Rainfall Changes and their Effects on Maize Production in Zambia

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Abstract Rainfall changes in Zambia were investigated from three viewpoints, using annual rainfall data of 23 stations during period of 1931–92.

The regional difference of rainfall change was examined, adopting principal component analysis. Annual rainfall variability in Zambia represents both a considerable communality among neighboring stations and heterogeneity between the northern and the southern parts.

Rainfall in the greater part of Zambia diminished in the 1980s, and 1991/92 had the least rainfall during the period of 1910–92. Connections between rainfall and the Southern Oscillation are recognized, and the region where the rainfall-Southern Oscillation connection had best defined migrated from the northern part to the southern part around the year 1970.

The effect of annual rainfall change on maize production is evident in the southern province. In the semi-arid zone with about 700 mm of annual rainfall becomes a basic factor directly affecting maize production.

Key words: rainfall change, drought, the Southern Oscillation, maize production, Zambia.

1 Introduction

Agriculture in Zambia is heavily dependent on summer (November to March) rainfall which provides 95 percent of the annual amount over most parts of the country. Numerous investigations have clarified the variability of rainfall in Southern Africa (*e.g.*, Tyson 1988 ; Lindesay 1988), but there are only a few Zambian rainfall studies. Iwasaki and Shinoda (1989) discussed rainfall features of Zambia from various aspects, especially regarding the 1983/84 drought. A more severe drought, however, occurred in 1991/92.

In this study, the auther intends to clarify rainfall changes in Zambia from three points of view. First, the regional difference of rainfall variability in Zambia, especially the difference between the northern and the southern regions. Second, secular change of rainfall for about sixty years ; whether its increasing or decreasing in recent years, and moreover, with reference to the El Niño Southern Oscillation. The third viewpoint is the relationship between rainfall and maize production in the semi-arid

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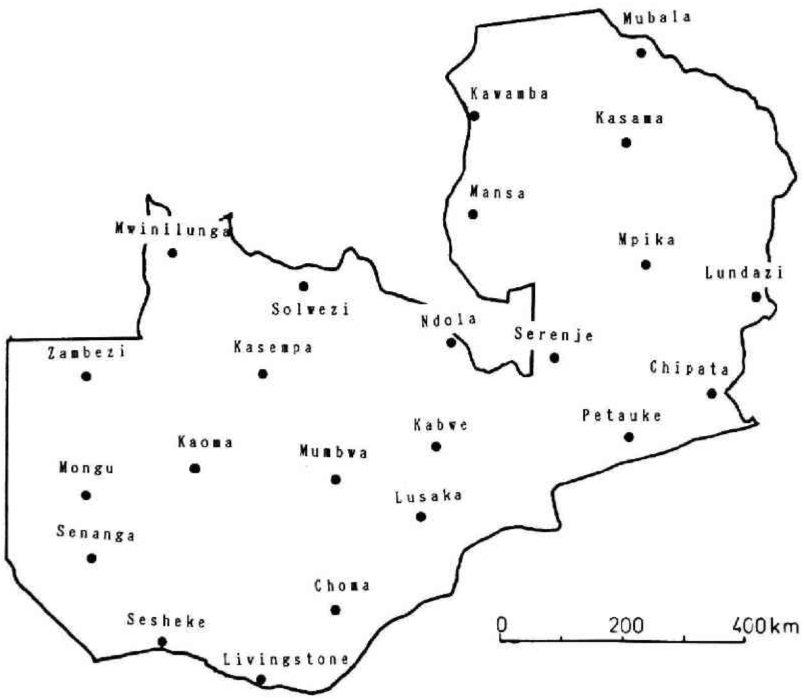

Fig. 1 Location of stations.

zone of this country.

Data used in this study are monthly rainfall figures from 1931 to 1992 for 23 stations (Fig. 1). In the period 1951-1992, rainfall data for 36 stations were provided by the Zambia Meteorological Department. However, these are not complete, and data for only 23 stations are available for the period 1960-92. Before 1960, rainfall figures were defermined by "Totals of Monthly and Annual Rainfall for Selected Stations in Zambia" issued by the Authority of the Ministry of Power, Transport and Works, which compiles the rainfall data for the period from the first record month to June 1970. The oldest rainfall data of Zambia were recorded in Chipata at the year of 1903, however ; all 23 stations were not complete until the beginning of 1931.

Monthly rainfall data are summed to determine annual values, from July to June of the following year. Moreover, the daily rainfall data of Kabwe, in central Zambia, are used to investigate the seasonal march of the rainy season during drought years.

