		
1968	25	1961	121.6		
1969	13	1962	196.8		
1970	26	1963	164.4		
1971	23	1964	47.4		
1972	34	1965	144.6		
1973	10	1966	76.3		
1974	15	1967	30.9		
1975	53	1968	165.2		
1976	27	1969	38.6		
1977		1970	47.4		
1978		1971	108.6		
1979		1972	59.9		
1980	0	1973	8.7		
1981	30	1974	32.7		
1982	3	1975	63.8		
		1976	122.9		
		1977	72.4		
		1978	104		
		1979	94.6		

Table 3.19. Annual rainfall in millimetres, Sinkat station.

1920	73	1965	54
1921	243	1966	88
1922	49.2	1967	146
1923	141	1968	109
1924	157	1969	71
1925	36.1	1970	7
1926	62.3	1971	45
1927	91	1972	75
1928	77.6	1973	86
1929	163.7	1974	95
1930	150.8	1975	64
1931	257.7	1976	102
1932	218.6	1977	31
1933	128.5	1978	20
1934	41.5	1979	94
1935	130.6	1980	12
1936	179.5	1981	68
1937	88.8	1982	50.1
1938	77.5		
1939	168.4		
1940	117		
1941	11		
1942	167.5		
1943	25		
1944	277		
1945	117		
1946	133		
1947	20		
1948	89.7		
1949	114		
1950	215.5		
1951	80		
1952	358		
1953	213		
1954	80		
1955	43		
1956	150		
1957	51		
1958	146		
1959	404.5		
1960	44		
1961	82		
1962	138		
1963	58		
1964	195		

Table 3.20. Annual rainfall in millimetres, Suakin station.

1890	139	1930	43.4	1970	35.2
1891	166	1931	191.4	1971	149.3
1892	152	1932	176.9	1972	212.1
1893	198	1933	258.9	1973	51.7
1894	106	1934	80.5	1974	35.2
1895	401	1935	170.1	1975	49.8
1896	617	1936	63.5	1976	281.1
1897	58	1937	185.1	1977	29.7
1898	443	1938	180	1978	73.6
1899	164	1939	104	1979	64.7
1900	151	1940	152	1980	36
1901	271	1941	138	1981	2.7
1902	452	1942	140	1982	80
1903	166	1943	100	1983	9.7
1904	178	1944	90	1984	35.8
1905	63.5	1945	118.8	1985	136.8
1906	155.3	1946	87.5	1986	37.9
1907	57	1947	273.5	1987	9.1
1908	64.9	1948	80	1988	72.9
1909	54.8	1949	131.6		
1910	65.5	1950	159.2		
1911	367.1	1951	95.6		
1912	325.4	1952	48.6		
1913	125.2	1953	33.5		
1914	78.2	1954	35.5		
1915	137.3	1955	67.5		
1916	294.3	1956	121		
1917	116.3	1957	116		
1918	135.2	1958	323		
1919	129.7	1959	159.5		
1920	106.3	1960	157		
1921	245.7	1961	334		
1922	74.1	1962	515		
1923	205.9	1963	626.3		
1924	148.3	1964	99.5		
1925	327.4	1965	450		
1926	85.7	1966	242.6		
1927	131.7	1967	98.9		
1928	97.1	1968	321.9		
1929	98	1969	52.1		

Table 3.21. Annual rainfall in millimetres, Tahamyam station.

1909	147.1	1955	
1910	305.7	1956	79
1911	168	1957	66
1912	75.5	1958	110
1913	311	1959	129
1914	135	1960	31
1915	38.1	1961	169
1916	54.5	1962	87
1917	63.3	1963	28
1918	102	1964	102
1919	20	1965	101
1920	156.6	1966	104
1921	175.6	1967	35
1922	49.4	1968	30
1923	142.3	1969	85
1924	140.9	1970	55
1925	57.1	1971	13
1926	50.1	1972	46
1927	77.7	1973	
1928	45.6	1974	123
1929	138.1	1975	70
1930	55	1976	51
1931	177.8	1977	59
1932	101.9	1978	40
1933	77.4	1979	84
1934	114.7	1980	19
1935	132.6		
1936	50.1		
1937	111.3		
1938	38.7		
1939	167.8		
1940	62.3		
1941			
1942	41		
1943	41		
1944	93.5		
1945	69		
1946	31.5		
1947	54		
1948	20.1		
1949	39		
1950	282.6		
1951			
1952	31		
1953			
1954			

Table 3.22. Annual rainfall in millimetres, Tokar station.

1913	67	1960	10.8
1914	132	1961	248.4
1915	139.9	1962	57
1916	51.8	1963	200.2
1917	84.4	1964	75.4
1918	71.5	1965	117
1919		1966	68
1920	95	1967	102
1921	64	1968	59.5
1922	62.1	1969	16
1923	64.3	1970	55
1924	111.7	1971	31
1925	87	1972	50
1926	45	1973	58
1927	46.5	1974	48
1928	50	1975	96.7
1929	109.3	1976	52
1930	41.7	1977	13.5
1931	22.7	1978	132.6
1932	9.7	1979	145.5
1933	38.9	1980	35.3
1934	8.5	1981	49.1
1935	8.6	1982	23.7
1936	124	1983	5.4
1937		1984	64
1938		1985	52.9
1939	9.3	1986	79.8
1940	28.3	1987	89.9
1941	166.4	1988	92.7
1942	81.3		
1943	161		
1944	171.8		
1945	33.8		
1946	100.3		
1947	50.2		
1948	27.5		
1949	42.2		
1950	82.4		
1951	144.7		
1952	25.5		
1953	44.9		
1954	10		
1955	51.6		
1956	85.5		
1957	165.5		
1958	113		
1959	44.5		

Appendix 3.4. Annual rainfall z scores for 19 gauging stations in Eastern Region, Sudan.

Figure 3.16. Annual rainfall z scores, 'Agig Station, 1921 to 1988.

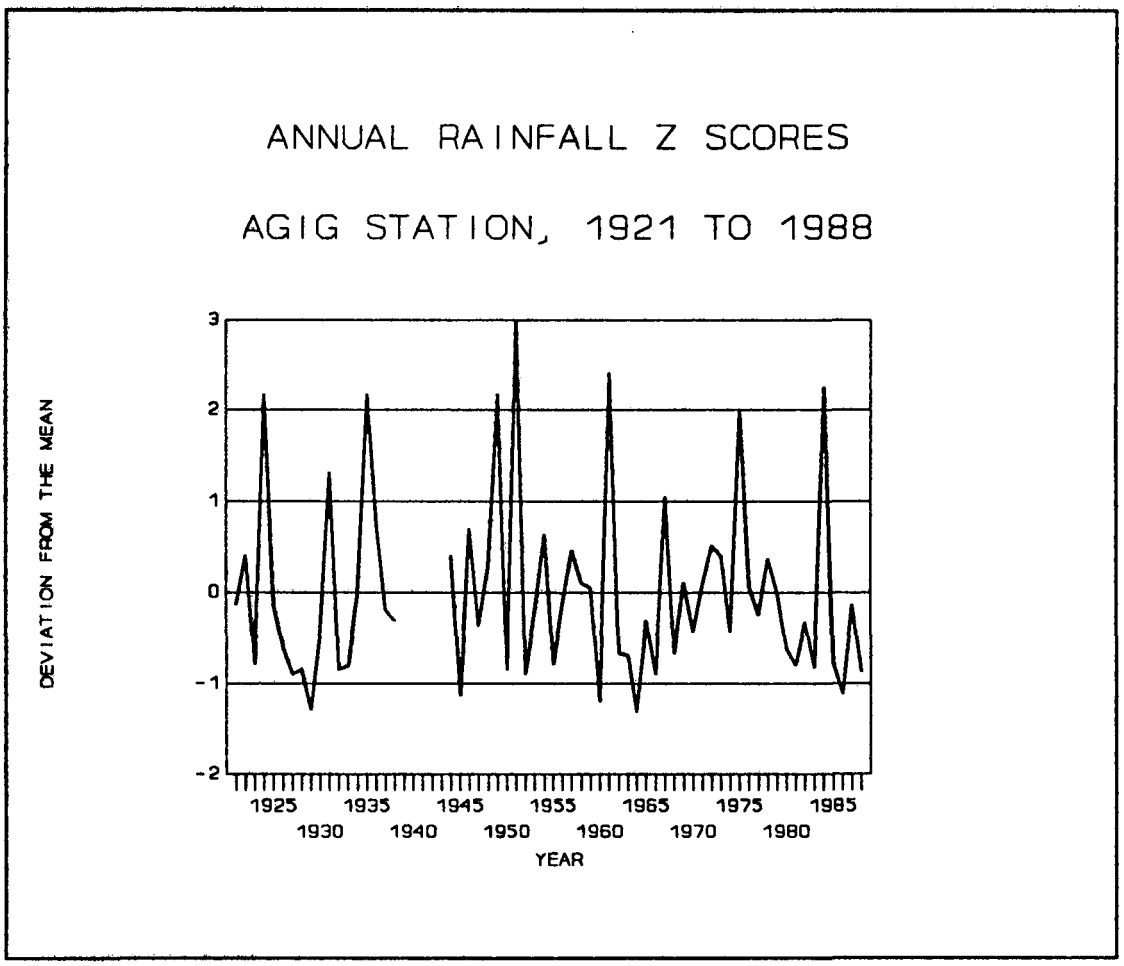


Figure 3.17. Annual rainfall z scores, Arba'at Station, 1943 to 1987.

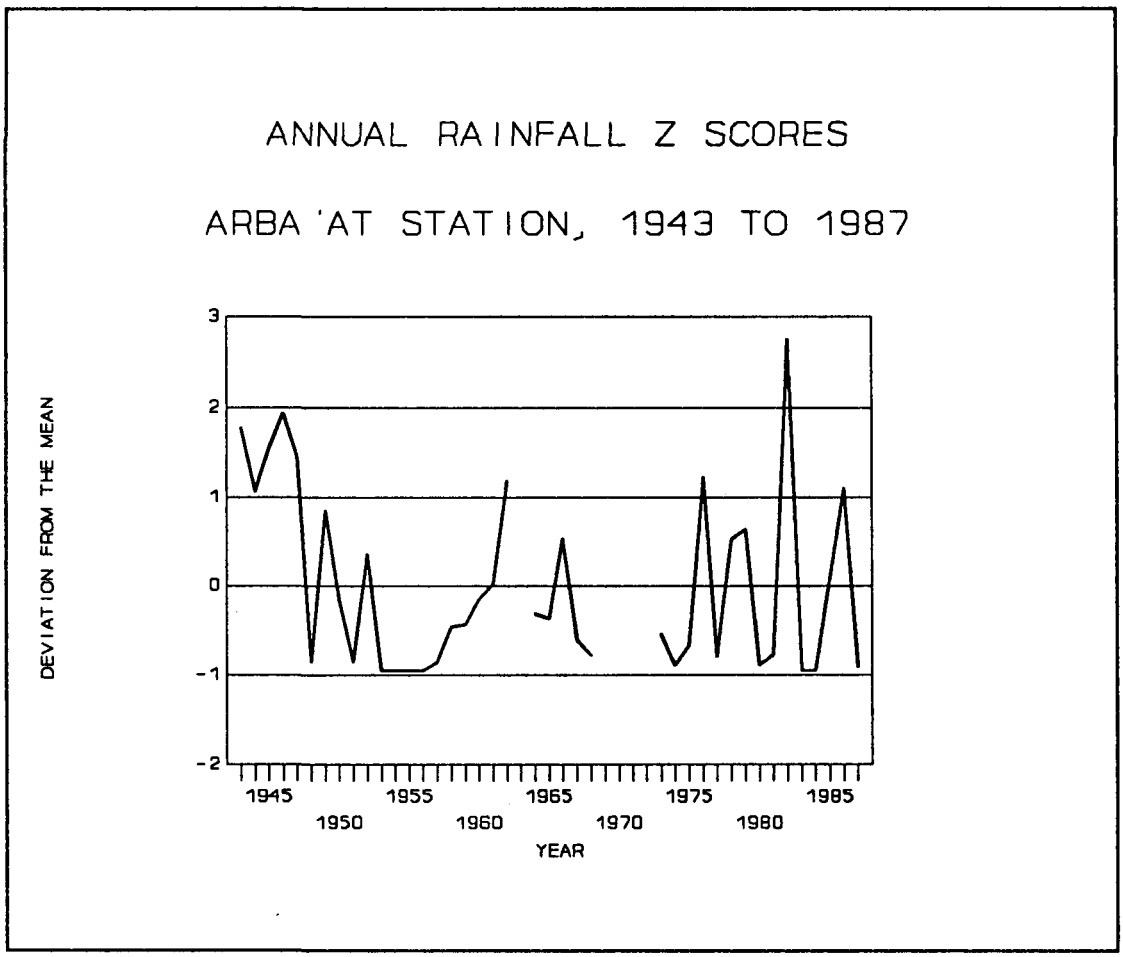


Figure 3.18. Annual rainfall z scores, 'Atbara Station, 1907 to 1988.

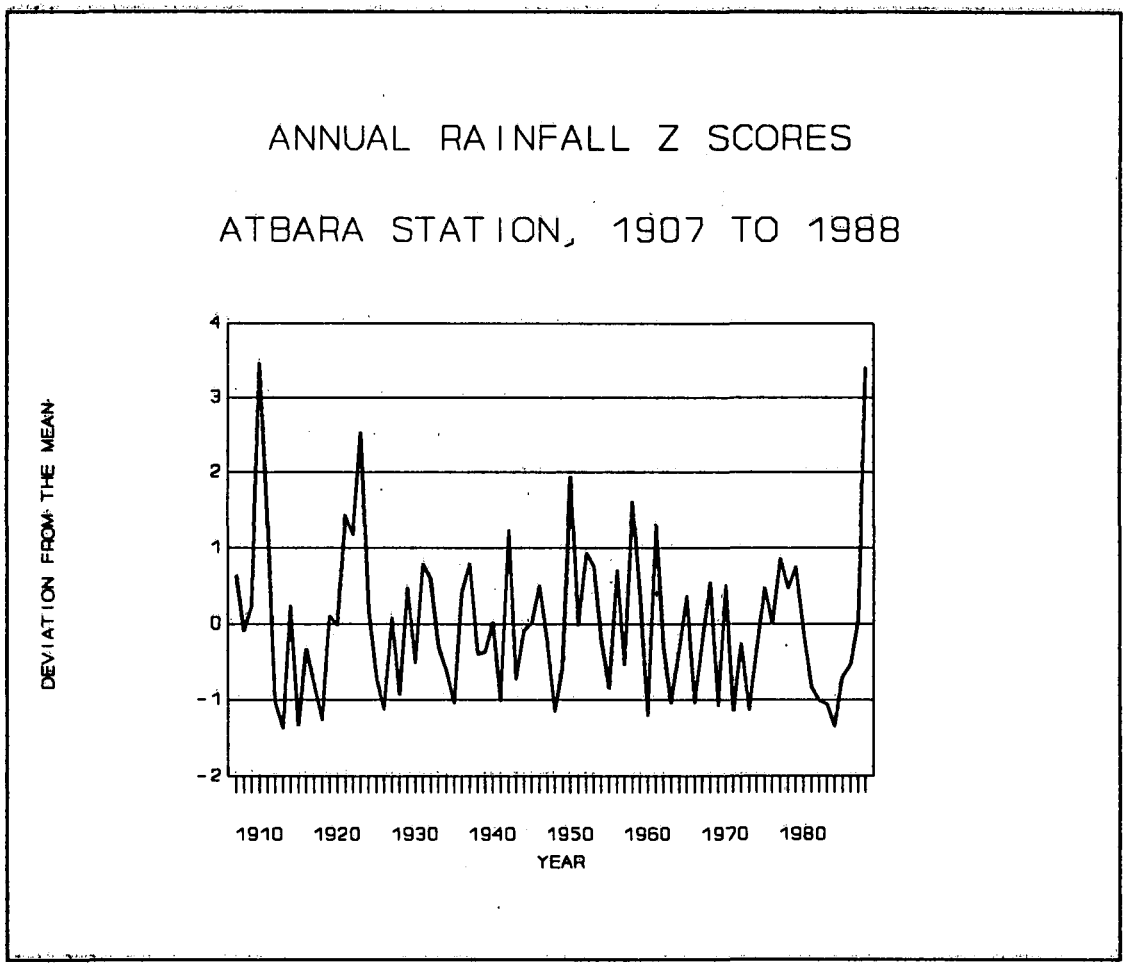


Figure 3.19. Annual rainfall z scores, Derudeb Station, 1944 to 1984.

