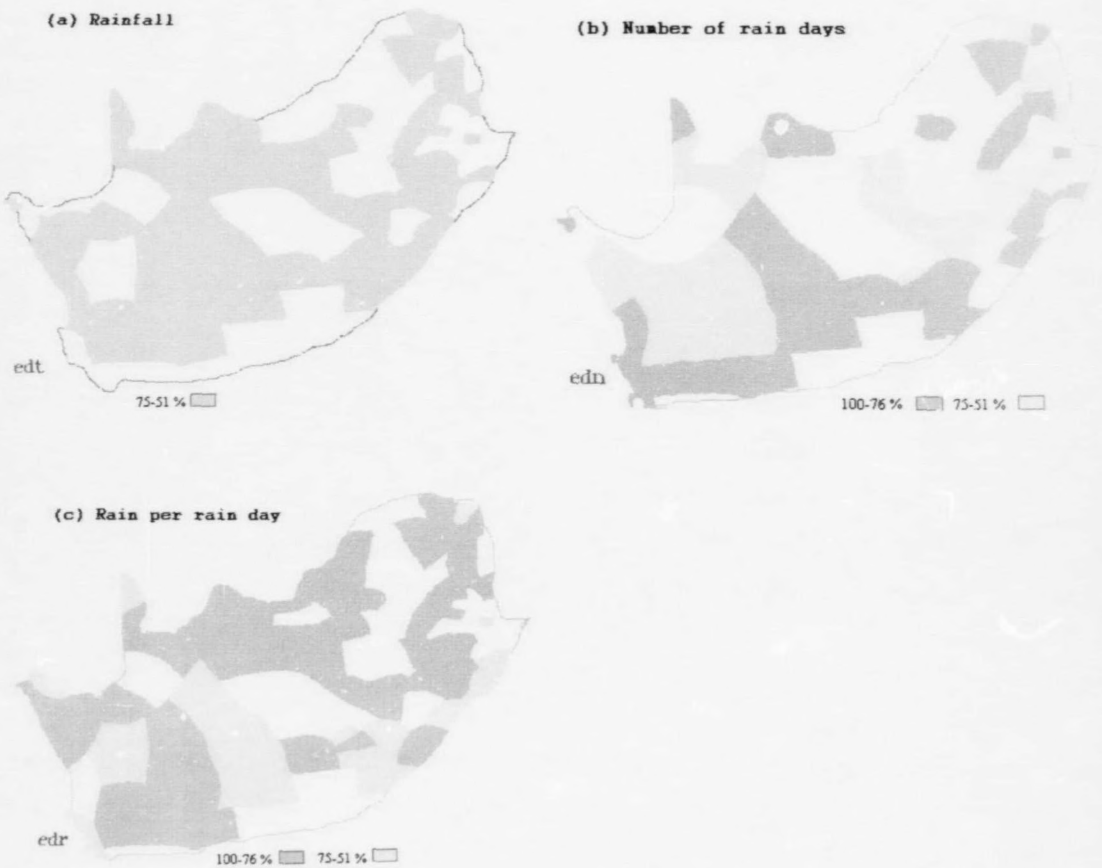

Figure 4. 8: Extreme dry conditions (i.e. rainfall < 75% of mean) in 10 driest years: percentage (a) rainfall, (b) number of rain days, (c) rain per rain days. Blanks on maps indicate areas where criterion is not met.

Extreme dry years

During extreme dry years, in which rainfall is less than 75% of mean, most of the subcontinent, except where extreme dry conditions do not meet the criterion (i.e. blank areas on maps), is characterized by rainfall receipts from 51-75% of mean (Fig. 4.8a). In extreme dry years, the number of rain days is 51-75% of mean in many areas, with a few areas showing a range of 76 to 100% and some (Fig.4.8b). The amount of rain falling per rain day likewise decreases significantly (Fig. 4.8c).

The wettest year in the period 1950-1997

The wettest year, over the period of record studied was 1975/76. In this year, rainfall increased over the whole subcontinent. The whole region, excepting the south coastal and other isolated areas where rainfall was below normal, received above normal rainfall (Fig.4.9a). Over much of the region, the rainfall increase is as much as 200% of the mean. Likewise, the rain days (Fig. 4.9b) and rain per rain day (Fig. 4.9c) increase substantially. However, some areas of the subcontinent, the south and extreme west coastal areas in particular, experienced below mean rainfall conditions.

The driest year in the period 1950-1997

Over the period of record studied, 1991/92 was the driest year. While the whole subcontinent, except some areas in the extreme west and the south coast, was wet in 1975/76, the opposite was experienced during the excessively dry year. Over the subcontinent, excepting the extreme arid west and other isolated areas where rainfall was above mean, experienced below mean conditions. Despite the dry conditions characterizing the whole southern African region, the extreme west experienced from 101 to 300 % of normal conditions. The greater decrease in both rain days (Fig. 4.10b) and amount of rain falling on those rain days (Fig. 4.10c) resulted in the excessively dry conditions in this year.

It emerges from this analysis that both positive departures in the number of rain days and rain per rain day were responsible for the excessively wet year of 1975/76; the opposite was responsible for the excessively dry year of1991/92.