2 Regional difference of rainfall variation in Zambia

The mean annual rainfall in the northern part of Zambia is 1,370 mm, and that in the southwestern part is 680 mm. In the northern part, the onset of the rainy season is earlier than in the southern part, the retreat is later (Hutcinson 1974 ; Iwasaki and Shinoda 1989). Moreover, there are considerable differences of ITC and ZAB (Zaire Air Boundary) activities between both regions (Hutcinson 1974 ; Mumba and Chipeta 1984). Therefore, in order to clarify the regional difference of rainfall variation in Zambia, the principal component analysis was adopted for 62 years of annual rainfall for 23 stations. Fig. 2 shows the spatial distribution of the first and the second components, which account for 50 percent of the total variance.

The first component locates in the central and the southern parts of Zambia, and covers a greater part of the country. The second component represents a variability of seesaw pattern between the northeastern and the southwestern parts of the country. The distribution of the second component bears resemblance to that of the mean annual rainfall. Therefore, the second component is regarded as a factor which increases or diminishes the difference of rainfall between the north and the south regions. That is, when the second component is positive, the difference increases. The distributions of two components show that the annual rainfall variability in Zambia represents both a considerable communality among neighboring stations and heterogeneity between the northern and southern parts.

Fig. 3 shows the time series of two components during the period of 1931-92. The first series shows that about a ten-year periodicity is predominant, a positive tendency in the latter part of the 1970s, and a negative tendency in the 1980s. The second

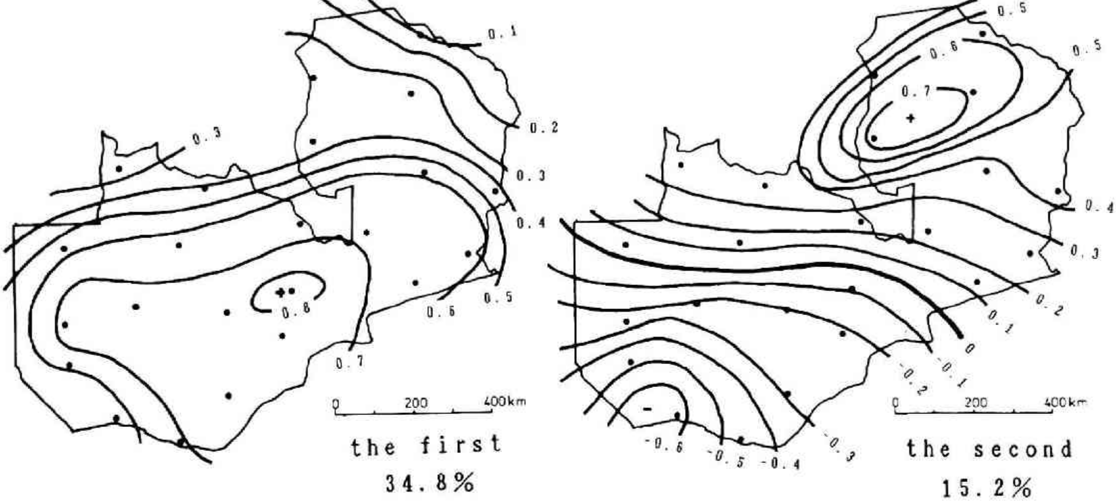

Fig. 2 Spatial distribution of components.
left : the first component right : the second component.

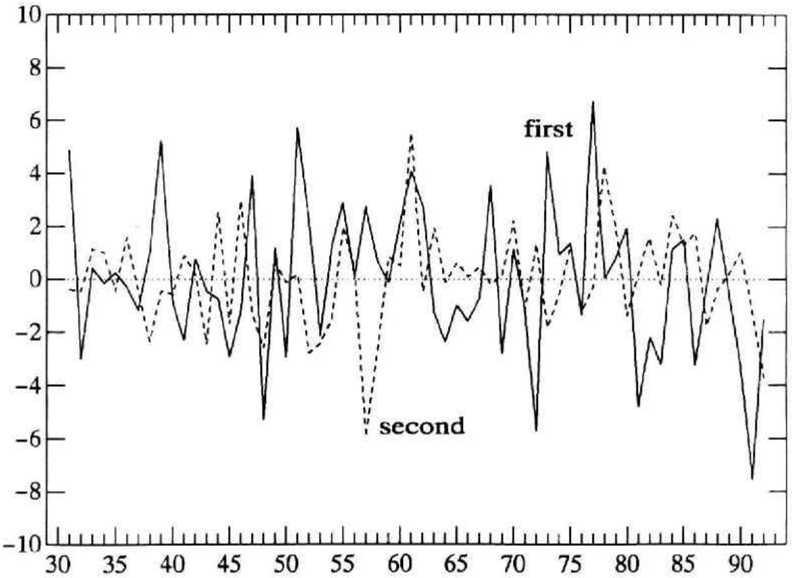

Fig. 3 Time series of two components.
solid line : the first component
dashed line : the second component.