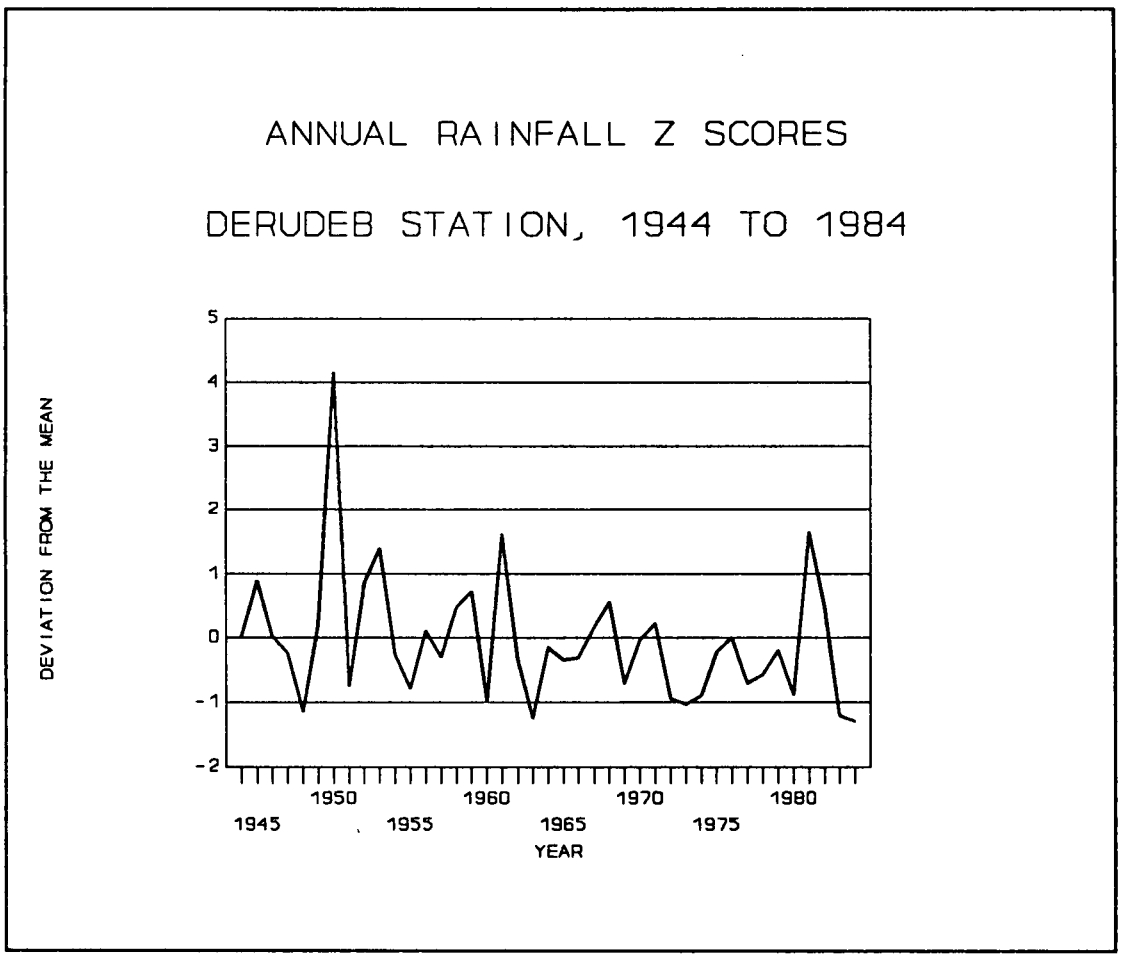


Figure 3.20. Annual rainfall z scores, Erba Station, 1943 to 1981.

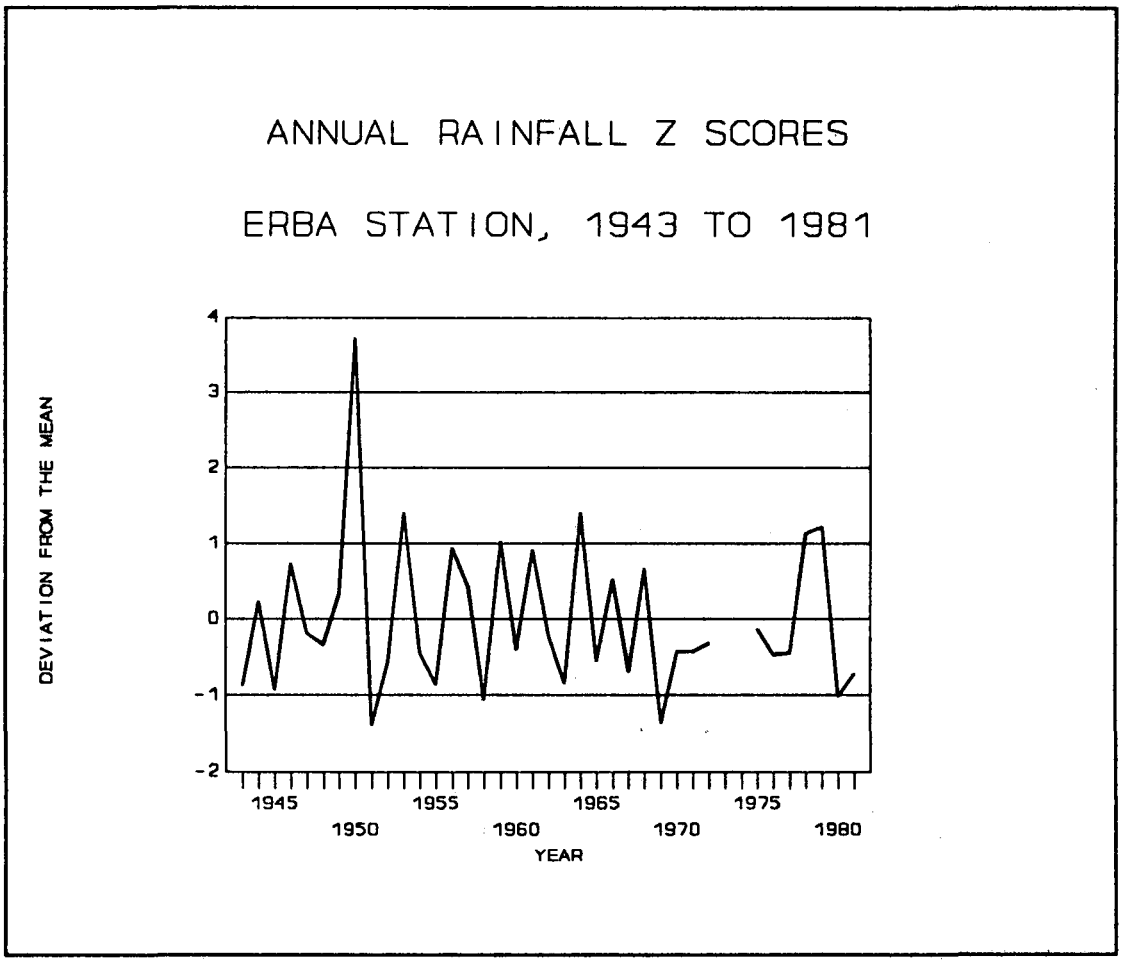


Figure 3.21. Annual rainfall z scores, Erkowit Station, 1943 to 1983.

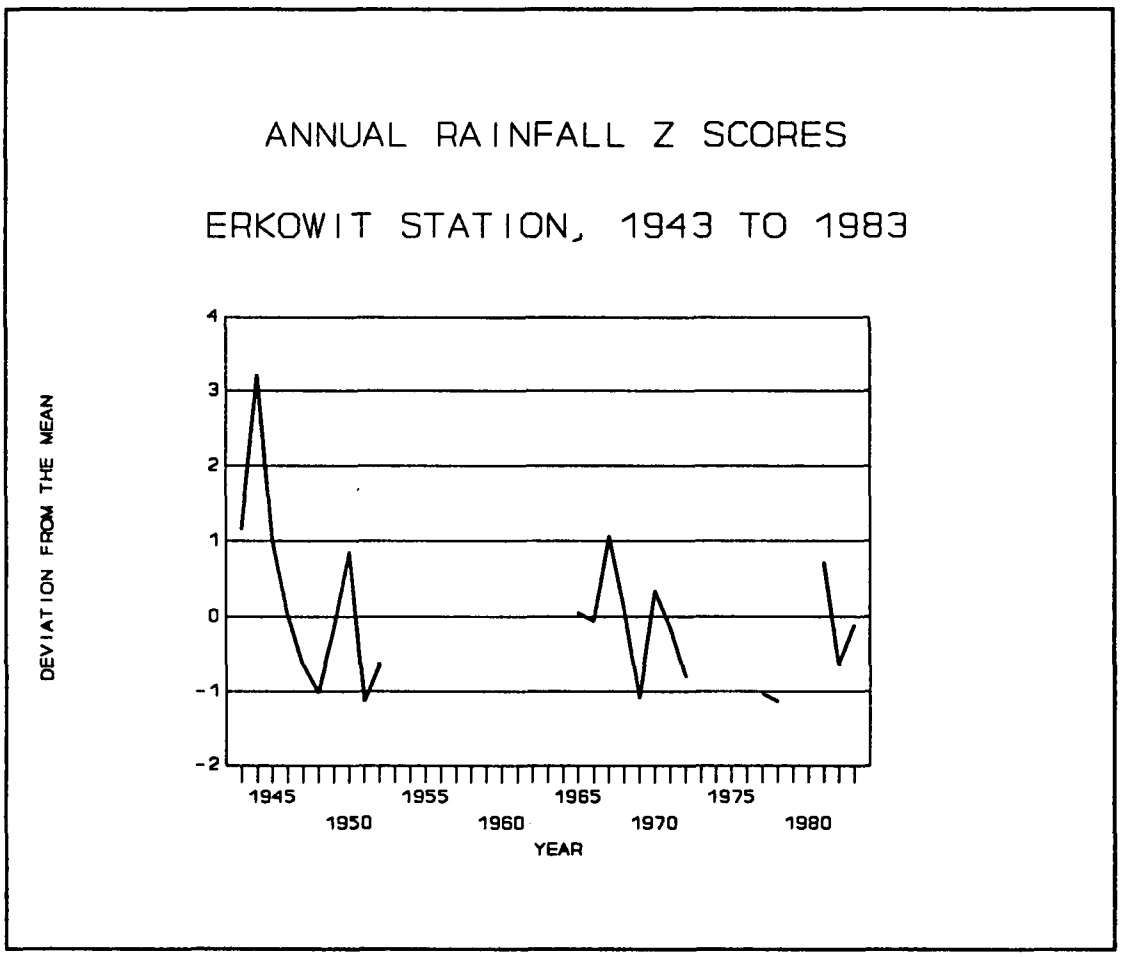


Figure 3.22. Annual rainfall z scores, Gebelt Station, 1908 to 1980.

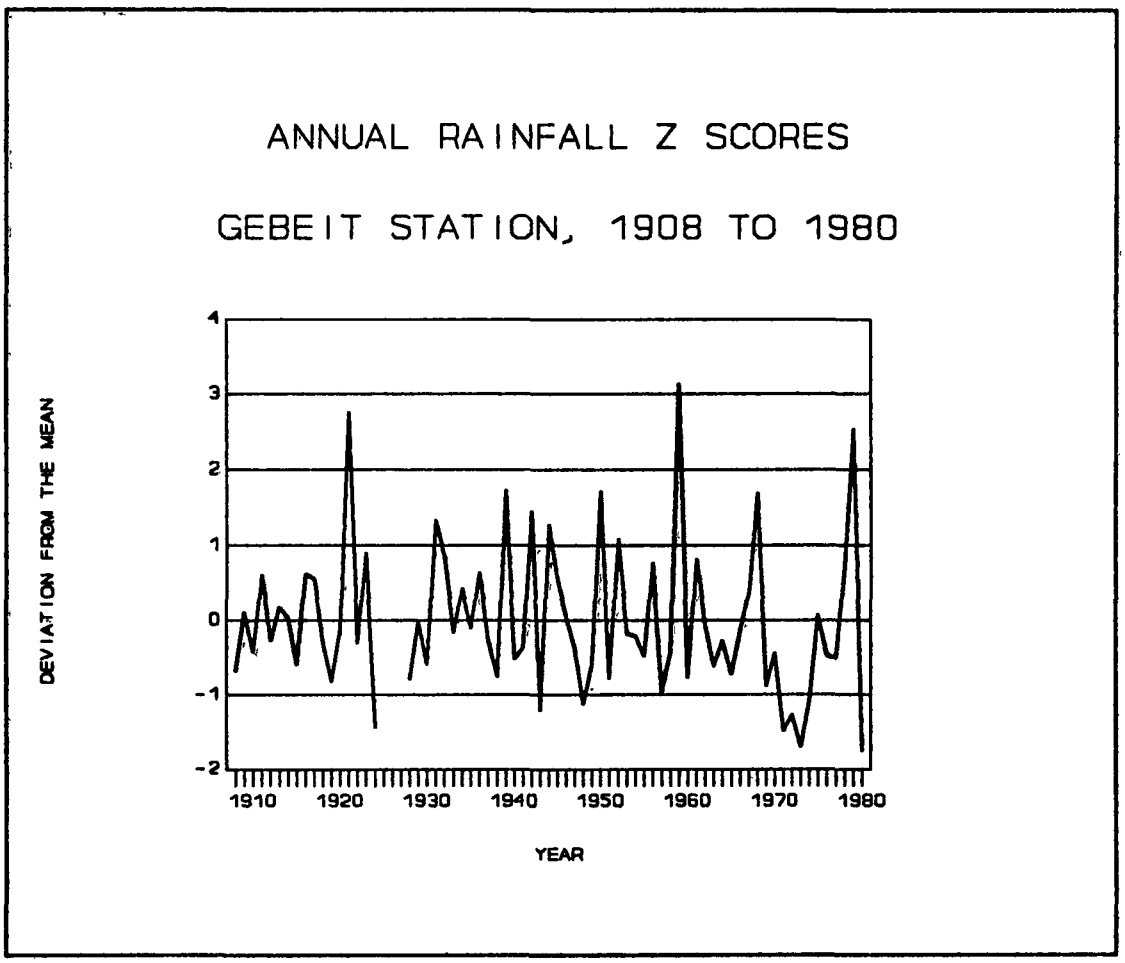


Figure 3.23. Annual rainfall z scores, Gebeit Mine Station, 1944 to 1981.