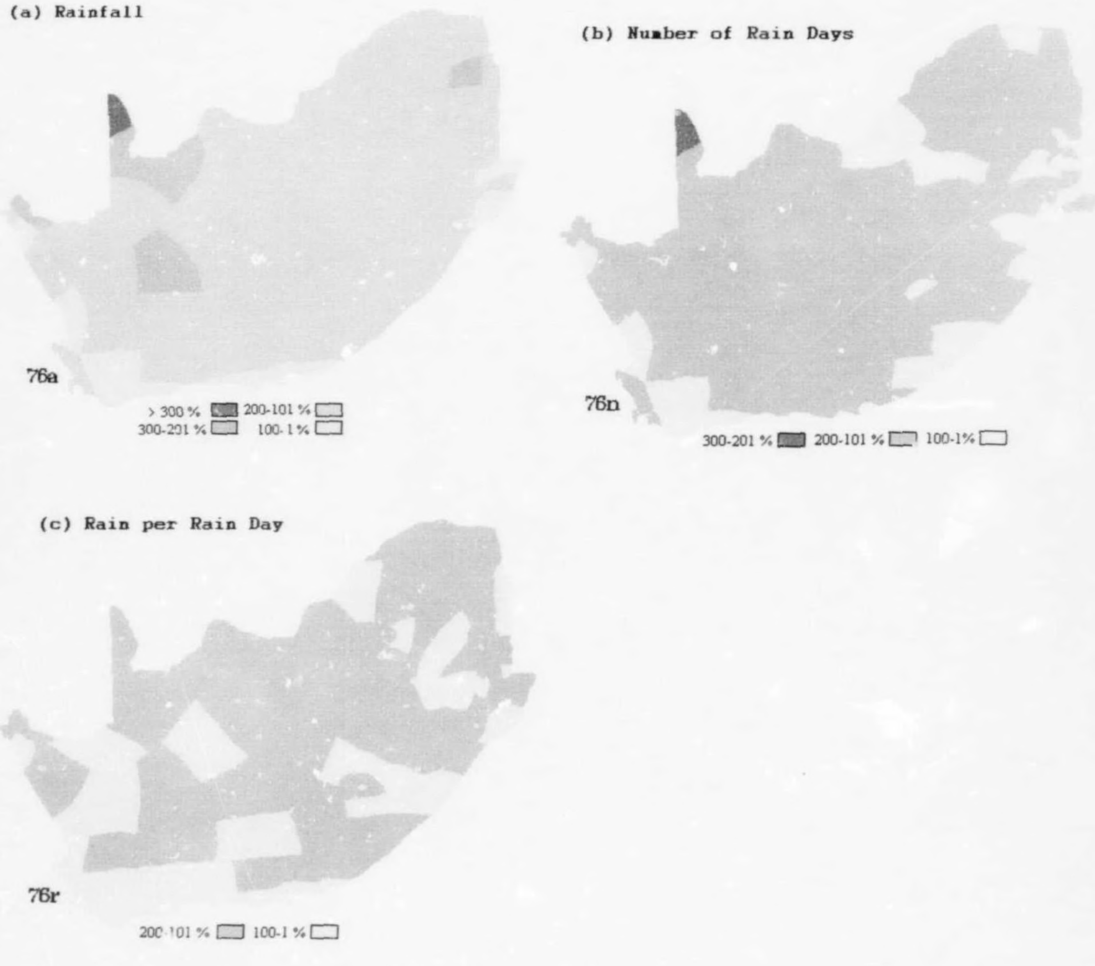

Figure 4.9: Wettest year between 1950-1997, 1975/76: percentage (a) rainfall,
(b) number of rain days, (c) rain per rain day.

Figure 4.10: Driest year between 1950-1997, 1991/92: percentage (a) rainfall, (b) number of rain days, (c) rain per rain day.

Chapter 5

Seasonal Rainfall Variability

Introduction

Preceding chapters have indicated the spatial and temporal relationships between rainfall, number of rain days and rain per rain day on annual basis. The influence of seasonal daily rainfall variability on annual rainfall patterns over the subcontinent still remains to be examined. However, not all seasons are important contributors to annual rainfall over most of the subcontinent. Here early-summer (Sep-Nov) and mid-summer (Dec-Feb) seasonal conditions will be considered. This chapter highlights the influence of rain days and rain per rain day on early-summer and mid-summer rainfall variability over the southern African region. This is done by first showing mean conditions in both seasons. Following this is the analysis of wet and dry seasons. Closing the chapter will be the highlight of seasonal rainfall conditions in the ten wettest and ten driest years.

Mean Conditions

Early-summer conditions

Early-summer rainfall displays the usual east-west gradient. About half of the subcontinent experiences below 50 mm during normal seasons, largely in the arid west (Fig. 5.1a). Over most of the summer rainfall region, rainfall ranges from 51 to 100 mm. The extreme east experiences an increased number of rain days (ranging from 6 to 10 days per season) than the rest of the subcontinent, where it falls below 5 rain days per season (Fig. 5.1b). The amount of rain received on rain days varies, but ranges from 6 to 10 mm per rain day over most of the subcontinent (Fig. 5.1c). There are areas, especially in the arid west which receive below 5 mm of rain on a rain day.

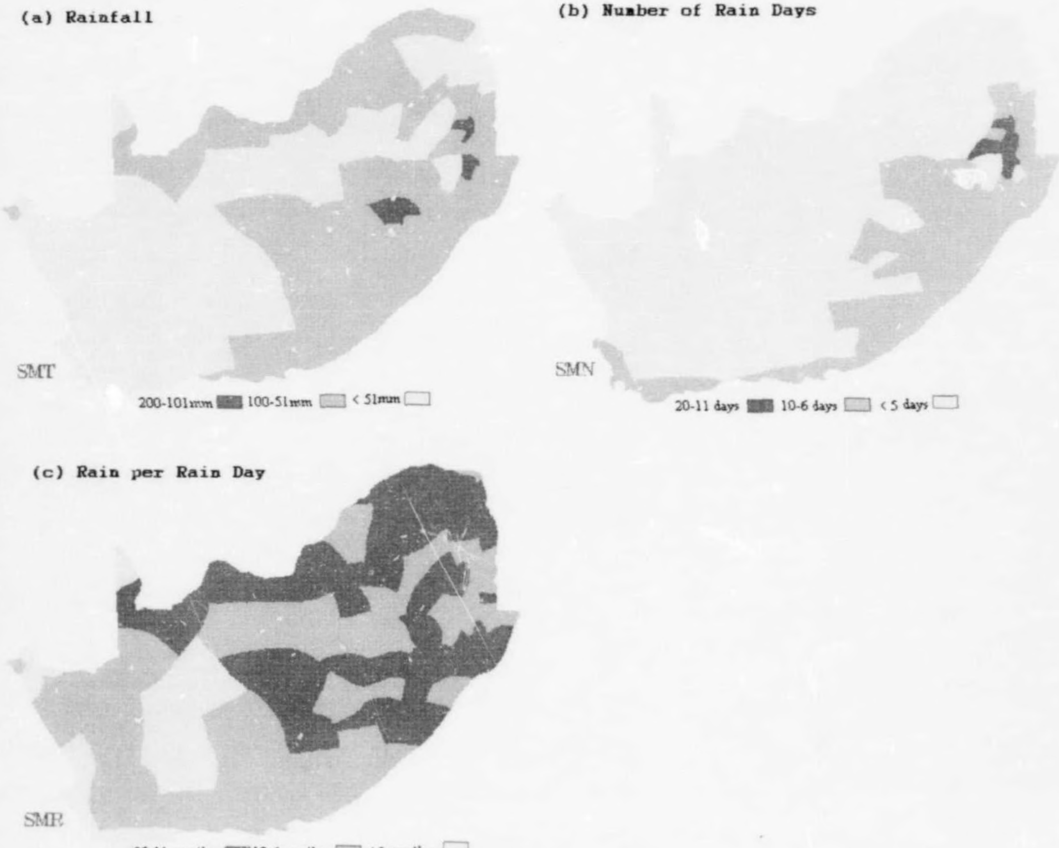

Figure 5.1: Mean early-summer conditions (a) rainfall, (b) number of rain days, (c) rain per rain day.

Figure 5.2: Mean mid-summer (a) rainfall, (b) number of rain days, (c) rain per rain day.

Mid-summer conditions

A clear rainfall increase from early-summer to mid-summer characterises most of the southern African subcontinent. Rainfall ranges from 51 mm to 100 mm over most of the subcontinent in mid-summer (Fig.5.2a). Increases greater than this occur in the northeastern parts of the summer rainfall region. Rain days also increase over most of the subcontinent in this season, particularly in the summer rainfall region where the number of rain days ranges from 6 to 10 days per season (Fig. 5.2b). Not does the mid-summer season experience an increase in rainfall and rain days, but the amount of rainfall received on those rain days also increases (Fig. 5.2c). Over most of the region rainfall intensity ranges from 11 to 20 mm per rain day.

Above and Below Normal Rainfall Conditions

Early-summer and mid-summer rainfall seasons show differential occurrence over the southern African region. This is so because the number of rain days and rain per rain day characterizing these seasons are different.