component, on the other hand, does not show any remarkable periodicity of tendency.

3 Secular changes and 1991/92 drought

3.1. Secular Changes

Fig. 4 shows secular changes of the average rainfall for all of Zambia (average for 23 stations), the average rainfall in the southern part of Zambia (six stations), and the southern oscillation index (SOI). Changes for the entire country and the southern parts are nearly synchronous throughout the period. However, the relationships between the SOI and Zambian rainfall have changed during the period of 1950–1992. It was already pointed out that the southern oscillation index is negative (El Niño event) when the southern part of Africa is affected by drought (*e.g.*, Ropelewski and Halpert 1989). However, it was also noted that the correlation between the SOI and rainfall in Zambia is not always significant (Mulenga 1993). For example, the El Niño event in 1982/83 was one of the largest during this century, but its impact on Zambian rainfall was not enormous, with a slighter impact than the drought of 1991/92.

The relationship between the SOI and rainfall does not seem to be established until 1970, *e.g.* no relationship seemingly exists in 1951, 1957 and 1965 (Fig. 4). After 1970, however without exception, *e.g.* in 1972, 1976, 1983, 1986 and 1991, and especially in the

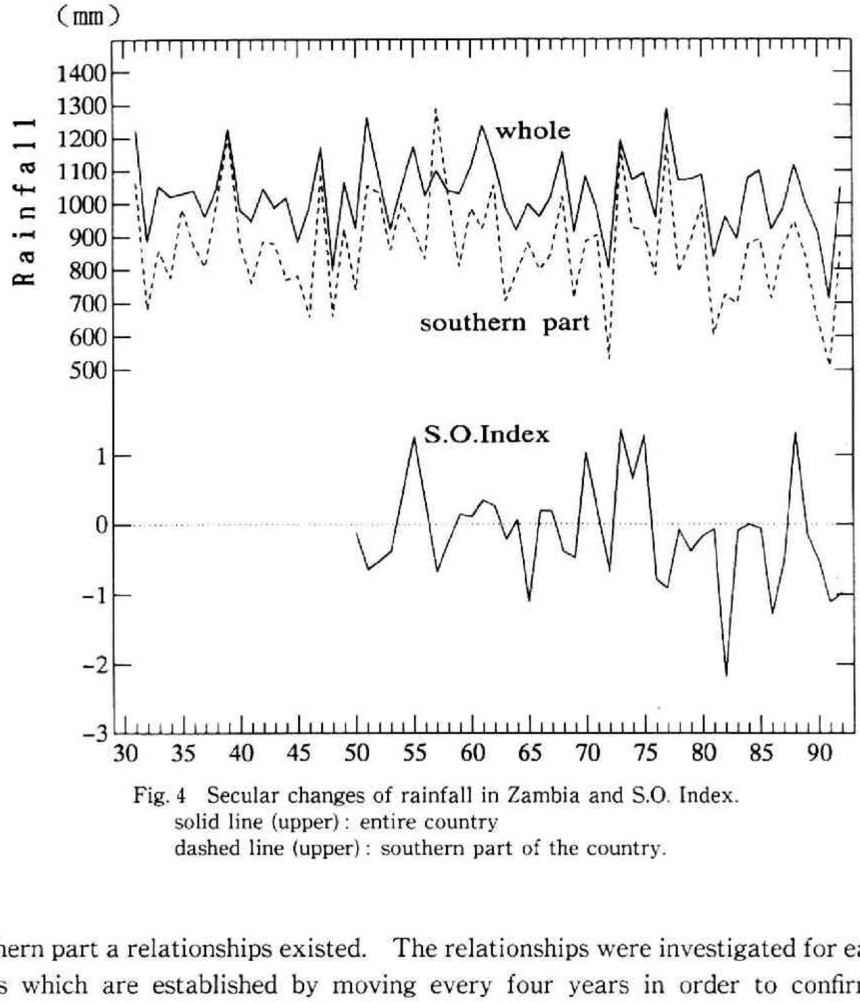

Fig. 4 Secular changes of rainfall in Zambia and S.O. Index.
solid line (upper): entire country
dashed line (upper): southern part of the country.