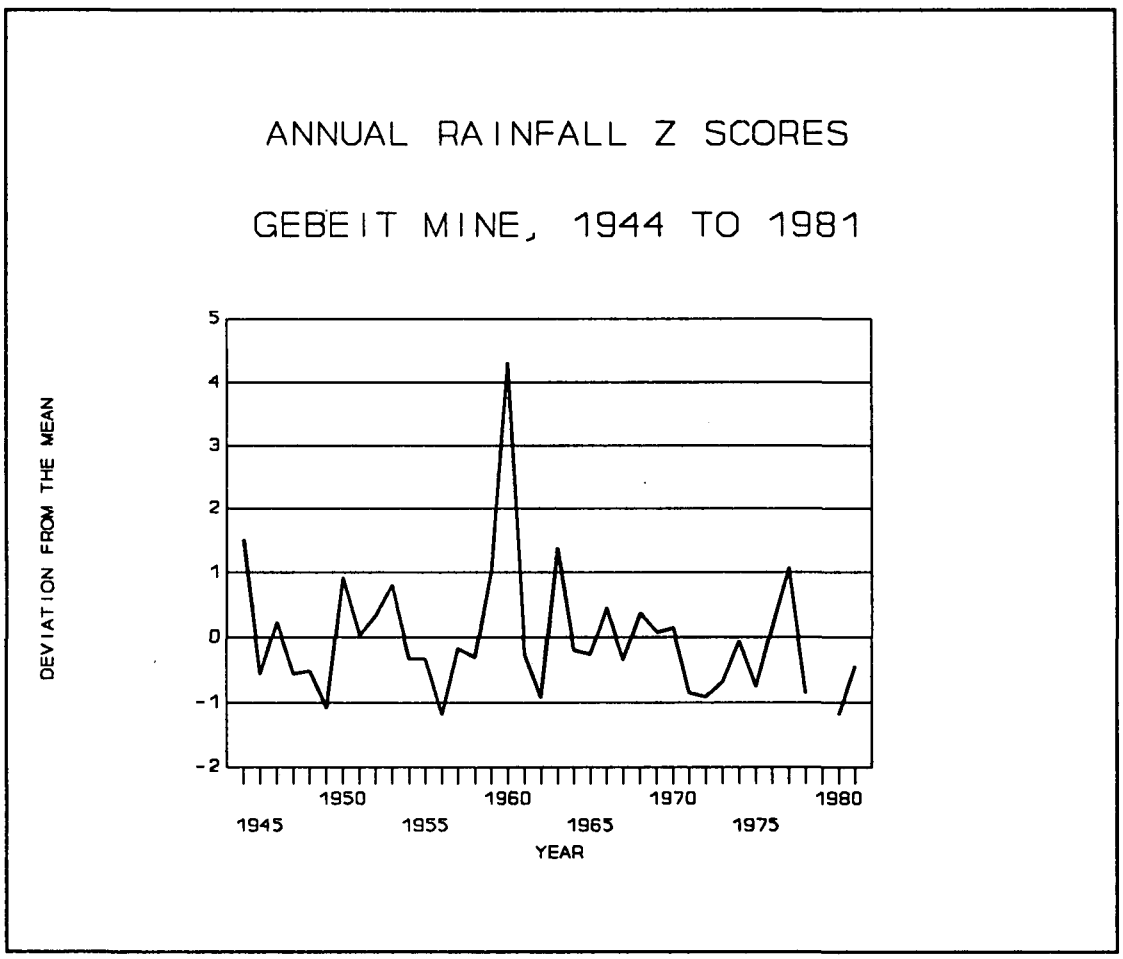


Figure 3.24. Annual rainfall z scores, Haya Station, 1940 to 1981.

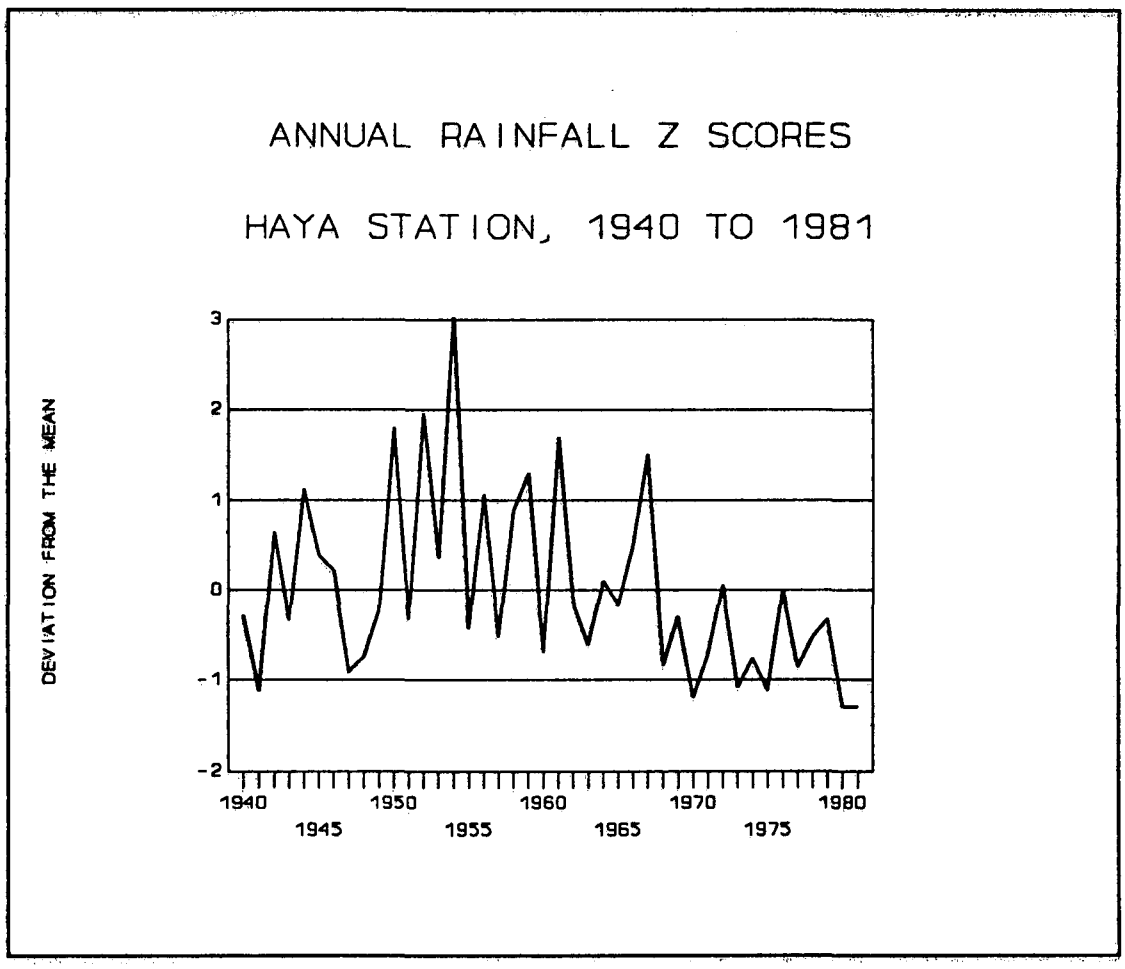


Figure 3.25. Annual rainfall z scores, Kassala Station, 1901 to 1988.

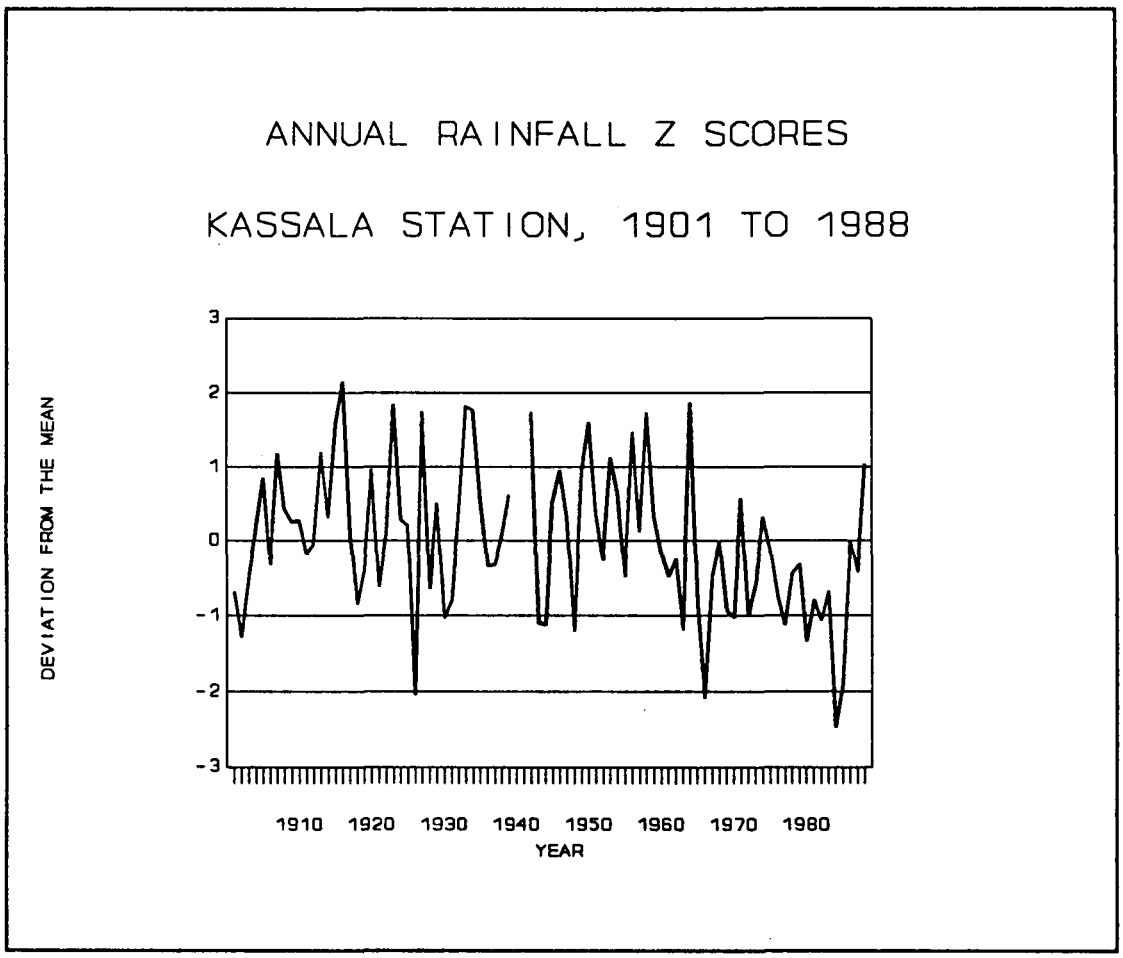


Figure 3.26. Annual rainfall z scores, Muhammad Qul Station, 1953 to 1980.

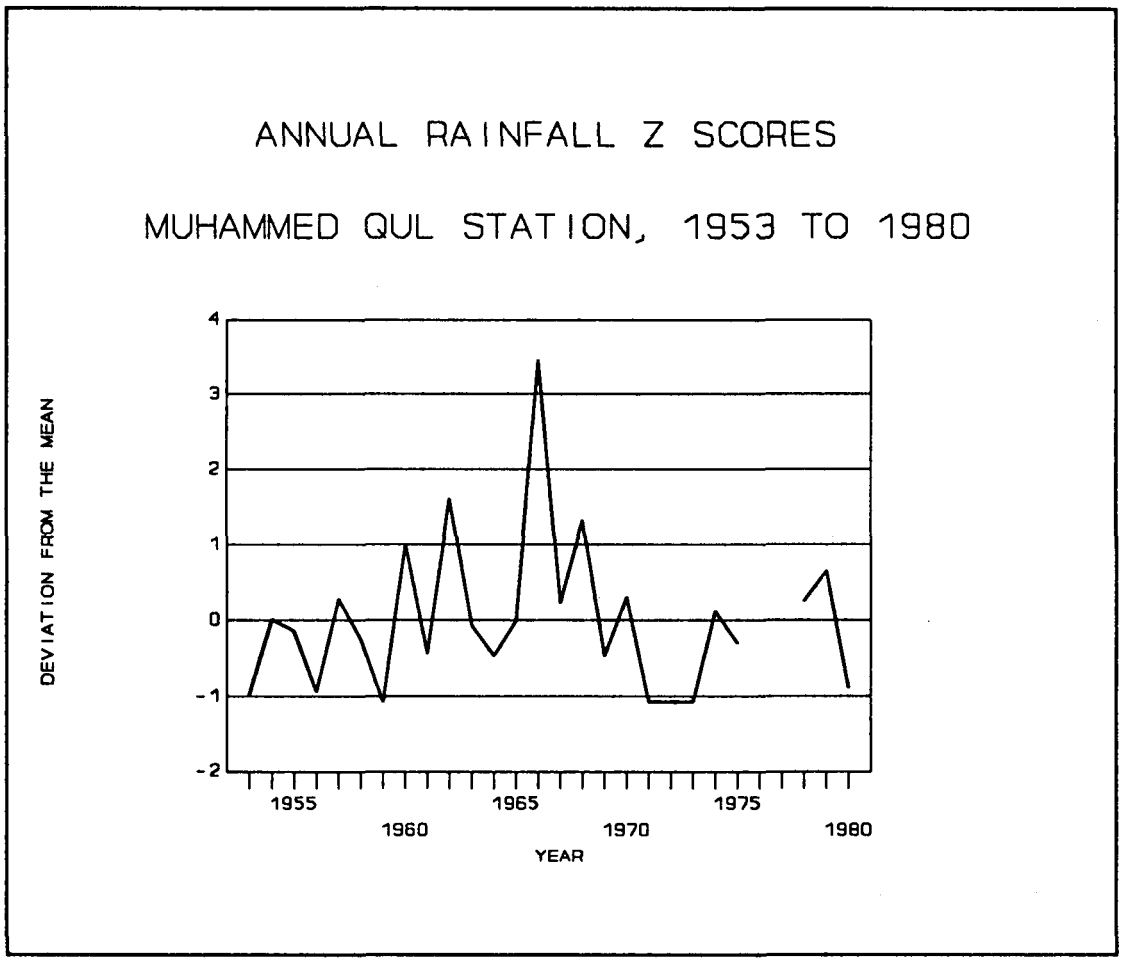


Figure 3.27. Annual rainfall z scores, Musmar Station, 1948 to 1982.