Wet early-summer conditions

Increased rainfall variability dominates over the semi-arid and arid regions of the subcontinent. Figure 5.3a shows that the greatest rainfall departures from normal occur over most of the semi-arid and arid regions, where rainfall ranges from 201 to 300% of normal. The lowest positive departures are experienced in the summer rainfall region, where rainfall ranges from 101 to 200% of normal. The frequency of rainfall occurrence above normal ranges from 26 to 50% over the whole subcontinent, but the central west to the extreme arid west where it fall below 25% (Fig. 5.3b). An increase in the number of rain days in wet mid-summer seasons is observed over the whole southern African region (Fig.5.3c), and so is the amount of rainfall falling on those rain days (Fig. 5.3d). Over most of the region, rainfall frequency ranges from 101 to 200% of normal, and so does the rain per rain day.

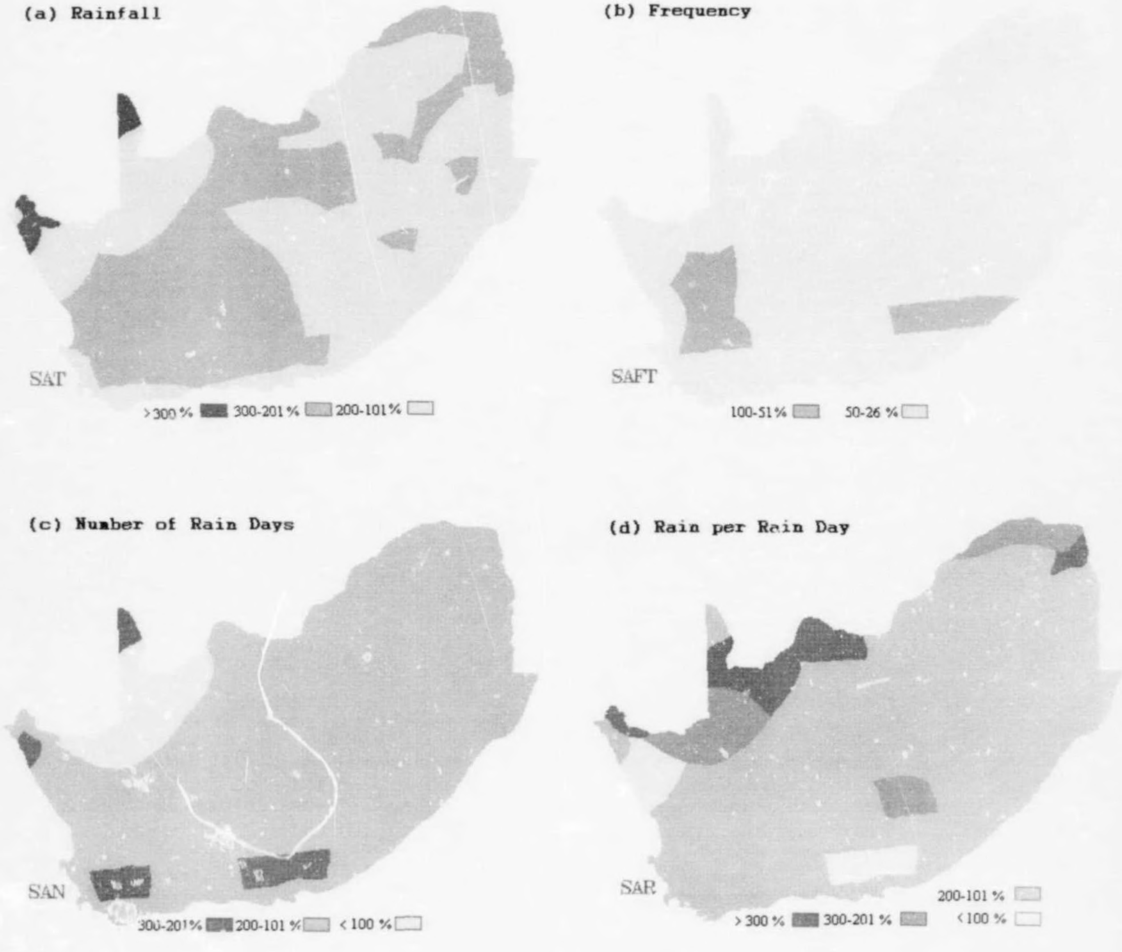

Figure 5.3: Wet early-summer conditions: percentage (a) rainfall, (b) frequency of occurrence, (c) number of rain days, (d) rain per rain day.

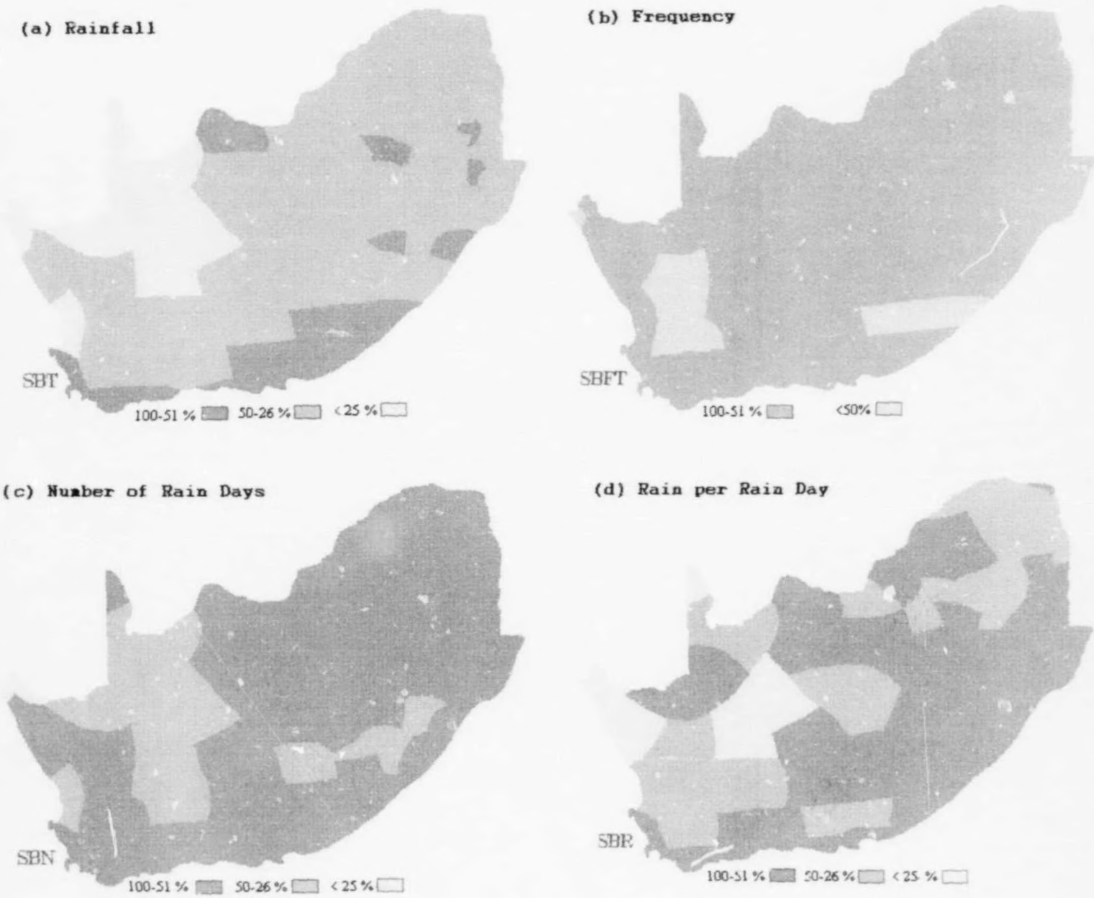

Figure 5.4: Dry early-summer conditions: percentage (a) rainfall, (b) frequency of occurrence, (c) number of rain days, (d) rain per rain day.