southern part a relationships existed. The relationships were investigated for each 20 years which are established by moving every four years in order to confirm the discontinuous change around 1970. Table 1 shows the correlation coefficients between the SOI and rainfall of the three parts of Zambia in each period during the 20 years. It is interesting to note that the correlation coefficient of the southern part turned from negative or not significant to significantly positive around 1970, and at the same time decreased in the northern part, where a significant positive relationship had been observed for 1950-69. These results suggest that the region where the rainfall and the Southern Oscillation connection are best defined migrated from the northern to the southern part around 1970.

Among 23 stations, six stations (Chipata, Livingstone, Mongu, Mumbwa, Sesheke, Solwezi) can be traced back to 1910. They are fortunately distributed throughout the country, therefore; their average rainfall can be roughly regarded as the entire

Table 1 Correlation coefficients between SOI and rainfalls of three provinces of Zambia.

	Southern	Central	Northern
1950-69	−0.162	0.192	0.347
1954-73	0.236	0.332	0.307
1958-77	0.279	0.067	0.244
1962-81	0.283	0.043	0.150
1966-85	0.344	0.056	0.061
1970-89	0.424	0.210	0.101
1973-92	0.460	0.228	0.201
1950-92	0.282	0.221	0.250

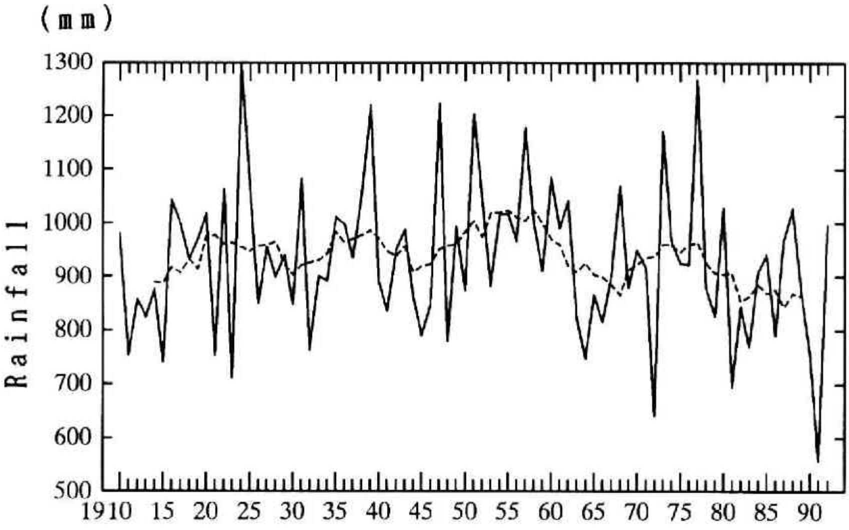

Fig. 5 Long-term change of six station's average annual rainfall. dashed line: 9-year running mean.

Zambian rainfall paitern. Fig. 5 shows the average rainfall of the six stations during the period of 1910-1992. It is noted that 1991/92 had the least rainfall, and the 1980s was the decade for least rainfall since 1910. Moreover, it is noteworthy that the variation has increased since 1970.

3.2. 1991/92 drought

The drought in 1991/92 was the most severe during the period 1910-1992 (Fig. 5). The 1991/92 rainfall distribution is shown in Fig. 6, which compares with recent other drought years. In 1991/92, large negative anomalies were widespread in the south, and annual rainfall did not reach 400 mm in Mongu and Sesheke.

The four drought years are classified into two types from the standpoint of rainfall distribution, though they have aspects in common with large negative anomalies of the south. One is the type in which above normal anomalies are widely observed in the northeastern and the northwestern parts. As a result, the north and south contrast is very striking (1972/73 and 1990/1991). The other is the type in which above normal anomalies are not clear, where below normal anomalies exist throughout the country (1983/84 and 1991/92). The second component mentioned above is positive in the