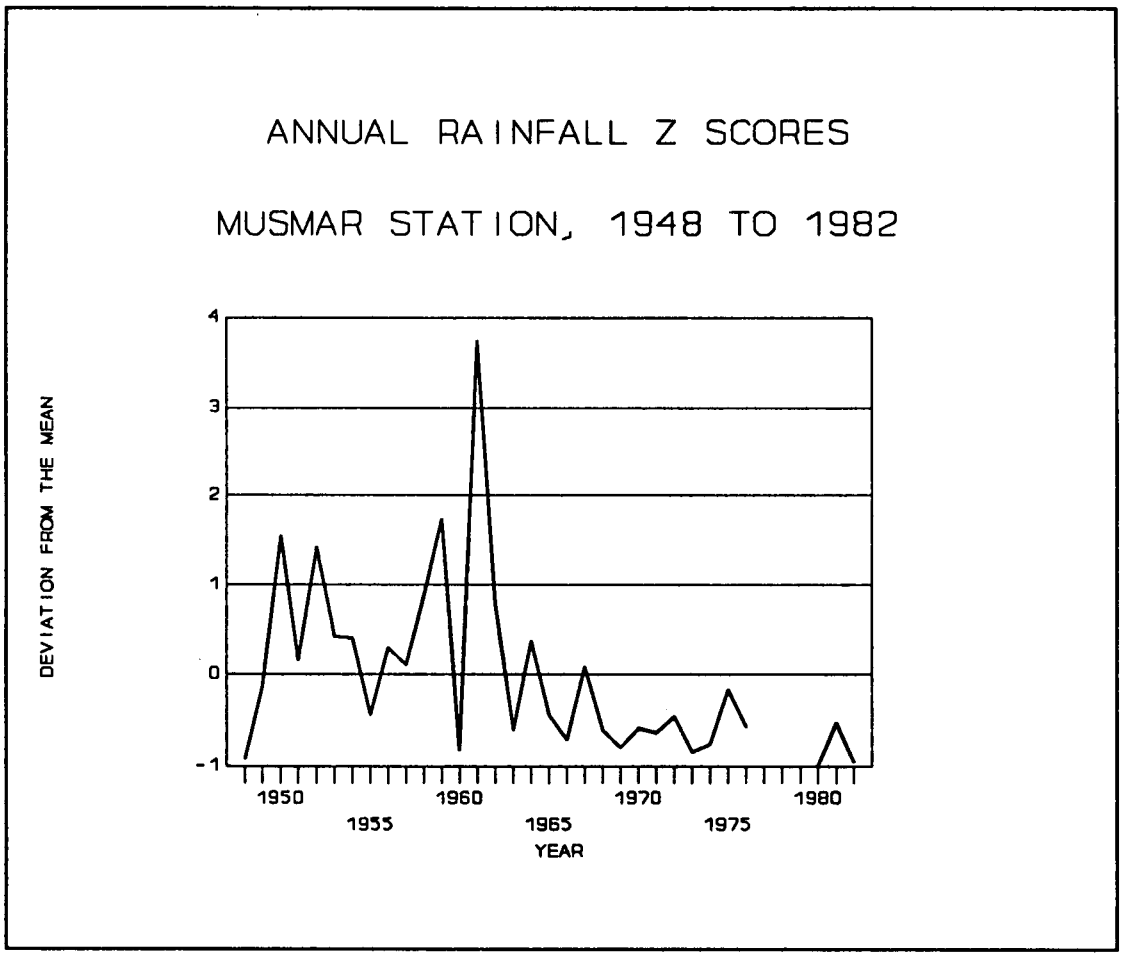


Figure 3.28. Annual rainfall z scores, Port Sudan Station, 1941 to 1988.

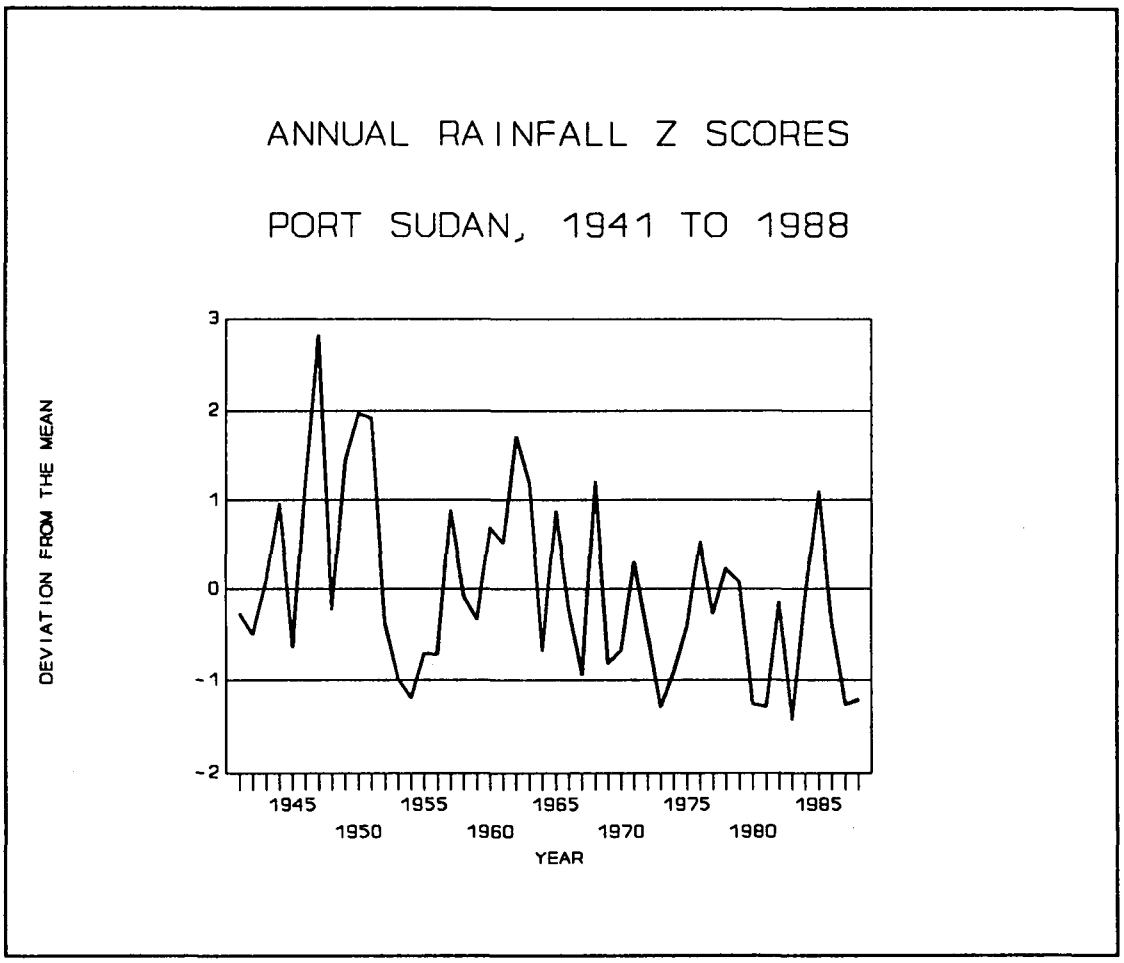


Figure 3.29. Annual rainfall z scores, Sinkat Station, 1920 to 1982.

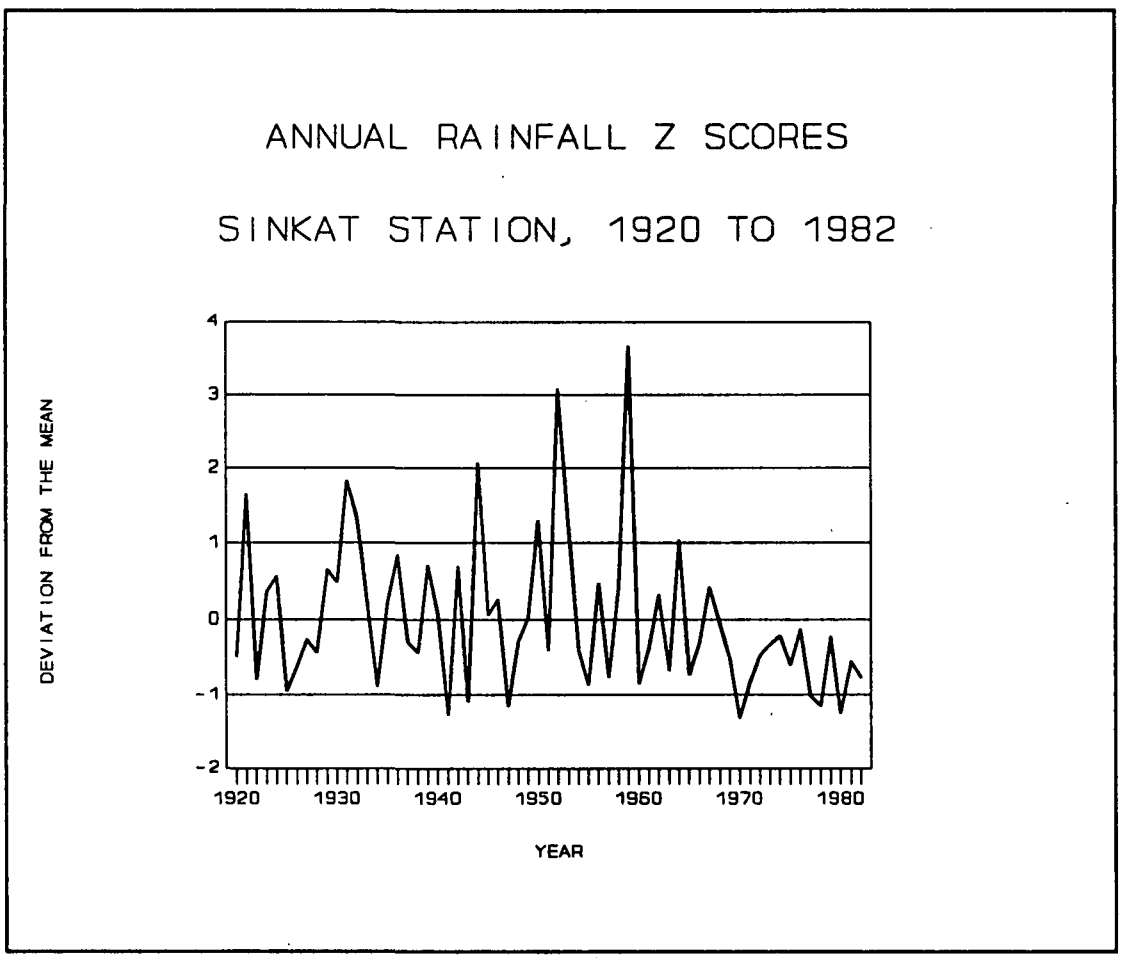


Figure 3.30. Annual rainfall z scores, Suakin Station, 1890 to 1988.

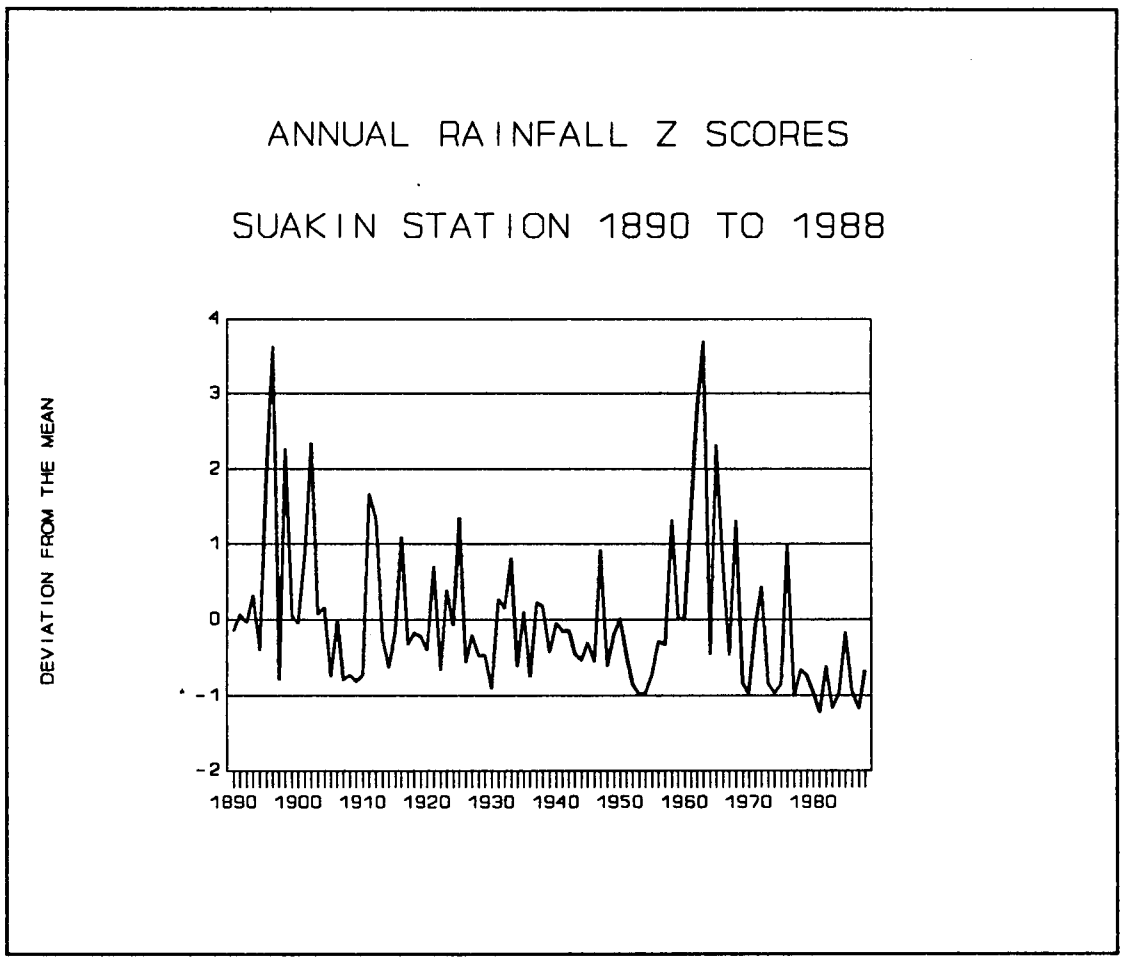


Figure 3.31. Annual rainfall z scores, Tahamyam Station, 1909 to 1980.