Dry early-summer conditions

Decreasing rainfall is experienced over the whole of southern Africa (Fig.5.4a). The frequency of rainfall occurrence also decreases (Fig.5.4b). Likewise, the number of rain days decreases (Fig 5.4c), as does the amount of rainfall received on those rain days (Fig. 5.4d).

Wet mid-summer conditions

During months of Dec-Feb, wet conditions are observed over the whole of southern Africa, particularly in semi-arid and arid regions (ranging from 201 to above 300% of normal) (Fig.5.5a). Over a large part of the subcontinent, the increase is from 101-200% of normal. The frequency of rain days is mostly in the range of 26 to 50% (Fig.5.5b). Wet mid-summer seasons experience an increase in number of rain days (Fig.5.5c) and rain per rain day (Fig. 5.5d).

Dry mid-summer conditions

A clear east-west rainfall gradient exists (Fig. 5.6a), with many eastern areas receiving as little as 50% of normal rainfall. The frequency of rainfall occurrence decreases everywhere (Fig. 5.6b). Rain days (Fig. 5.6c) and the amount of rain received on those rain days (Fig.5.6d), ranges from 51 to 100% of normal over most of the region. The greatest decrease in both parameters occurs over the arid regions, intensifying in the extreme west, where the decrease is occasionally more than 75%.

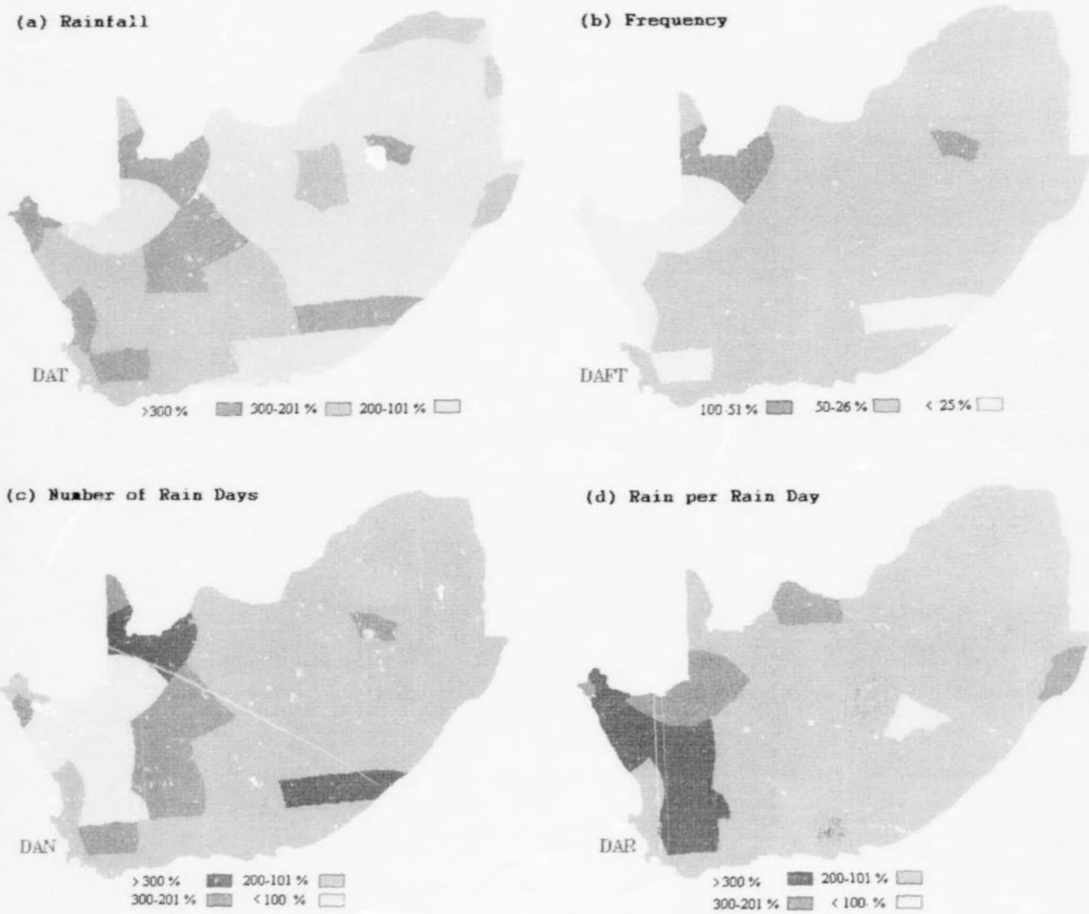

Figure 5.5: Wet mid-summer conditions: percentage (a) rainfall, (b) frequency of occurrence, (c) number of rain days, (d) rain per rain day.