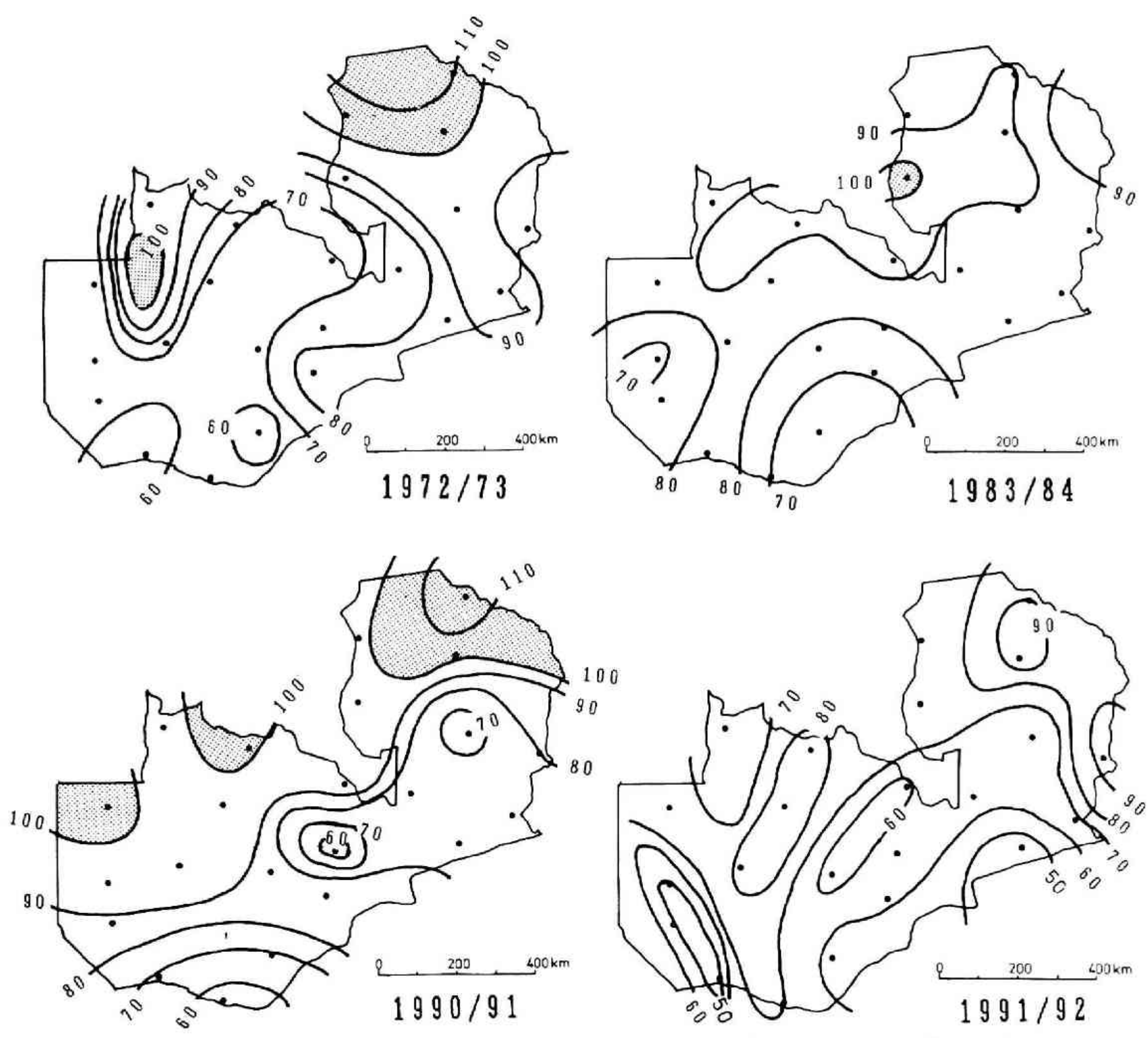

Fig. 6 Rainfall distribution of recent drought years, expressed as a percentage of normal value.