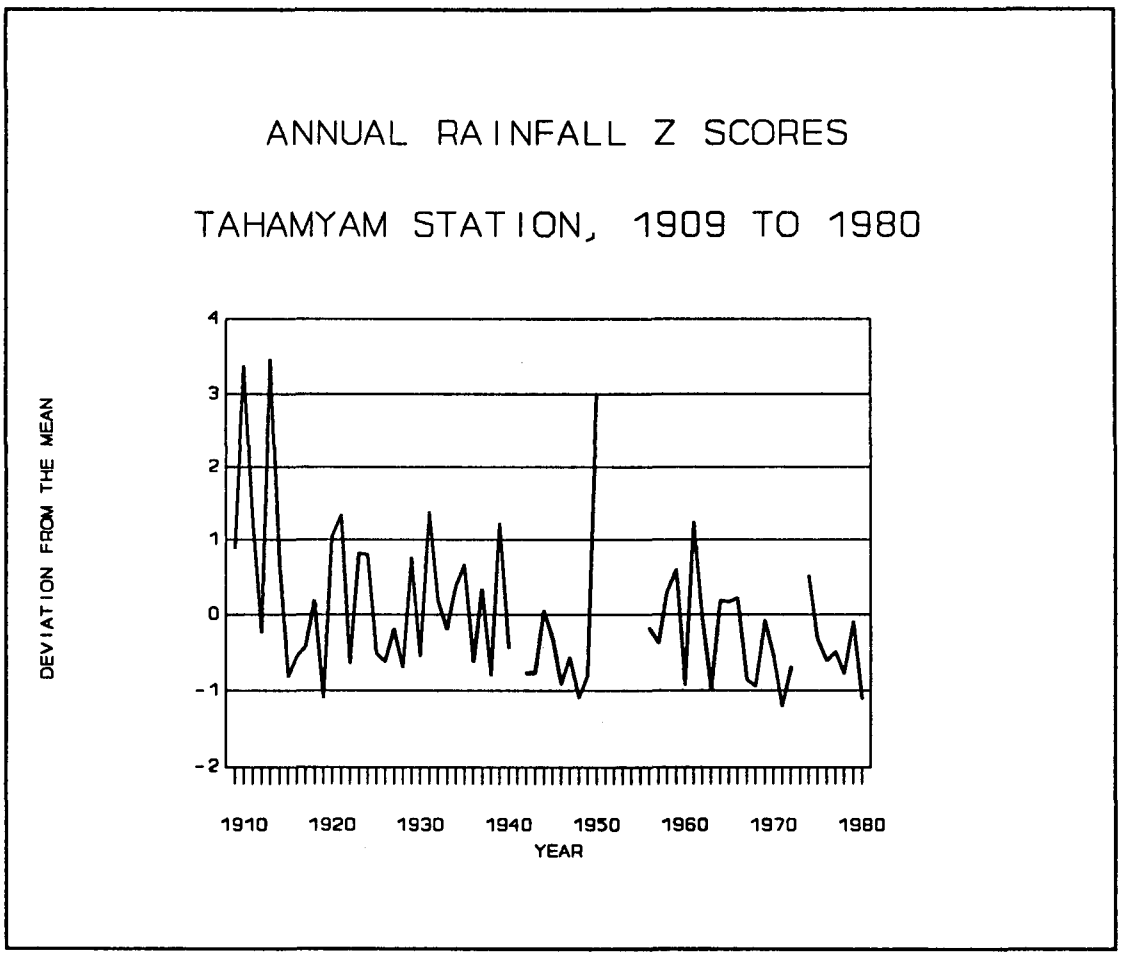
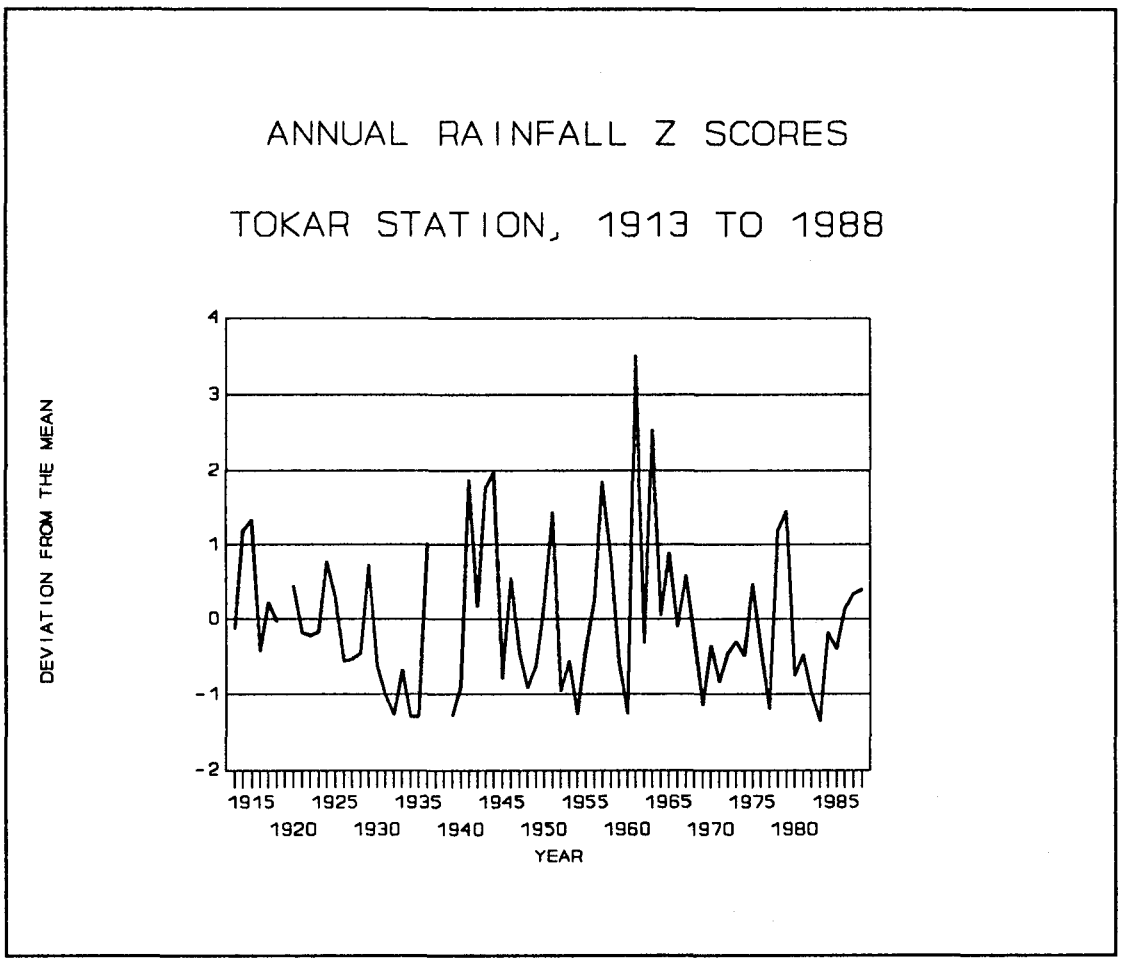


Figure 3.32. Annual rainfall z scores, Tokar Station, 1913 to 1988.



4. DROUGHT, THE MARKET, AND THE IMPACT OF FOOD AID IN RED SEA PROVINCE, 1980 TO 1989. Roy Cole

Summary

Drought-induced cereal price inflation and the consequent turning of the terms of trade against livestock was the principal mechanism identified in Red Sea Province that upset existing exchange entitlements and contributed to higher than normal mortality rates among the rural Beja populations. The present paper was written to synthesise data collected from several sources in the past with data collected by the Research Section at Oxfam Port Sudan.
The study had three objectives:

1. To examine market performance especially that associated with the famine in the mid-1980s in Red Sea Province.

2. To examine how the present inflationary period differs or resembles the early to mid-1980s.

3. To make statements regarding the benefits of free relief food distributions in the past and to evaluate the usefulness of continued free food deliveries in Red Sea Province.

The findings of the study are summarised below.

1. The terms of trade of cereals to goats turned largely to the detriment of those selling goats in 1984.

2. The terms of trade of cereals to livestock during the early 1980s seems to have not turned against sheep prices as they did against goat prices.

3. When free relief grain was made available in 1985 average cereal prices dropped by more than half (56%) and the terms of trade turned against cereals. This trend has been maintained to the present.

4. The terms of trade have been against cereals since 1986 but have dropped in favour of cereals since 1988 and are now levelling off.

5. Although free food deliveries seem to have been beneficial in reversing cereals price inflation in 1985 their benefit has diminished greatly as economic recovery has progressed. Those that still need some assistance, refugees and individuals marginalised by social circumstances should be assisted but on different terms from those used in the general feeding of the entire rural population of Red Sea Province.

Introduction

Since the Sahel drought of the 1970s analysts of drought and food stress have come a long way in the understanding of the mechanisms that contribute to food stress and mortality in Africa. These economic, social, political, or environmental processes acting alone or together may originate from the local, national, or international levels or from a combination of levels. The present paper is concerned with one causal element of all the possible elements that could be examined: drought and price inflation.

Drought-induced cereal price inflation and the consequent turning of the terms of trade against livestock was the principal mechanism identified in Red Sea Province that upset existing exchange entitlements and contributed to higher than normal mortality rates among the rural Beja populations. The terms of trade of goats to sorghum declined from about one to one in the very early 1980s to about six to one in 1984 according to a report by Oxfam (1987). The present paper was written to as a result of new data collection since 1986 and is an attempt to synthesise those data collected in the past with the new data. The study has three objectives:

1. To examine market performance especially that associated with the famine in the mid-1980s in Red Sea Province.

2. To examine how the present inflationary period differs or resembles the early to mid-1980s.

3. To make statements regarding the benefits of free relief food distributions in the past and to evaluate the usefulness of continued free food deliveries in Red Sea Province.

The principal sources of data for the study were Oxfam Port Sudan files, the files of the Tokar Delta Board in Tokar town, and the Department of Agricultural Economics in the Ministry of Agriculture. The Oxfam data were collected by market clerks in the Derudeb and Tokar markets. The data were collected four times a month and, for the purposes of the present study, averaged by year. The Tokar Delta Board data are routinely collected monthly as part of a wider study on the prices of a variety of commodities in Tokar. These data will be presented for both markets below. Cereals prices will be discussed first, then livestock prices, and lastly both will be discussed together prior to the conclusion of the paper.

Drought and the Market

Movements of prices probably are the most significant factor affecting the well-being and even the survival of the majority of people in the world today. Environmental variations such as drought change the relationship between marketed commodities through the production of relative scarcities and abundance. Sen (1981) demonstrated two entitlement relations that are affected by drought but have different relations to the market: direct and indirect entitlements.

A direct entitlement is best characterised by farmers who produce the same good that they consume. These people do not have to enter the market to obtain their staple cereal. The herder, in contrast, with an indirect entitlement is obliged to enter into a market relation to get cereals. Sen identified three features of the indirect entitlement that make the impact of economic stress on pastoralists more significant than for farmers.

1. Cereals are cheaper nutrition at normal prices than livestock. In a situation of environmental stress demand shifts in that direction. Under ordinary circumstances the herder obtains cereal calories cheaply through the exchange of animals for grain. In situations of economic stress the herder is impelled to be even more dependent on cereals. This is why a drought that reduces both the animal stock and the grain output often leads to a decline in the terms of trade of livestock to cereals (Sen 1981).

2. Livestock for pastoralists are both production and capital. In periods of stress there is a "bigger burden of adjustment on animal supply to the market to meet the herdsman's grain demand as well as his other needs for cash" (Sen 1981: 110-111).

3. Consumption of the infinitely divisible and liquid cereal is more controllable than that of livestock.

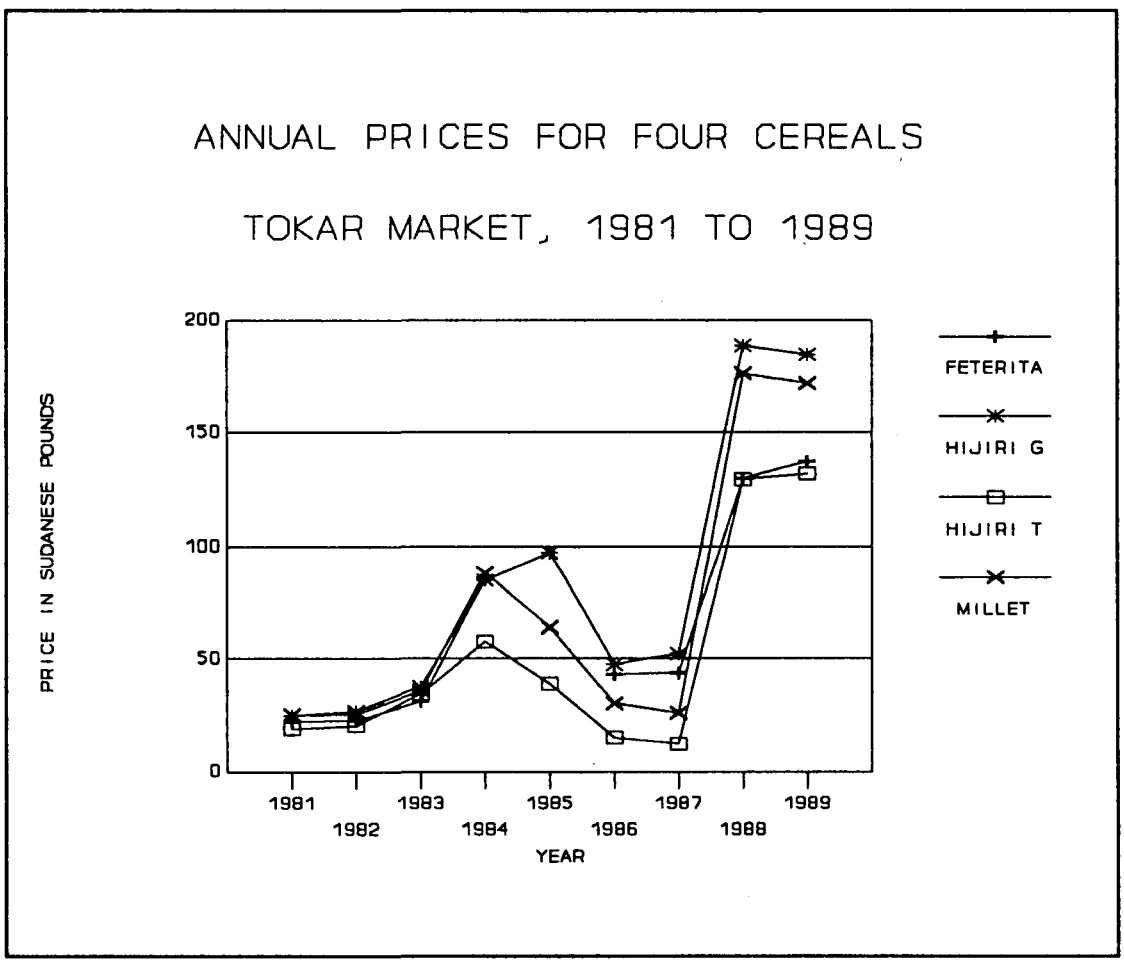
In reality, pure pastoralists are rare. Most people who raise livestock have several occupations as a means of spreading risk. Most Beja in Red Sea Province farm as well as herd and engage in many other activities as well.

Cereals Prices

The recent drought most commonly referred to in Red Sea Province occurred in 1982 and 1983 in the Tokar area when rainfall was well below the annual mean of sixty millimetres. In the populous interior areas of the province the worst years were 1983 and 1984 where, for example, in the agriculturally important Khor Arab basin there were no floods for both years.

The following figure presents prices for four cereals in the Tokar market: three types of sorghum, Feterita, Hijiri Gedarif, and Hijiri Tokar and one millet.