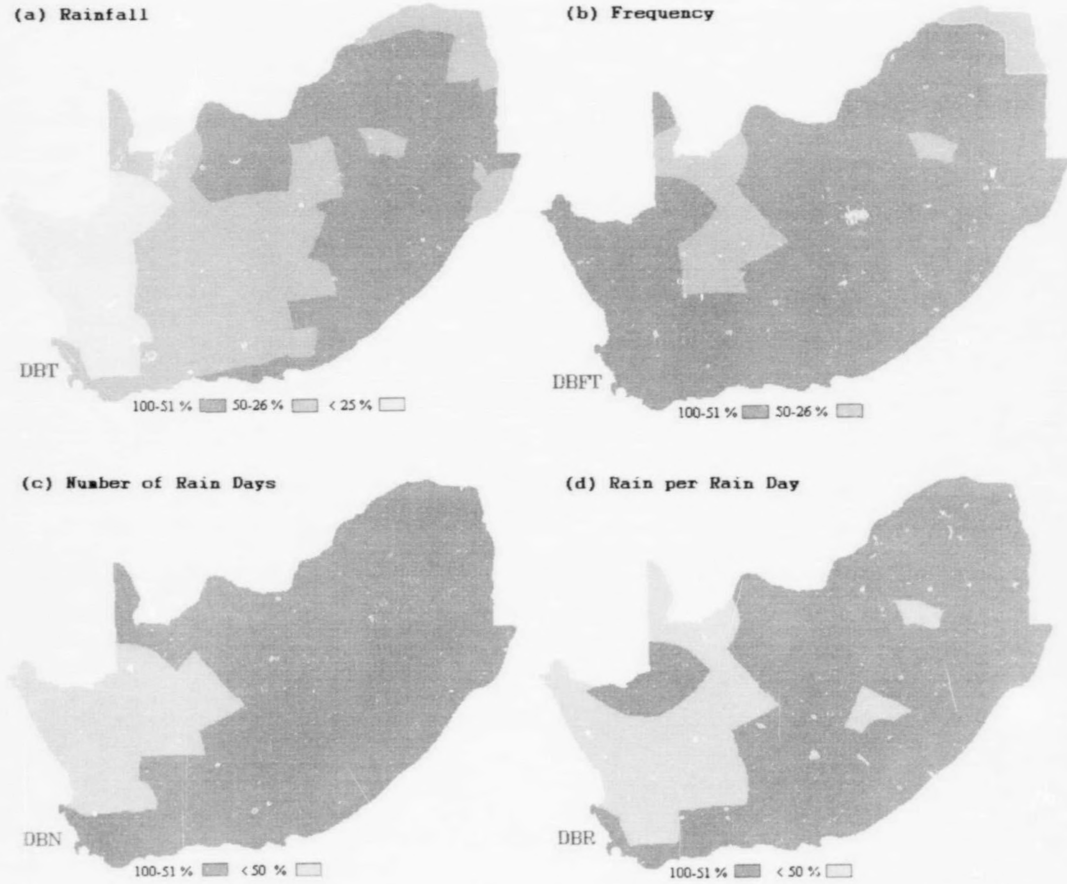

Figure 5.6: Dry mid-summer conditions: percentage (a) rainfall, (b) frequency of occurrence, (c) number of rain days, (d) rain per rain day.

Excessive Seasonal Conditions in the Ten Wettest and Ten Driest Years

As before, given that extreme wet years and wet seasons result from greater numbers of rain days and rain per rain day, and the opposite in extreme dry years and dry seasons, the question to be answered is whether the same holds for extreme wet and extreme dry seasons in the ten wettest and ten driest years. Extreme wet seasons are defined as those seasons receiving above 125% of mean; extreme dry seasons are those with 75% or less of mean seasonal rainfall in the 10 driest years.

Extreme wet early-summer seasons

During extreme wet periods, the degree of rainfall excess varies from 100 to 200% over much of southern Africa (Fig. 5.7a). Many regions show rainfall excess exceeding 200%. Rain days, like seasonal rainfall, show east-west gradient, where the number of rain days decrease from 200 to less than 126% over most of the subcontinent, largely in the summer and all-seasons rainfall (Fig. 5.7b). Extreme wet seasons not only result from increased number of rain days, but also increased amounts of rain falling on those days (Fig. 5.7c).

Extreme wet mid-summer seasons

Like extreme wet early-summer seasons, extreme wet mid-summer rainfall seasons show a distinct west-east gradient, from above 200% to 126% of mean over the region (Fig. 5.8a). Southern Africa experiences significant increases in number of rain days during extreme wet Dec-Feb seasons (Fig. 5.8b). Likewise, the amount of rain falling on those rain days (Fig. 5.8c). This increase is greater in semi-arid and arid regions of the subcontinent.

Figure 5.7: Extreme wet early-summer conditions in 10 wettest years: percentage (a) rainfall, (b) number of rain days, (c) rain per rain day.

Figure 5.8. Extreme wet mid-summer conditions in 10 wettest years: percentage (a) rainfall, (b) number of rain days, (c) rain per rain day. Blanks on the maps indicate areas that do no meet the criterion.

Extreme dry early-summer seasons

Reduction of rainfall occurs over the whole of southern Africa in extreme dry Sep-Nov seasons (Fig.5.9a). Over most of the region, rainfall diminishes to less than 50% of the seasonal mean. There is a strong cohesion between seasonal rainfall and number of rain days (Fig.5.9b). Over most of the subcontinent, the number of rain days diminishes to 50% below mean. Characterizing subcontinent is the greater decrease of rain per rain day in extreme dry Sep-Nov seasons (Fig.5.9c). Over a large part of the region, rainfall ranges from 50 to 100% of seasonal mean.

Figure 5.9: Extreme dry early-summer conditions in the 10 driest years: percentage (a) rainfall, (b) number of rain days, (c) rain per rain day. Blanks on maps show areas where criterion is not met.

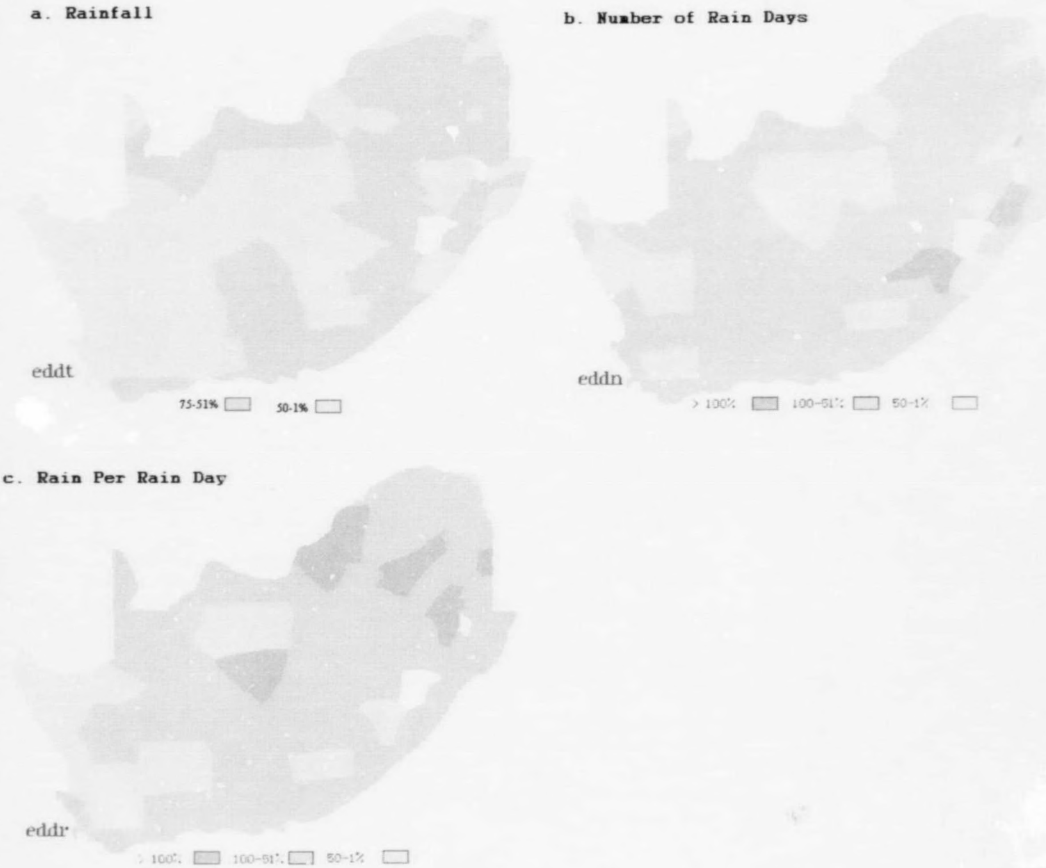

Figure 5.10: Extreme dry mid-summer conditions: percentage (a) rainfall, (b) number of rain days, (c) rain per rain day. Blanks on maps indicate areas that do not meet the criterion.

Extreme dry mid-summer seasons

The whole subcontinent experiences a decrease in seasonal rainfall (Fig.5.10a). Rain days, decrease substantially over the whole of southern Africa (Fig. 5.10b), with most areas showing a decrease of 50% below mean. Rainfall intensity per day decreases everywhere (Fig. 5.10c).