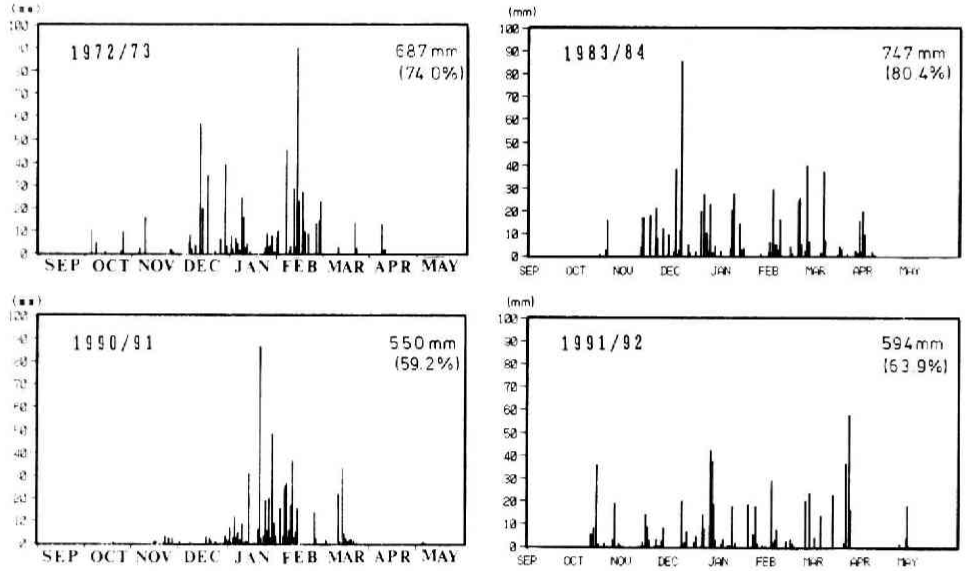

Fig. 7 Seasonal march of daily rainfall of Kabwe for recent drought years.

former type, and negative in the latter. In 1991/92, the both components are negative, and record minimums in 62 years are observed in many stations.

Fig. 7 shows the seasonal march of daily rainfall of Kabwe in central Zambia for the recent four drought years. The rainly season in 1991/92 began on 19th October, which was somewhat earlier than usual. The date for the retreat was at the end of March, which was normal. There was, however, little rain during the season, particularly in December, and annual rainfall was only 594 mm, which was 64 percent of normal. 1983/84 had something in common with the earlier onset and longer rainy season. The rainy seasons of 1973/74 and 1990/91 were, on the contrary, short, and rain was inclined to be concentrated in February.

It is interesting to note that rainfall distribution of drought years corresponds to the seasonal march of daily rainfall in central Zambia.

4 Relationships between maize production and rainfall change

4.1. Maize production and production data

Maize is the most important crop in Zambia, therefore, people are greatly concerned with its production and the price. Various investigations have shown that maize production is significantly influenced by precipitation, temperature, sunshine and other meteorological parameters. For example, Das (1973) revealed that maize yield could be predicted by the rainfall in November, the average daily maximum temperature in November, the number of rainy days in December to January, and the technical trend. Simango and Das (1977) discussed the relationship between annual rainfall and maize yield using their decile range. In this study, the relationships between rainfall and maize production are examined, with emphasis on regional differences.

Data of maize production are obtained from "Annual Agricultural Statistical Bulletin". According to these data, maize production is limited to the period of 1982-1988. More continuous and more reliable figure is maize intake by official marketing organizations. The quentity of maize marketed is not equal to that produced, because the former does not include self-consumption, small scale dealings and smuggling. However, as mentioned below, the difference is considerd to be regular to a certain extent.

Fig. 8 shows the distribution of the average maize intake by provinces during the period of 1973-1988. Maximum intake was recorded in the Central Province which includes the Lusake Province, which is followed by the Southern Province. Total amount of intake by these two provinces involves 70 percent. These are the provinces in which most big cities are located and the transport system is best developed.