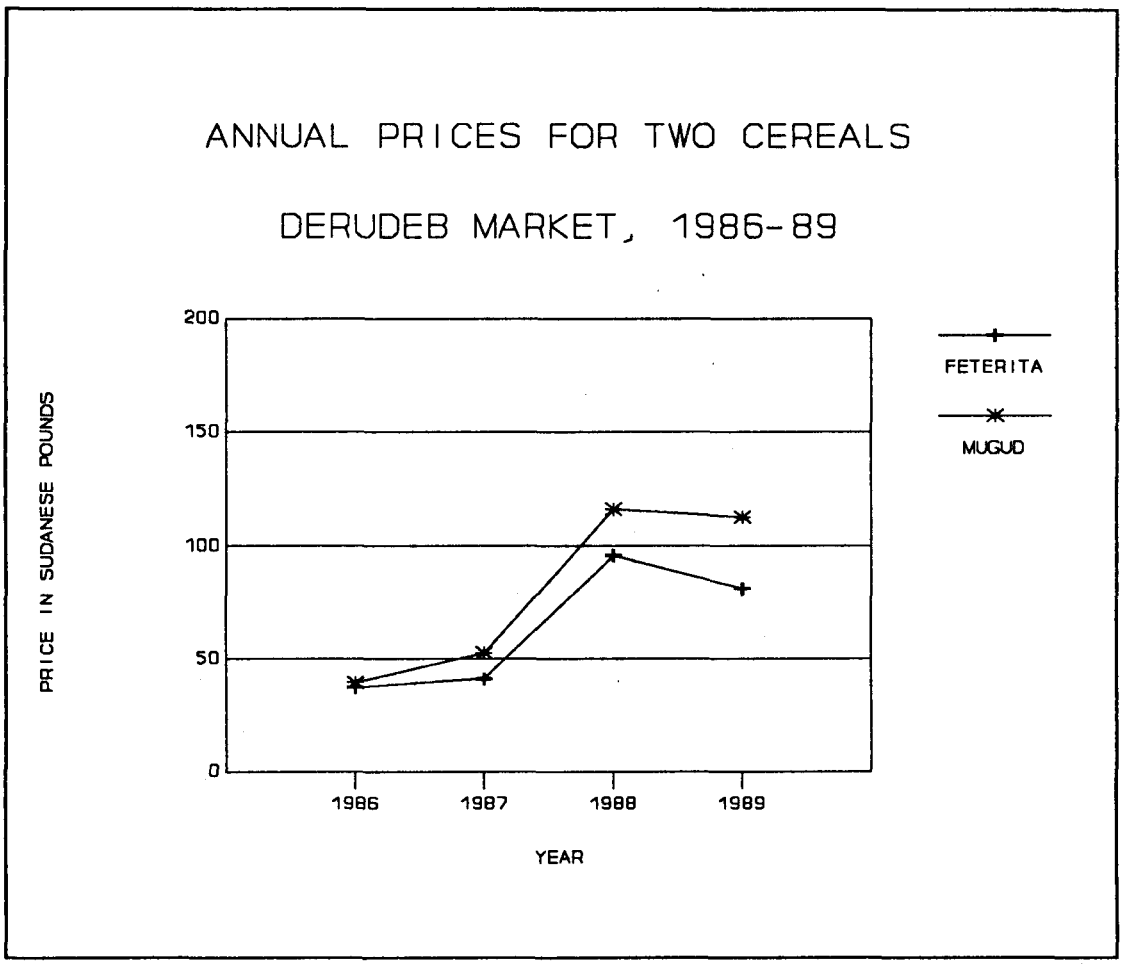
Figure 4.1. Annual prices for four cereals, Tokar market, 1981 to 1989.



From 1981 to 1989 average prices in Tokar for the four cereals presented above rose 684% from 22.8 to 156 Sudanese pounds per 100 kilogram sack. Within this trend there are two peaks and two troughs. More properly speaking, perhaps the peaks should be called one peak and one plateau rather than two peaks. Although it is too early to tell how 1989 will turn out, our data for 1989 run to August, and prices should fall after harvest near the end of the year. Because of this uncertainty, what appears now to be a 1988-89 plateau may well be a peak. However that may be, the first peak in our present dataset was in 1984. From 1981 to 1984, cereals prices rose 346%, from 22.8 to 79 Sudanese pounds per 100 kilogram sack. Cereals prices dropped 56% in 1985 and 1986, almost to their 1983 levels then rose 457% in a second peak from 1988 to the present, from 34 to 156 Sudanese pounds per sack.

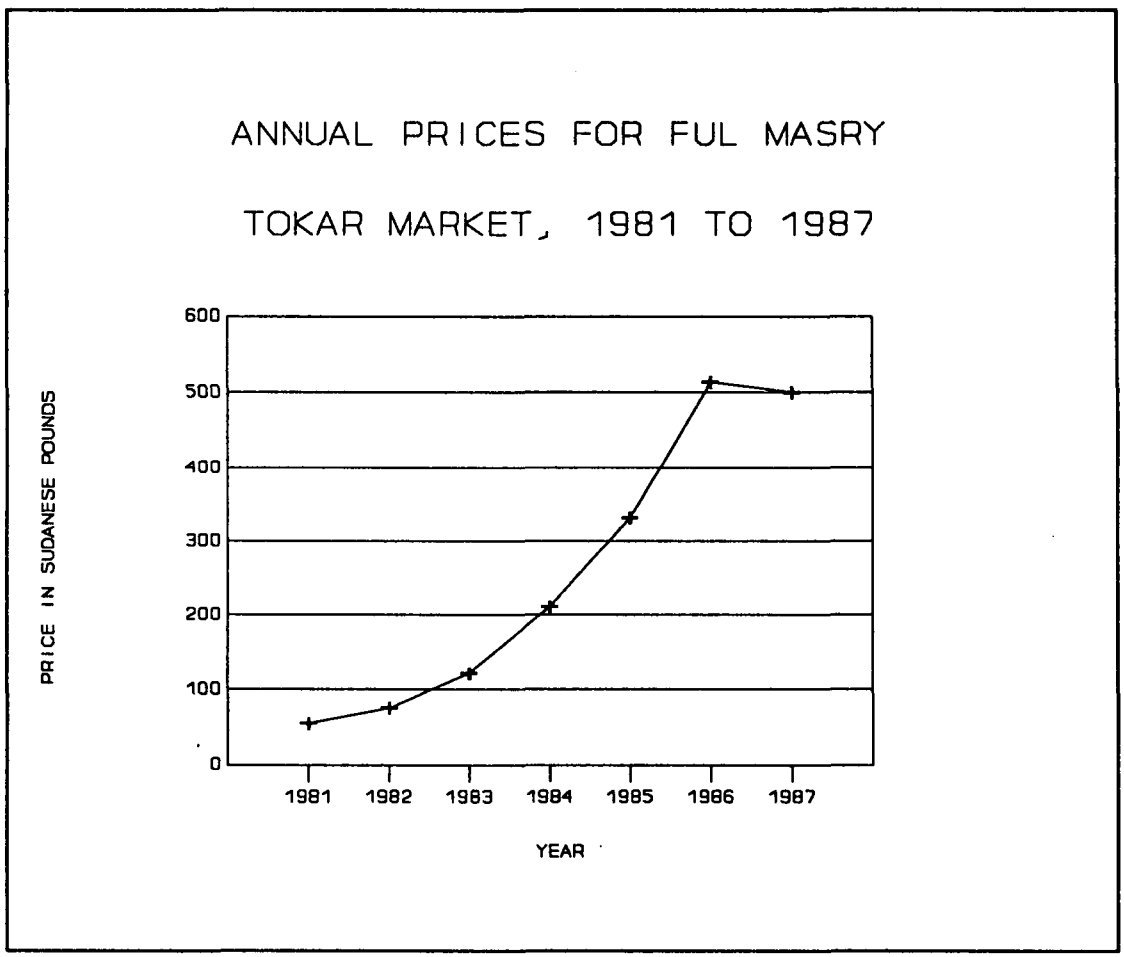
The figures for Derudeb Town present a partial but much the same story as the Tokar market. The two cereals for which we have data are Feterita and Mugud Gedarif sorghum. The increase in the average price of these two sorghums from 1986 to 1989 was 249%, from 38.8 to 96.9 Sudanese pounds per 100 kilogram bag. Some caution should be exercised with the Derudeb data because the 1989 dataset has only one month's observation. The actual difference is probably higher because the observation that we have is from not long after the harvest of 1988 and prices generally rise between harvests.

Figure 4.2. Prices for two cereals, Derudeb Market, 1986 to 1989.



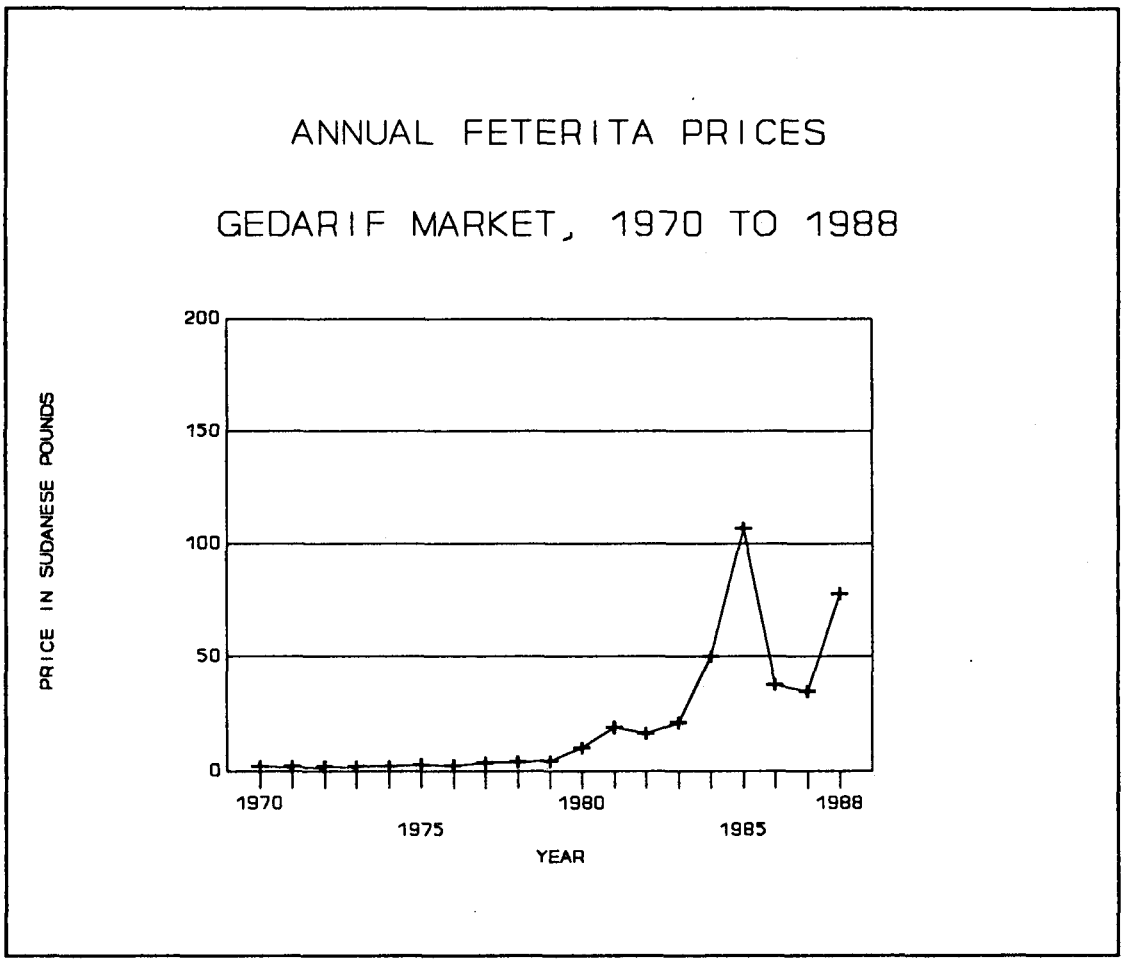
It is important to place changes in cereal prices in the context of changes in two other commodities: cash crops in Tokar and sorghum in Gedarif, the principal source area for cereal imports into Red Sea Province. The figure below presents the prices of a cash crop from the Tokar market Egyptian beans (ful masry). Interestingly, the Egyptian bean price changes exhibit an upward curve of constantly inflating prices quite different from that of cereals prices in the same market. Prices since 1987 have risen further although we do not have figures from the Tokar market.

Figure 4.3. Ful masry prices in Tokar market.



There is much mechanised rainfed cereal production in the Gedarif area. It is one of the few surplus producing areas in the Sudan. Cereals from Gedarif are readily available in all Red Sea Province markets and make up shortfalls in local production. The following figure presents the prices for Feterita sorghum in the Gedarif market from 1970 to 1988.

Figure 4.4. Feterita prices, Gedarif market 1970 to 1988.



The Department of Agricultural Economics of the Ministry of Agriculture estimated (1988) that after the excellent crop year of 1986 in the Gedarif area cropped area declined 71% for several reasons:

1. The low prices received by farmers in 1986 discouraged them from planting more.

2. Low and unevenly distributed rainfall and late plantings.

3. Pest infestations.

4. Unavailability of engine oil at planting time for mechanised agriculture.

The Department of Agricultural Economics (1985) found that the 1984 and 1985 seasons were affected by drought, particularly in Gedarif. Only a third of the planted areas were harvested in 1985 and prices were highest during that year. On the area that was harvested yields were below average.

It is interesting to compare the cereal prices in the Tokar market with those from Gedarif, a major source of imported grain for Red Sea Province, to show that production outside Red Sea Province had little to do with the fall in cereal prices in Red Sea Province from 1985 to 1987. The free food deliveries beginning in early 1985 in Red Sea Province had a significant impact on cereal prices and was the principal factor behind the drop in cereal prices after the drought-related inflation of 1983 and 1984. The Gedarif market, in contrast, had exceedingly poor performance in 1984 and 1985 and prices were rising during this period. The Red Sea Province prices began falling a full year before those of Gedarif did so.

Livestock Prices

The key to understanding food stress in Red Sea Province is not the price of cereals alone but the price of cereals in relation to other commodities that may be exchanged for cereals. Under ideal circumstances we would have to take into account the change in value of wage labour, sharecropping arrangements, charcoal, firewood, and other rural products, handicrafts, and livestock because few people in the rural areas of Red Sea Province herd livestock exclusively as an occupation. Most people have several occupations: cereals cultivation, vegetable cultivation, cotton cultivation, wage labour migration, fuel production, handicrafts, bush food collection, et cetera. Many are involved with the religious establishments of Hamashkoreb and Tumaala, located in southcentral and northcentral Red Sea Province respectively, where nationally and internationally-connected social support mechanisms have developed to cushion food stress. We have only data for livestock value and, consequently, our conclusions must be limited and tentative.

The following figures present prices for goats and sheep by sex and age class at the Derudeb town market and milk prices for the Tokar market.

Figure 4.5. Annual prices of male goats, Derudeb Market, 1980 to 1989.