Clear relationships have been established between increasing and decreasing rainfall, the number of days on which rain occurs and the amount of rainfall per rain day on a larger spatial scale. Whether the same relationships hold over limited areas remains to be determined. This will now be done for Swaziland as a test case.

Chapter 6

Rainfall Variability in Swaziland

Introduction

The analysis to this far has considered spatial and temporal rainfall variability and the relationships between rainfall, rain days and rain per rain day over the whole of southern Africa. In this chapter, conditions at a very different scale will be examined for the limited sub-region of Swaziland.

In the case of Swaziland, it is useful to break the summer rainfall into two parts, Oct-Dec (early-summer) and Jan-Mar (mid-summer). These seasons determine various types of agricultural activities having different water requirements.

Wet and Dry Conditions

Annual rainfall departures from mean show distinct spatial variability, which is more pronounced in the dry areas of the country.

Wet years

In wet (above–normal rainfall) years, Swaziland's annual rainfall varies from 120 to 140 % of normal (Fig. 6.1a). Largest increases occur in the dry eastern lowlands. Not only does the greater frequency of rainfall occurrence (Fig. 6.1b), but also the greater increase in both rain days (Fig. 6.1c) and amount of rain received on those rain days (Fig. 6.1d) contribute to wet years.

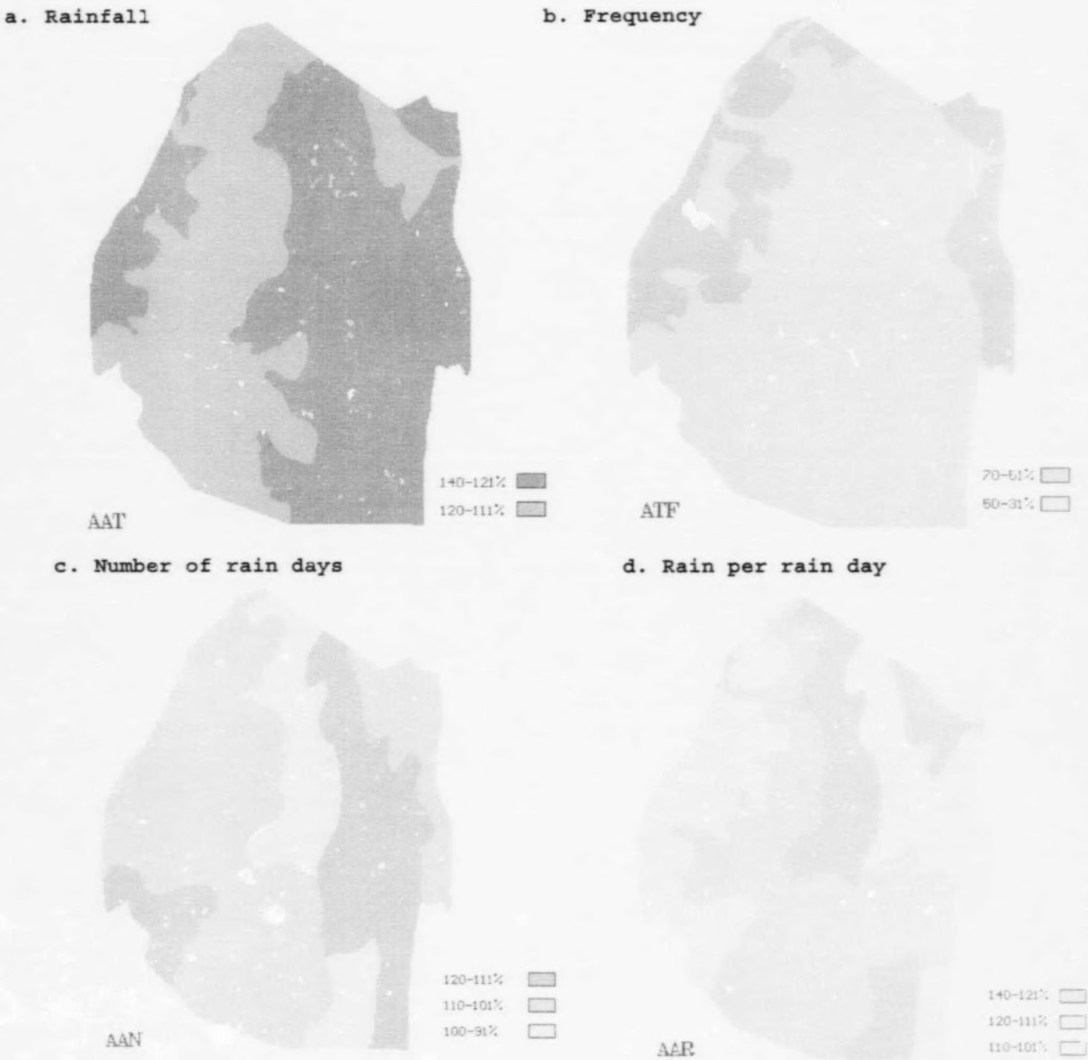

Figure 6.1: Wet years: percentage (a) rainfall, (b) frequency of occurrence, (c) number of rain days, (d) rain per rain day.

Figure 6.2: Dry years: percentage (a) rainfall, (b) frequency of occurrence, (c) number of rain days, (d) rain per rain day.