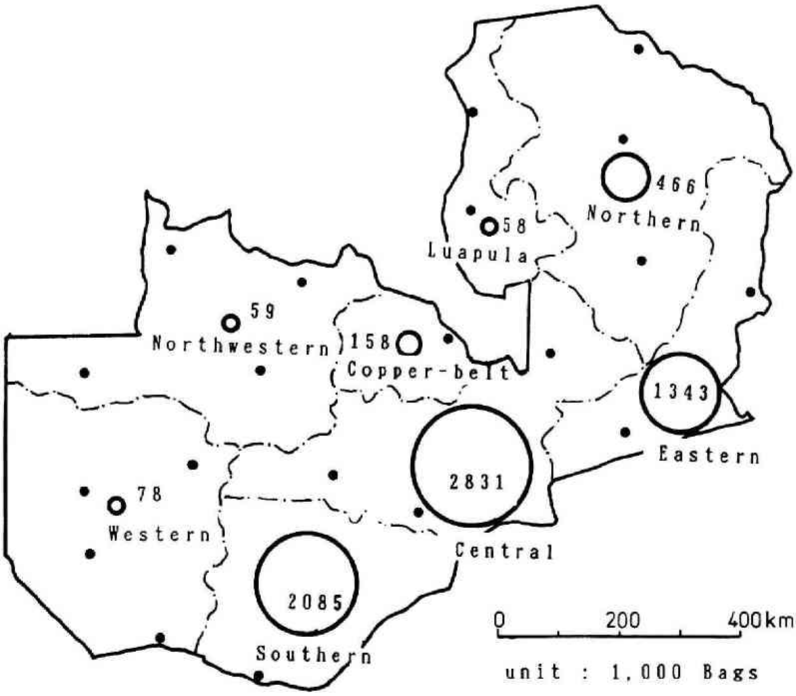

Fig. 8 Maize intake for provinces in Zambia, average for the period of 1973-1988.

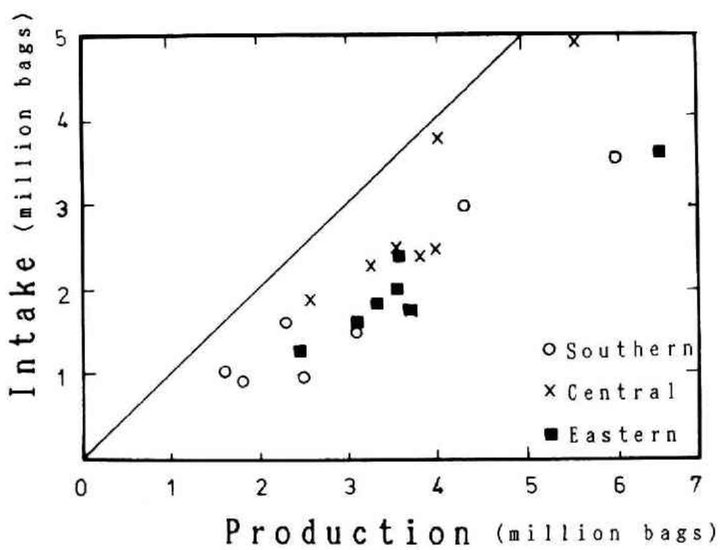

Fig. 9 Relationship between production and intake of maize for three provinces during the period of 1982-1988.

Fig. 9 shows the relationship between production and intake of maize for the period of 1982-1988, only for the case when the both data were reported. It is recognized throughout the three provinces that the differences between the amount of production and intake is about one and a half million bags, which is regarded as the self-consumptions and so on. Therefore, intake is substituted for production of maize in the following analysis.

Year-to-year change of maize production by provinces is shown in Fig. 10. Production fluctuation in the Southern and Central Provinces is relatively large, and contributes to the fluctuation of the total amount. The production of the Southern and the Central Provinces accounted for 80 per cent of the total amount until 1981, but with increasing of the production of the Eastern and the Northern Provinces under the policy of dispersing drought crisis, subsequently the production of the Southern and Central Provinces decreased to 56 percent of the total amount in 1988.

4.2. Effect of rainfall on maize production

As maize production in the Eastern and Northern Provinces has been increasing remarkably, it is difficult to clarify the effect of rainfall on maize production. Therefore, the effect of rainfall will be examined in the case of the Southern and the Central Provinces.

Fig. 11 shows the relationship between the rainfall and maize production ratio to

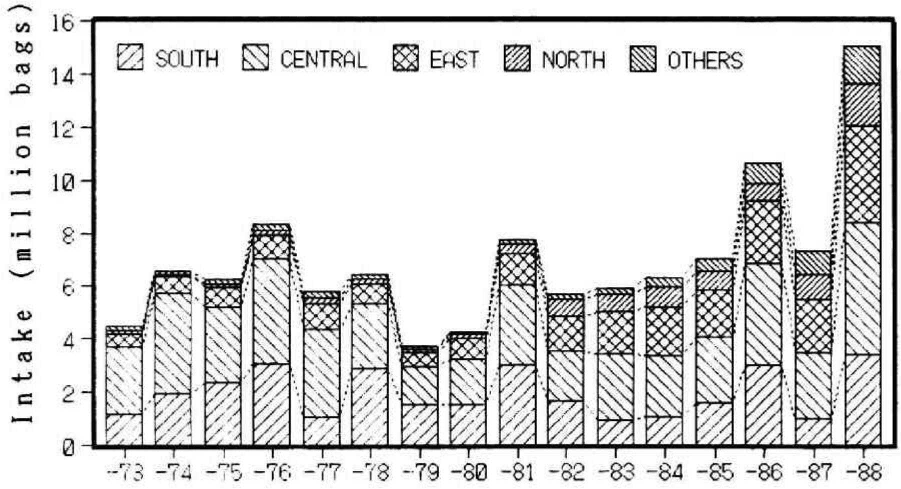

Fig. 10 Year-to-year change of maize production by provinces.