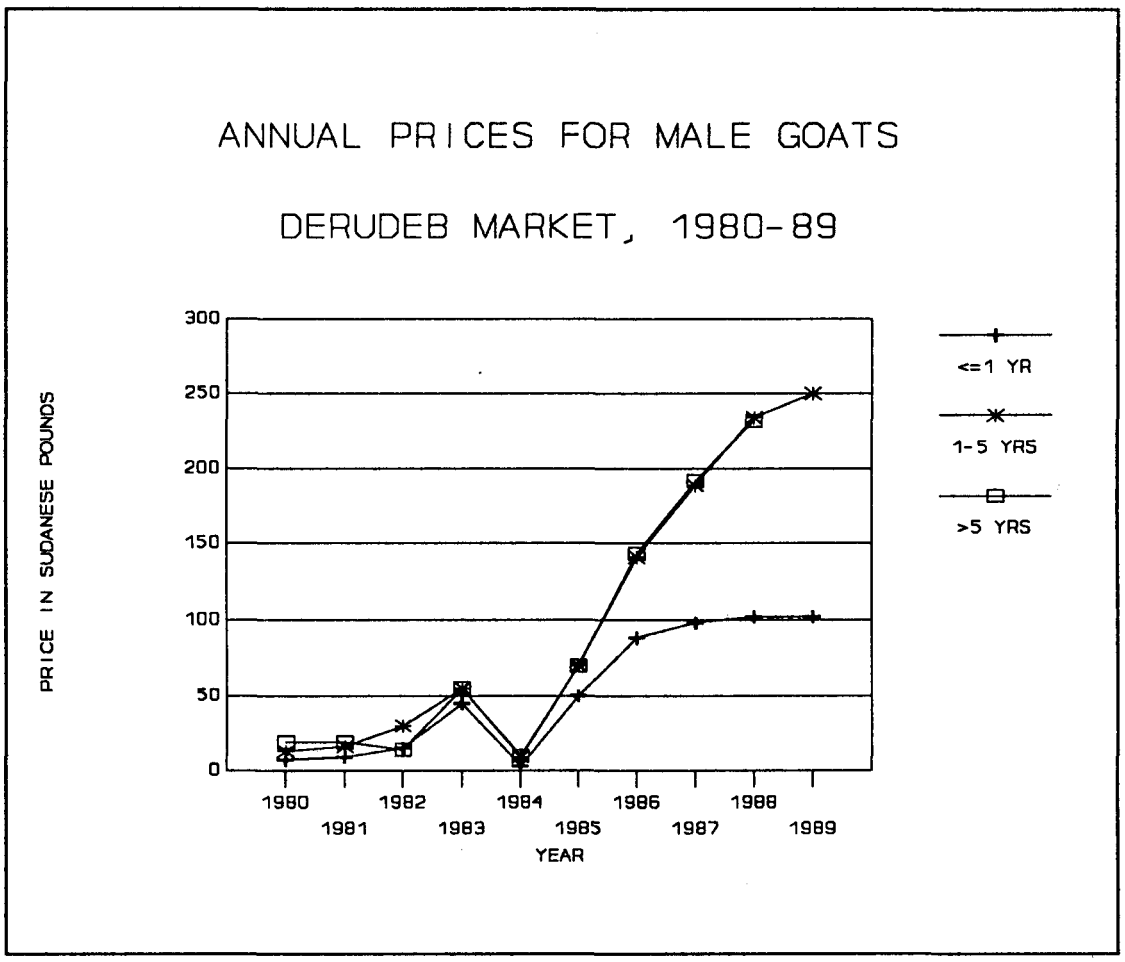


Figure 4.6. Annual prices of female goats Derudeb Market, 1980 to 1989.

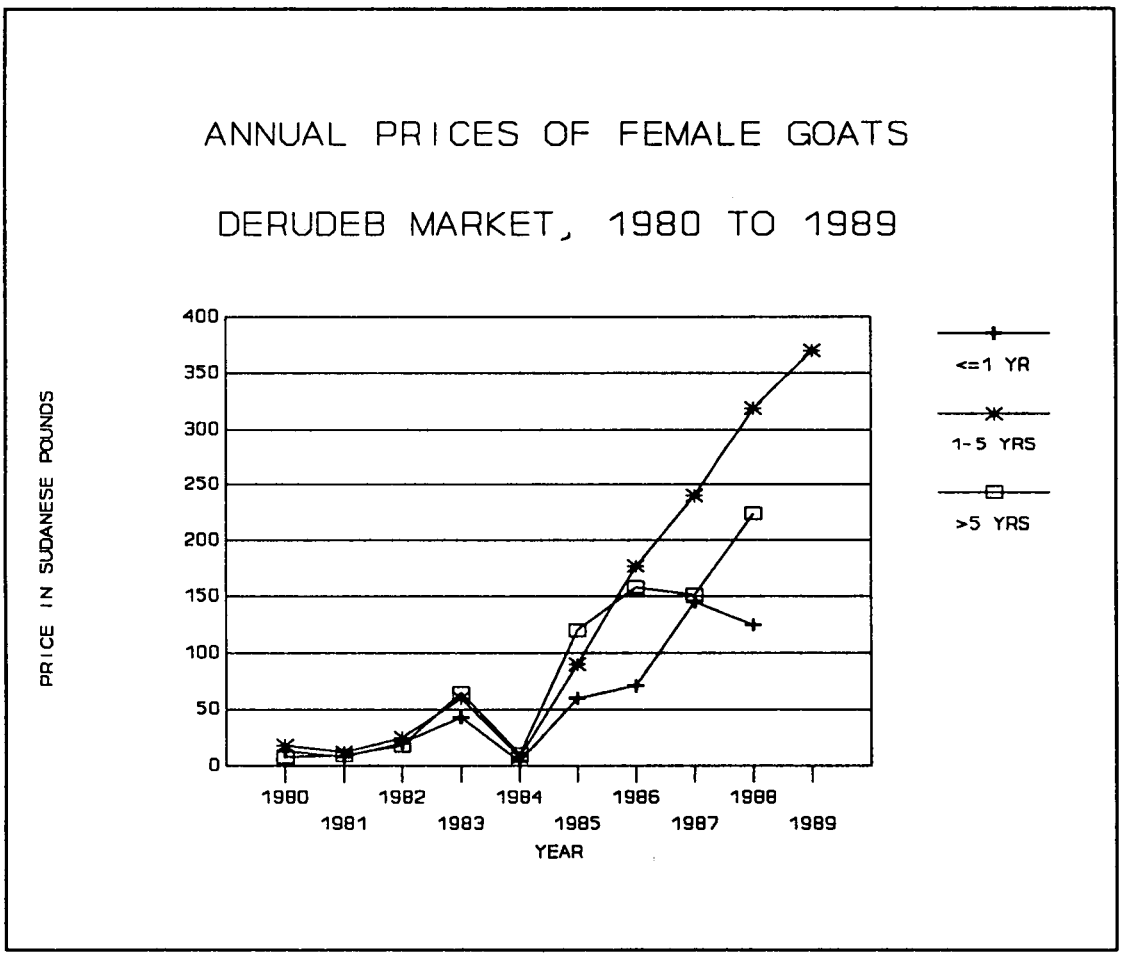


Figure 4.7. Annual prices of male sheep, Derudeb Market, 1980 to 1989.

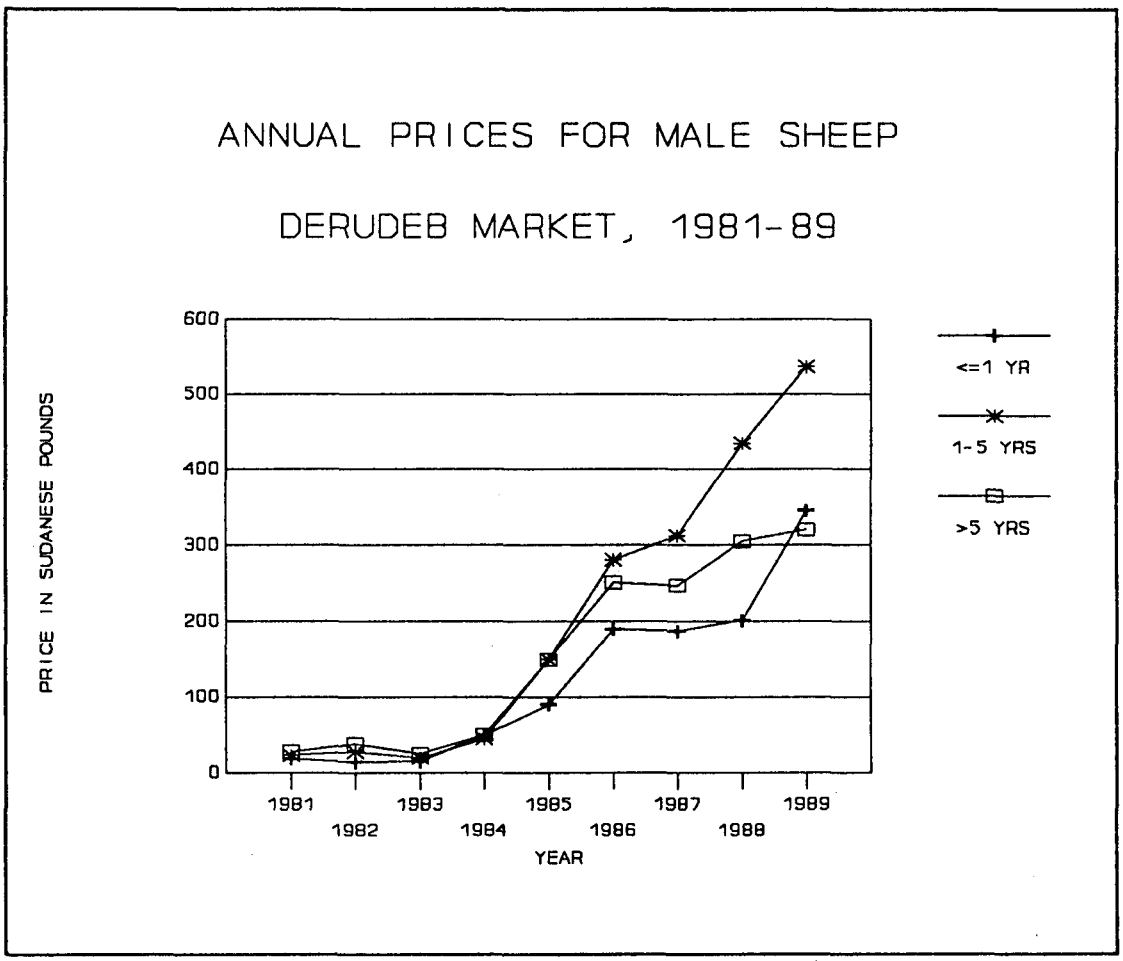
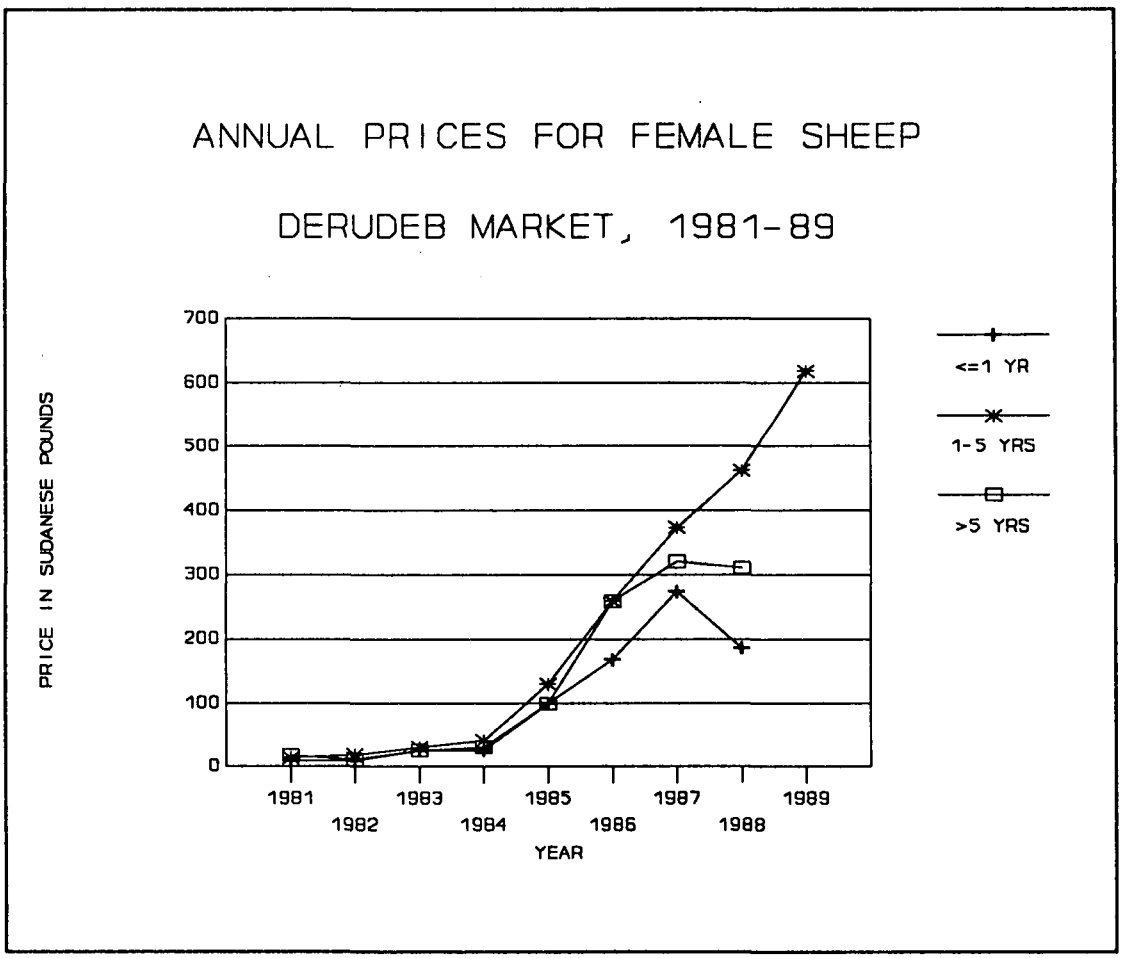


Figure 4.8. Annual prices of female sheep, Derudeb Market, 1980 to 1989.



Cereals and Livestock Price Changes

The following figures illustrate the relation between average prices for small stock and cereals prices from 1980 to the present.

Figure 4.9. Annual average goat and cereal prices, Tokar and Derudeb markets, 1980 to 1989.

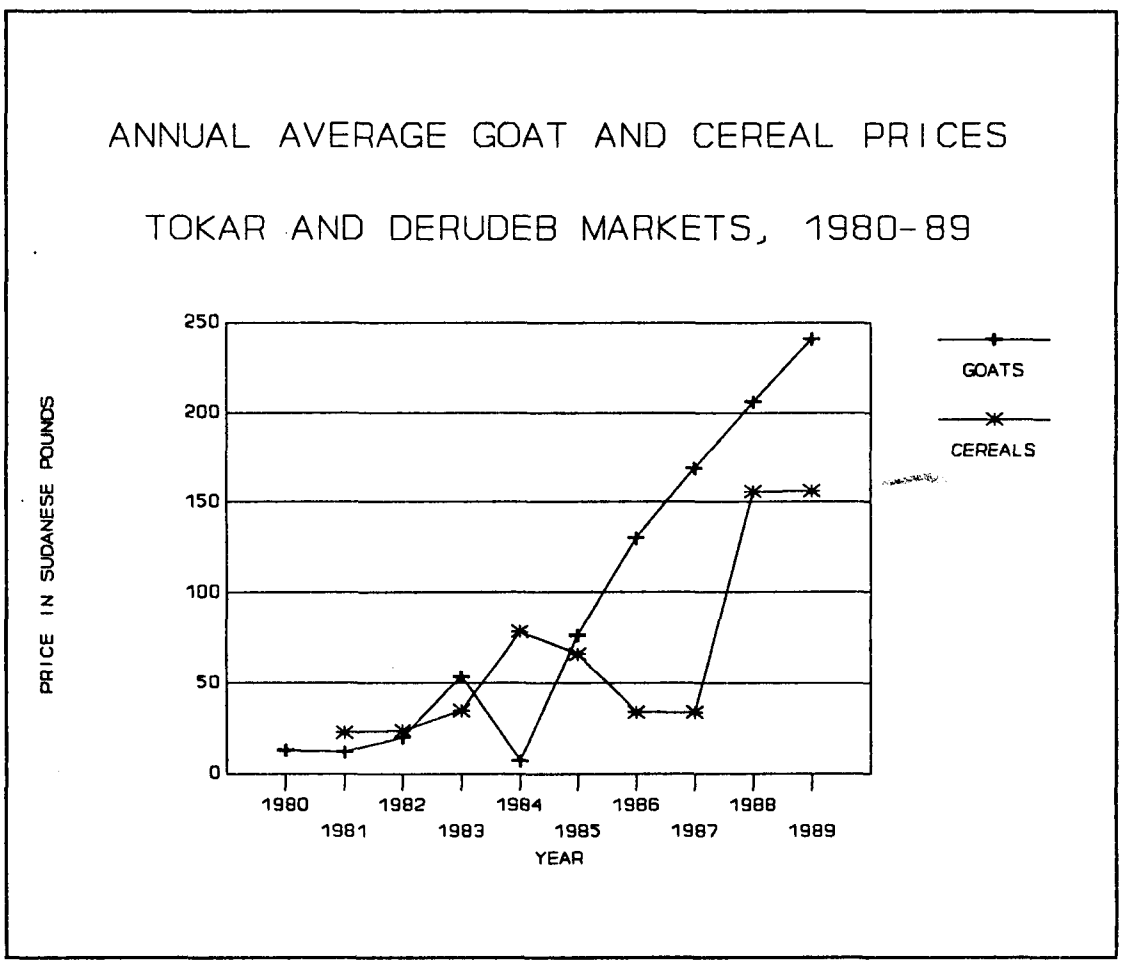


Figure 4.10. Annual average sheep and cereal prices, Tokar and Derudeb markets, 1980 to 1989.