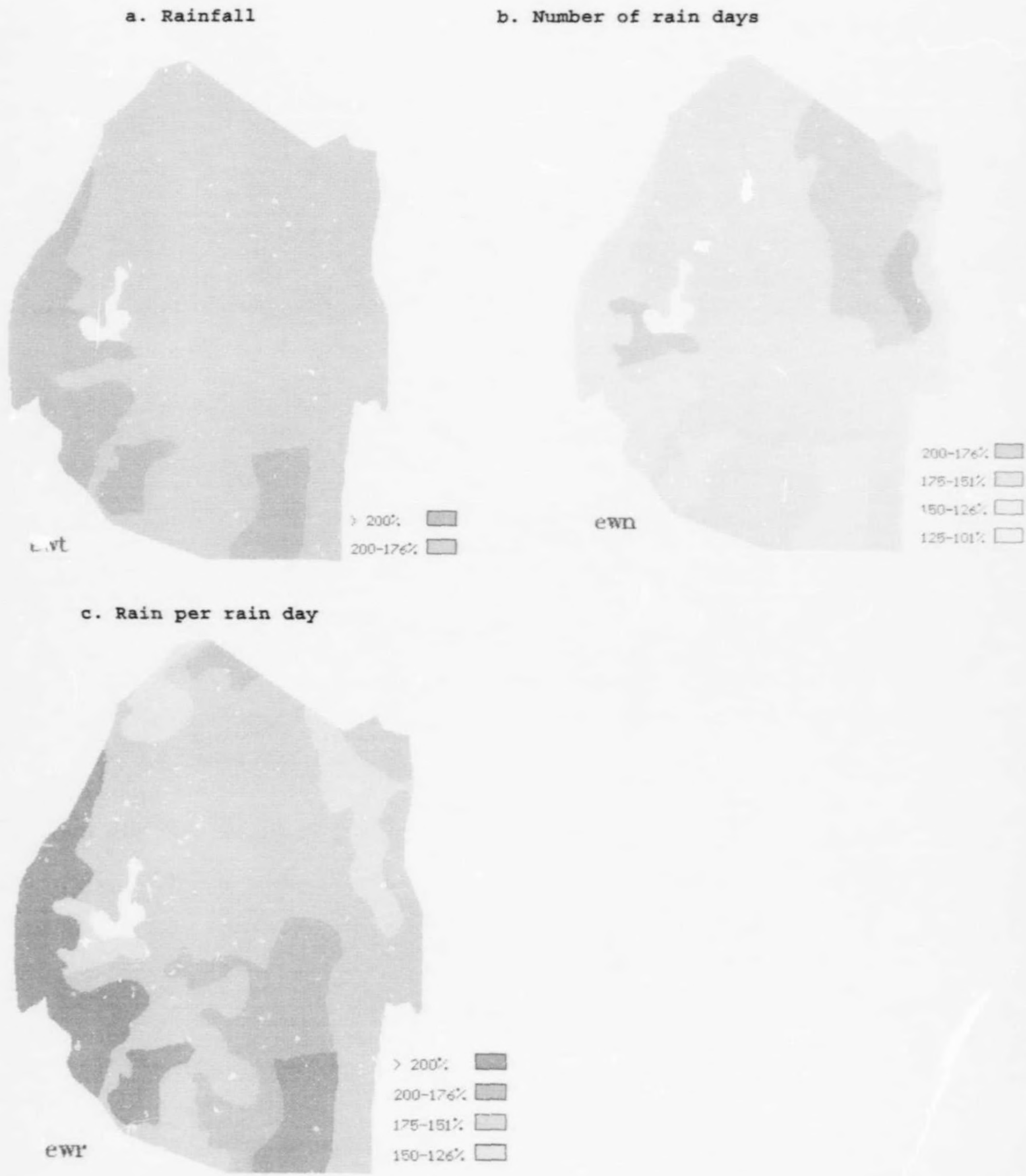

Figure 6.3: Extreme wet years (i.e. rainfall > 150% of normal): percentage (a) rainfall, (b) number of rain days, (c) rain per rain day. Blanks on maps illustrate areas where criterion is not met.

Dry years

In dry years (Fig. 6.2a) the frequency of rainfall decreases (Fig. 6.2b), as does the in number of rain days (Fig. 6.2c) and the amount of rainfall experienced on those rain days (Fig. 6.2d).

Extreme wet and extreme dry years

During extreme wet years (Fig. 6.3a) both rain days (Fig. 6.3b) and rain per rain day (Fig. 6.3c) show clear positive departures from the mean. In extreme dry years rainfall is uneven over the country and lowest in the dry eastern lowlands.

Seasonal Rainfall Departures from Mean Conditions

Wet early- and late-summer conditions

In both wet early-summer and late-summer conditions the increases in rainfall are characterised by both increased numbers of rain days and rain per rain day (Figures are not shown).

Dry early- and late-summer conditions

As was the case for southern Africa as a whole, in dry summers (both early and late) dry conditions in Swaziland are characterized by considerably decreased numbers of rain days and the amounts of rainfall received per rain day (Fig. 6.4 and 6.5).

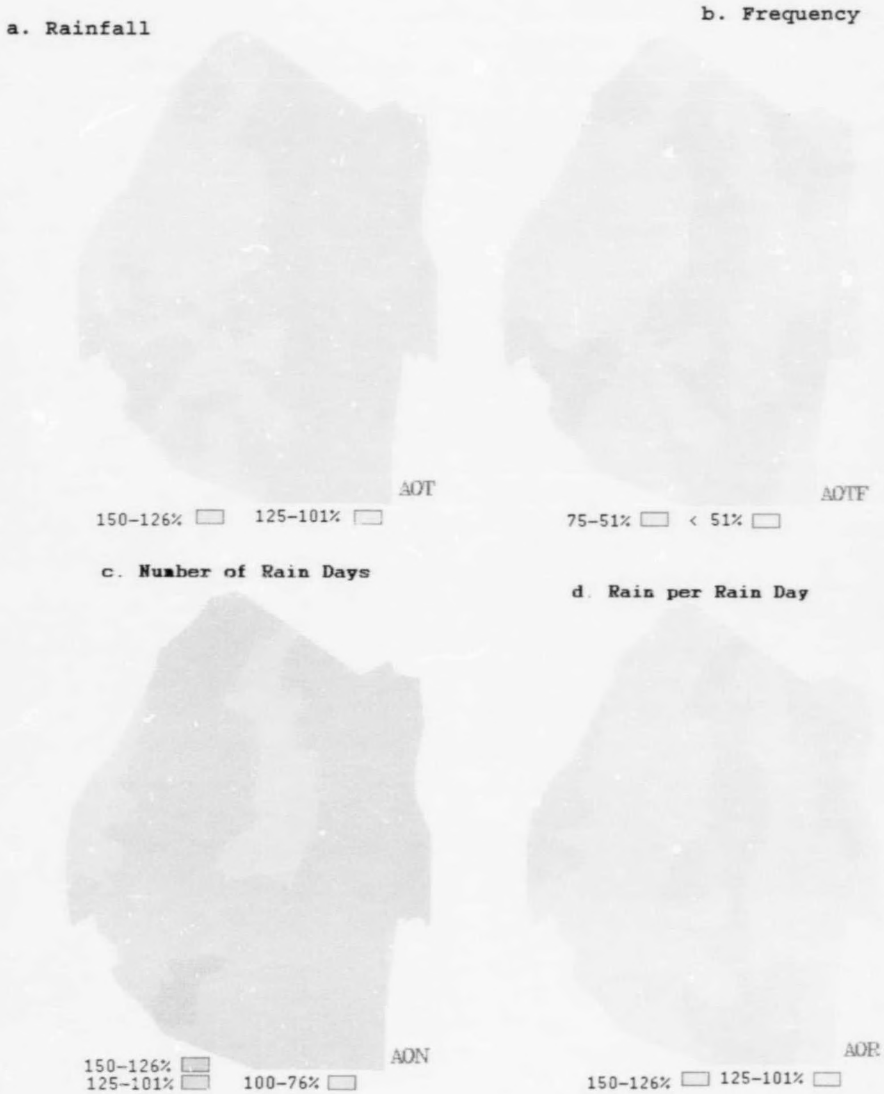

Figure 6.4: Wet early-summer seasons: percentage (a) rainfall, (b) frequency of occurrence, (c) number of rain day, (d) rain per rain day.