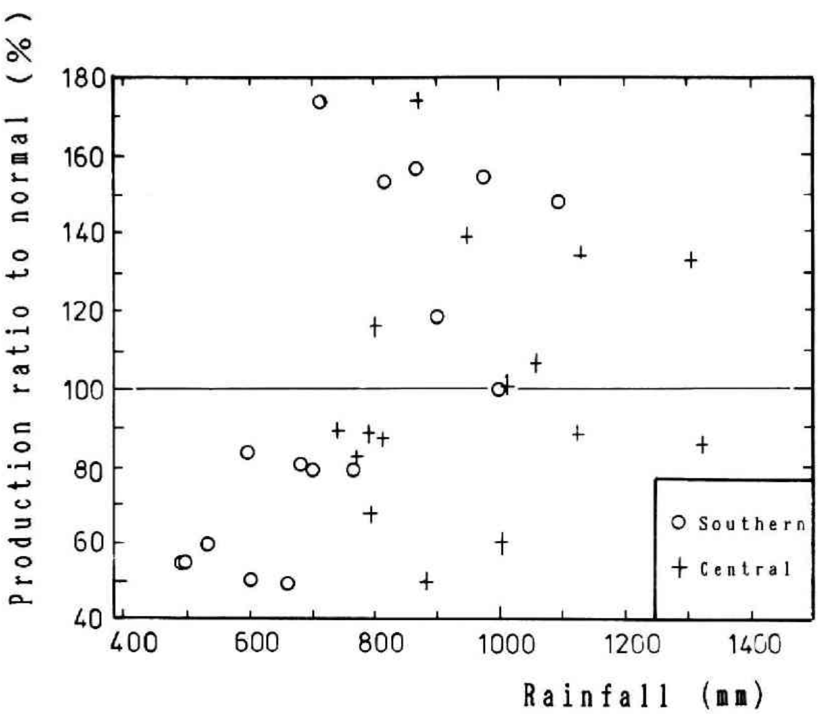

Fig. 11 Relationship between rainfall and maize production ratio to the normal in the Southern and the Central Provinces.

the normal average during 1973–1988. In the Southern Province, there is a clear positive correlation. The correlation coefficient is 0.712. On the other hand, there is no significant correlaion in the Central Province, the correlation coefficient is 0.203. However, there is a rather remarkable disruption in the production of maize at the 700 mm rainfall level. This can not be certified in the case of the Central Province where there was no year with less than 700 mm of rain. But in the case of the Southern Province, there is not even a year when maize production was less than the average of 1973–1988, in spite of low rainfall of less than 700 mm.

Needless to say, the climatic condition of maize production is affected not only by annual rainfall, but also by its seasonal distribution, temperature, sunshine and other aspects. Moreover, there are many non-climatic factors affecting maize production. As a result, with rainfall greater than about 800 mm, production ratios vary widely. However, it is noteworthy that there is no good crop of maize if rainfall drops under 700 mm.

5 Conclusion

Rainfall in the greater part of Zambia has diminished in the 1980s, and a severe drought affected the country in 1991/92, which was the driest for the period 1931–92 for many stations. The drought in 1991/92 spread throughout the country, though the southwestern part was damaged more severely. The rainy season was relatively long during that rainfall year, but there was little from November to February when there is an abundance during a normal year. Other type of drought is characterized by above normal rainfall in the northern part. Dry areas were found in the central and the southern parts, during the 1972/73 drought. This drought type is accompanied by a shorter rainy season and relative concentration of rainfall in January.

The other interesting result is obtained with regard to the connection with the Southern Oscillation. The region where rainfall-Southern Oscillation connection was best difined migrated from the northern to the southern part around the year 1970. However, the El Niño event impacted Zambian rainfall in 1982/83 which was slighter than 1991/92. Because the relationship is complicated, more detailed investigation is necessary.

The effect of annual rainfall change on maize production is evident in the Southern Province and obscure in the Central Province. That is, in the Central Province even with enough rainfall, maize production is influenced by various factors, including those that are non climatic. On the other hand, in the Southern semi-arid Province, around 700 mm annual rainfall becomes a basic factor directly affecting maize production.

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