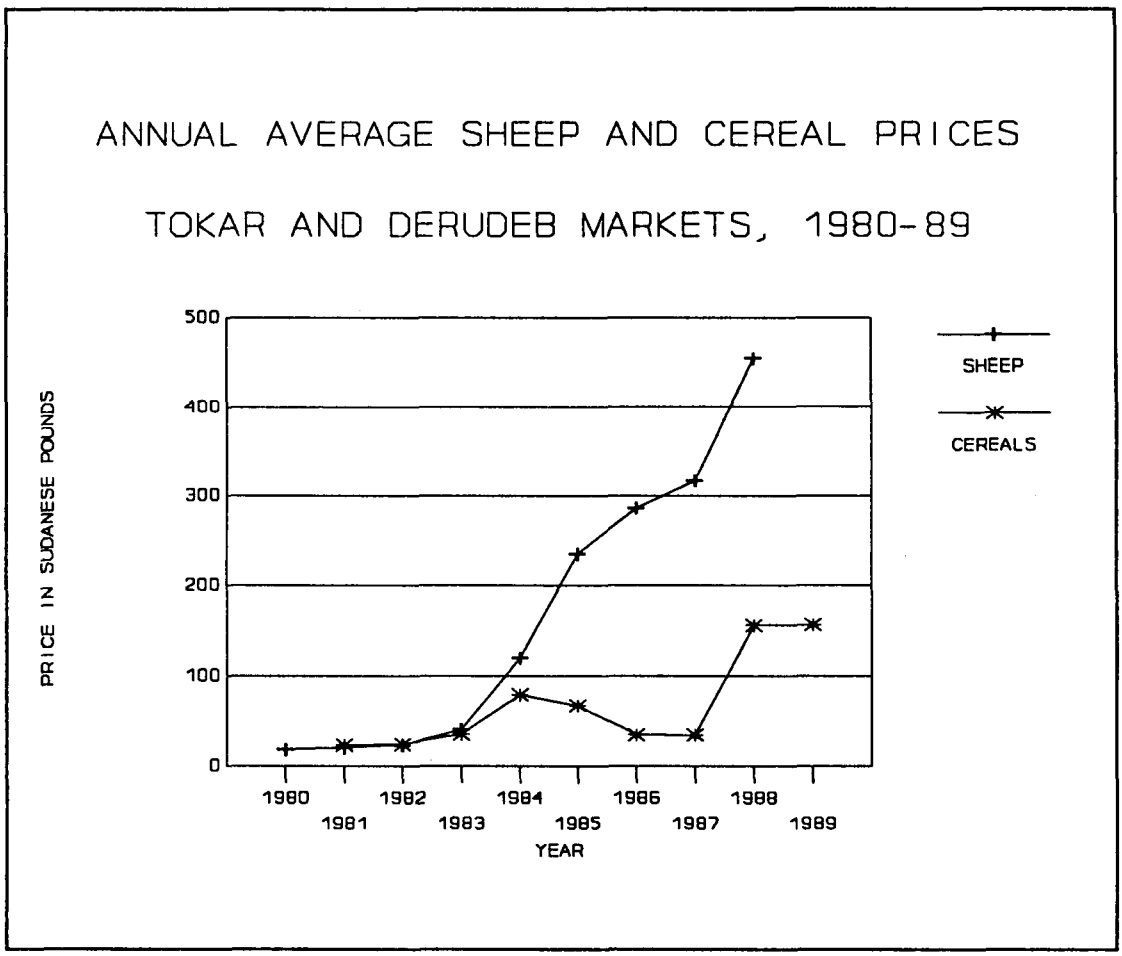
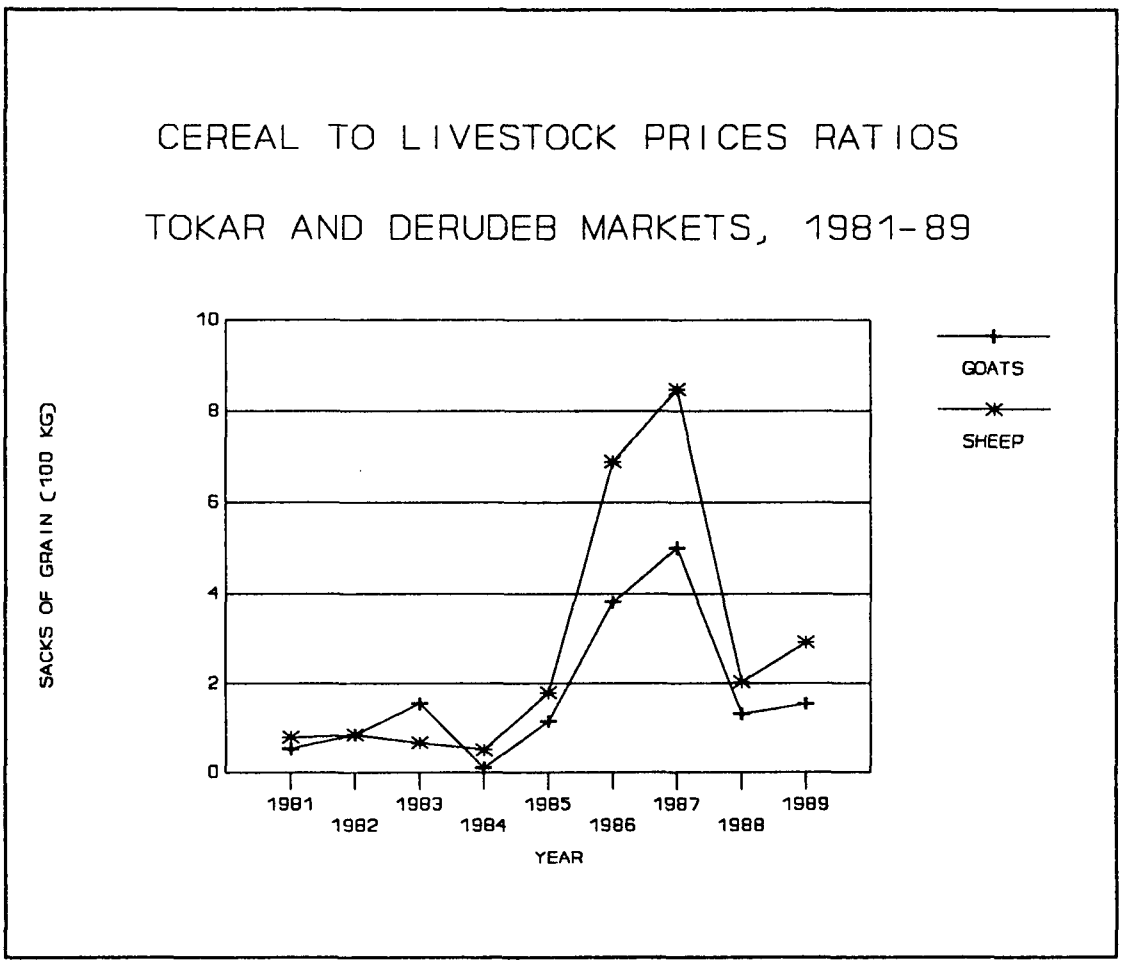


Figure 4.11. Cereals to livestock price ratios, Tokar and Derudeb markets, 1981 to 1989.



Conclusion and Discussion

Judging from the available data and with all the caveats that such data warrant, four statements may be made by way of a conclusion.

1. The terms of trade of cereals to goats turned largely to the detriment of those selling goats in 1984. This was probably due to two factors acting in tandem to exacerbate what might otherwise have been a local crisis.

A. Local drought and harvest failure in 1983 and 1984 in the important interior grain producing districts of Red Sea Province.

B. Harvest failures elsewhere in the Sudan such that the Red Sea Province deficits could not have made up through the market mechanism. The extent of the harvest failures throughout the Sudan during this period contributed to the food stress experienced by many people in Red Sea Province during the mid-1980s.

2. The terms of trade of cereals to livestock during the early 1980s seems to have not turned against sheep prices as they did against goat prices. The reasons for this are unclear. It may simply be due to the fact that sheep are more expensive than goats (see Hassan Mohammed Salih 1976) or it may be due to any one or all three of the following factors.

   A. Because of the extreme annual variation in forage availability in southcentral and southwest Red Sea Province sheep are naturally scarce except for the rainy season.

   B. High sheep mortality against relatively low goat mortality during the drought of 1983-1984. Sheep are much less resistant to stress than are goats.

   C. The nature of sheep as a preferred commodity relatively immune from market price collapse. Goats are the liquid currency of trade in Red Sea Province. Sheep are a specialty product raised for export to the towns and to Saudia Arabia. The high prices paid for male sheep reflects the high demand and value associated with their use in religious ceremonies three times a year.

3. When free relief grain was made available in 1985 average cereal prices dropped by more than half (56%) and the terms of trade turned against cereals. This trend has been maintained to the present.

4. The terms of trade have been against cereals since 1986 but have dropped in favour of cereals since 1988 and are now levelling off. The reasons behind this change probably lie at the national and international levels rather than the local level and are related to the

devaluation of the Sudanese pound and the general and extreme commodity price inflation that has occurred since the early part of 1988.

Although one would normally expect cereal prices to drop after the unprecedented harvest of 1988 they have not done so. There is an explanation for this that goes some way in resolving the sluggish response of the market: commercial producers are storing their cereals to sell at a later date and small producers are storing their harvest as a security measure. In any case, the alarmingly high cereal prices and the declining terms of trade against livestock deserves watching. People who do not farm and those who have few or no livestock are at risk. Particularly vulnerable are households headed by women in rural areas. They may not have been able to build up assets when the terms of trade were overwhelmingly against cereals.

The Impact of the July Change in Government on Livestock Prices

There has been no price control on cereals in the Sudan since the change in government of 30 June, 1989 with the exception of a short period when price controls were placed on relief food in the Derudeb area. The new government is controlling the inter-provincial movements of cereals and had forbidden the export of cereals. An attempt has been made to control livestock and meat prices. The cheapest available meat in Port Sudan, beef, was brought down 30 Sudanese pounds per kilogram, from 50 to 20 £S per kilogram, in early July. Since early July price ranges, minima and maxima, have been set for livestock by age class. In November price controls were imposed on milk in Port Sudan. There may be negative effects felt by producers of sheep for the religious holiday markets although it is difficult to judge how important this will be to the general economy.

Comments on Continued General Free Food Distribution

Are there any arguments for the continued distribution of free food aid in Red Sea Province? The answer is yes and no. Yes to a social security type assistance and no to a general free food distribution. The majority of people in Red Sea Province do not need food aid. Those who do need continued assistance are refugees and divorced women and widows with dependent children (see Cole and Cole, Nutritional status of children in Red Sea Province, November 1985 to November 1987, below). The refugees are principally Beni 'Amer, or Habaab who transhume from the coastal areas of South Tokar and the Tokar Delta to the Eritrean highlands. Those who are not Beni 'Amer are found generally in the camps near Garora. The Beni 'Amer, because their population is split between the Sudan and Eritrea, have been able to reside in the Sudan as Sudanese. The closure of the Sudanese-Eritrean border and the mining of the area behind the border in the early 1980s had much to do with their present position. They were

trapped in the Sudan for several dry seasons. Their animals were sold or died. When the EPLF took control of the border areas these people were assetless. Most of them remain in the Sudan today. Those in the camps are the "real" refugees supported by the United Nations High Commission for Refugees (UNHCR). The hidden refugees are the Beni 'Amer and the Habaab.

Knowing as we do that most people have more than one occupation as a risk minimising strategy recovery from drought assumes a different perspective than that it possessed several years ago when NGOs believed that the only significant occupation of rural people in Red Sea Province was herding livestock and that income from the towns did not return to the rural areas[5]. However, those people who possessed livestock after the drought of 1983-84 have had several good years in which to recover their assets through employment in the urban or rural areas and through the natural reproduction of their animals. The best years have been the last two. The terms of trade of cereals to small stock have been extremely favourable to the animal owner as well. Most of those people who were unfortunate enough to have some of their livestock due to drought in 1983 and 1984 have gone to the towns and/or have taken up other occupations. According to a report by the Environmental Research Group Oxford (ERGO), currently doing an aerial survey of livestock and human population in and around Red Sea Province, there is already a drift from the town to the country. This same group of researchers also maintain that the majority of people in Red Sea Province live in towns and not the countryside. The implication of their finding is that people are accumulating assets in the urban areas, investing in livestock, and then seasonally returning to the country. It is likely that these people have strong linkages both the urban and rural areas and if they did not have a foot in both the urban and rural areas before the drought, they have such a position now. The dichotomy between urban and rural is not absolute in Red Sea Province just as it is not absolute anywhere else in the world. The urban and the rural coalesce in such towns as Derudeb, Sinkat, Tokar and Haya and places in Port Sudan such as Daym al-'arab, Hai Walli, Daym al-wuhda, and Ongwob where goats and sheep are more numerous than people and camels more populous than automobiles. There is a constant drift and exchange of people and products between these places, rural Red Sea Province, the rest of the Sudan, and the world. It seems that a more targeted approach is needed to help marginalised people in Red Sea Province and that the urban countryside, quarters like Daym al-'arab and towns like Derudeb, may be the best places from which to begin assisting the rural areas.

Limitations of the Study

There was no way to validate independently the data collected by the market clerks and the Tokar Delta Board. The clerks and the Board take the average figure for the cereals and animals presented at the market. How well they followed this method is not known. Caution should be exercised in interpreting data from one market in

[5] Unfortunately, some people persist in referring to the people of Red Sea Province as "nomads". This is a value-laden term far off the mark and it should be replaced with more specific references to what people actually do.

conjunction with another. Because so little is known about market performance around the Sudan we do not know how appropriate it was to examine cereals prices from one market in conjunction with livestock prices from another.

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