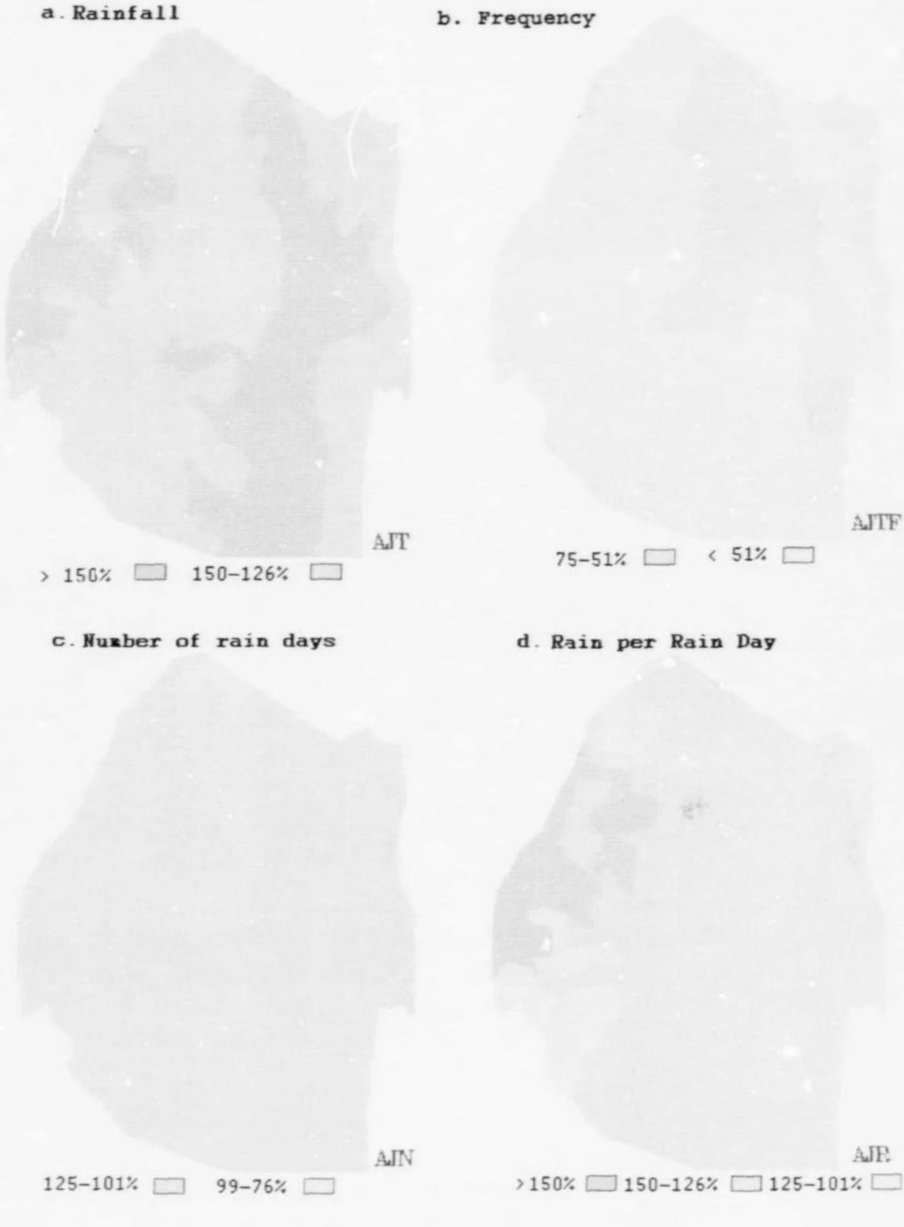

Figure 6.5: Wet late-summer seasons: percentage (a) rainfall, (b) frequency of occurrence, (c) number of rain day, (d) rain per rain day.

Extreme wet and extreme dry early- and late-summer conditions

In extreme years the same relationships that hold for the subcontinent as a whole hold for the Swaziland region. Furthermore, analyses are not needed to make the point and maps showing the distribution characteristics of daily rainfall will not be given.

Chapter 7

Summary and Conclusion

Global rainfall variability has been investigated at a variety of spatial and time scales (Amanatidis *et al.*, 1993; Yu and Neil, 1993; Wildman and Schar, 1997). Furthermore, there is an increasing number of studies based on instrumental records that show the relationships between rainfall amounts, number of rain days and rain per rain day (Lough, 1993; Yu and Neil, 1993; Mitra *et al.*, 1997; Hecht, 1998). Below is a summary of daily rainfall conditions over southern Africa.

In this dissertation the variability of annual and seasonal daily rainfall has been examined in respect of rain days and rainfall on those rain days. The question whether wetter conditions are produced by more rain falling on roughly the same number of rain days in a year or season, or whether as a result of much the same amount of rain falling on more rain days, or as a result of increases in rain days and rain per rain day has been investigated. Furthermore, consideration has been given to the degree of spatial variability associated with changes in the daily rainfall regime. To a much greater detail, the influence of early-summer and late-summer rainfall on annual rainfall trends has been established for the whole subcontinent with emphases on regions characterised by high summer (Sep-Feb) rainfall. Essential to the application of the findings made over the whole subcontinent on a smaller scale, sub-regional daily rainfall variability has been investigated using Swaziland. The findings of the study are clear and may be summarized as follows:

A. Wet and dry years:

1. A strong relationship exists between rainfall, rain days and rain per rain day. Wetter years are due to increases in number of rain days and amount of rain received on those rain days over the whole of southern Africa.

2. In extreme dry years negative departures in the numbers of rain days and rain therein characterize the spatial pattern of daily rainfall.
3. The subcontinent may show differential occurrence of wet and dry conditions in any given year. When most of the summer rainfall region experiences wet conditions, the extreme arid west may be dry. The opposite when the arid and semi-arid regions experience wet conditions.

B. Extreme wet and extreme dry years:

1. Extreme wet years are characterised by even greater positive departures of rain days and rain per rain day from mean.
2. In extreme dry years much greater negative departures in the numbers of rain days and rain therein characterize the spatial pattern of daily rainfall.
3. Largest anomalies are frequently experienced in dry regions than in humid regions of the subcontinent.

C. Summer rainfall:

1. Wet summers, like wet years, experienced increased numbers of rain days and rain per rain day.
2. Decreased number of rain days and amount of rain received on those rain days characterise dry summer seasons.
3. Extreme wet summers experience even greater positive departures in number of rain days and rain per rain day.
4. The subcontinent experiences much greater decreased number of rain days and rain per rain day in extreme dry summers.
5. Rainfall amounts, number of rain days and rain per rain day characterising early-summer seasons are much less than those characterising mid-summer rainfall.

D. Local scale variability:

Rainfall analysis over Swaziland confirms the validity of the findings made over southern Africa as a whole and prove to apply to any other sub-region of the subcontinent. The analysis shows that:

1. Extreme wet years (or wet years or seasons) are due to increased number of rain days and amount of rain experienced on those rain days, rather than due to almost the same amount of rain falling on more rain days or more rain received in almost the same number of rain days.
2. Diminishing number of rain days and amount of rainfall received on those rain days result in dry and extreme dry years or seasons.

Until now, the dependence of wet and dry conditions on changes in daily rainfall characteristics over southern Africa has not been available. No idea of the spatial variability of these characteristics has been presented. It is now clear that annual or seasonal rainfall surplus is effected not by increasing rainfall amount falling on roughly the same number of rain days, nor by much the same number of rain days characterized by higher rainfall received on those rain days, but by greater increase in both variables. A decrease in frequency of rain days and amount of rain received on those rain days leads to rainfall deficiencies over the whole southern African region. This finding holds for time scales of years through seasons to months. It also holds from subcontinental to local spatial scales.

Findings of this study are limited by the lack of statistical spatial analyses of daily rainfall variability, which could determine the level of significance of the relationships between the analyzed rainfall variables. Future daily rainfall analyses should concentrate on providing better understanding of the statistical significance of the findings of this study.

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