RAINFALL ANALYSIS FOR IMPROVED AGRICULTURAL PLANNING

S. ABEYASEKERA*† and C.S. NEMBOU*††

ABSTRACT

It is demonstrated that for a comprehensive analysis of rainfall data to give results of importance in agricultural planning, daily rainfall measurements should be used. Methods of analyses are described and illustrated using daily rainfall records for 30 years from Madang.

INTRODUCTION

In a recent paper (Abeyasekera 1987), a classification of 300 rainfall stations around Papua New Guinea was made in an attempt to provide a basis on which particular stations could be selected for further study of their rainfall patterns. Sixteen clusters of rainfall stations were identified such that patterns of rainfall were similar within clusters and different between clusters. In this paper, a single station from one of the cluster groups has been selected to demonstrate the type of analysis that is possible in order to answer important questions relating to agriculture, such as the commencement and length of the rainy season, the distribution of rainfall throughout the year and the risk of dry spells.

Related studies have been carried out by McAlpine *et al.* (1975 and 1983) and Short (1970), where the percentile distributions of rainfall amounts and a few other descriptive measures have been produced on a monthly basis. However, these have the severe drawback that they do not provide flexibility for varying the period of interest to a period other than monthly. This limits the study of the pattern of rainfall over the growing season or over the harvesting season of a crop. With access to daily rainfall records however, it is possible to obtain results of agricultural importance for any particular period in the year, and this is the subject of this paper.

* University of Papua New Guinea, N.C.D., Papua New Guinea.

† Present address: Department of Applied Statistics, University of Reading, Reading RG6 2AN, England.

†† Present address: Industrial Engineering Department, University of New South Wales, P.O. Box 1, Kensington 2033, New South Wales, Australia.

MATERIALS

Daily rainfall records from 54 stations were obtained, on magnetic tape, for the period from 1956 to 1970, from the Division of Water and Land Resources at CSIRO in Australia (see Appendix). These had been collected as part of a larger study of the climate and water resources of Papua New Guinea, the results of which have been reported by McAlpine *et al.* (1983). Daily rainfall records for the period from 1971 to 1985 were obtained from the National Weather Office in Port Moresby for 10 stations (listed in the Appendix) and computerised. Rainfall records for eight of these stations were also available on the tape provided by CSIRO.

For these stations, it was thus possible to combine the 1956 to 1970 data with the 1971 to 1985 data.

One station, Madang, having a rainfall record from 1956 to 1985, was selected for analysis. This station is located at a latitude and longitude of 5°13'S and 145°47' respectively and at an elevation of 4 metres above mean sea level. It has an annual rainfall varying from 2000 mm to 4000 mm with a heavy rainfall season occurring in the period from October to April (see Figure 1).

The software needed for the analysis has been developed by the Tropical Agricultural Meteorology Group at Reading University in the United Kingdom. This software was implemented on the Prime Computer at the University of Papua New Guinea (UPNG) by the first author.

METHODS

The statistical methodology applied in this paper is the direct method of analysis developed by Stern *et al.* (1982). The distinctive feature of this method is that for any event or characteristic of interest, each year of data provides just one number. Thus if N years of data are available and the rainfall total for a particular week is of interest, the N years would provide N rainfall totals for that week. These observations are then treated as a random sample of observations from the population of weekly totals for that week of the year. Estimates of the probability of an event can then be found, either directly from the relative frequency of occurrence or by fitting a suitable distribution to the sample values.

In this paper the application of the direct approach will be demonstrated.

RESULTS

The software for an analysis by the direct method derives information on the rainfall characteristics of interest by coding the days of the year from day 1 to day 366 (February 29th is given a zero rainfall for non-leap years) and requesting the relevant information for a specified period from day n1 to day n2 within the year. The possible analyses are described below and illustrated using the Madang rainfall data.

Amounts of rain within a period

In agroclimatic analyses, a common practice is to sum rainfall totals over periods of seven or ten days or over months, and use the totals, one from each year, to estimate the amounts of rain that can be expected, at given probability levels. If for example, the first 10 days in September are of interest (this is day 245 to day 254 inclusive), then the rainfall totals over these 10 days for each year of the record can be ordered to give empirically the 80th percentile, for example, as 58 mm. This means that the probability of receiving more than 58 mm rain in the first 10 days of September is estimated as 0.2.

An alternative approach is to fit a distribution to the rainfall totals. When periods of a month or longer are considered, rainfall totals are often found to be approximately normally distributed. A histogram of totals for January in Madang (Figure 2) shows that this is likely to be the case here. Properties of the normal distribution then provide an estimate of the 80th percentile as 437.2 mm, whereas the empirical method of ordering totals gives the percentile as 430 mm. This shows good agreement between the two methods.

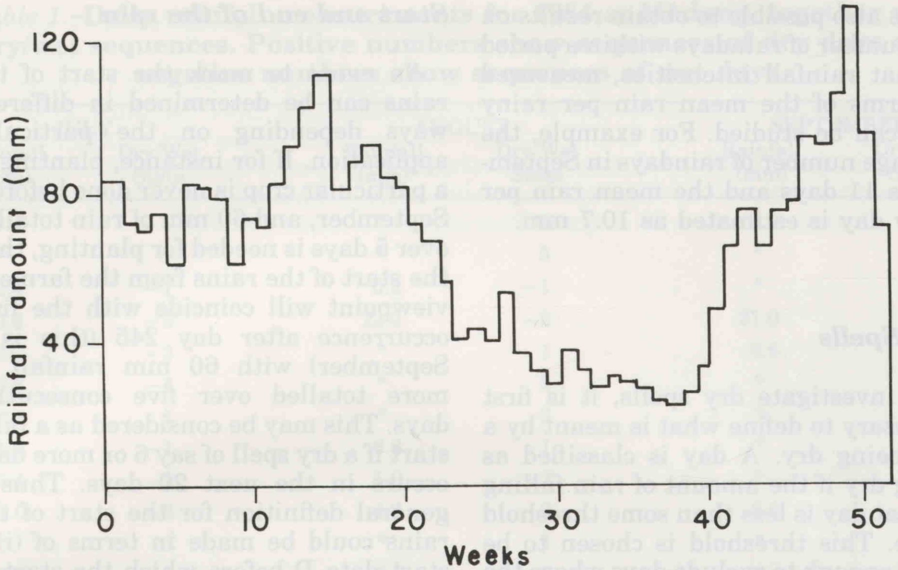


Figure 1.–**Distribution of average weekly rainfall amounts at Madang, from the first week of January to the last week of December.**

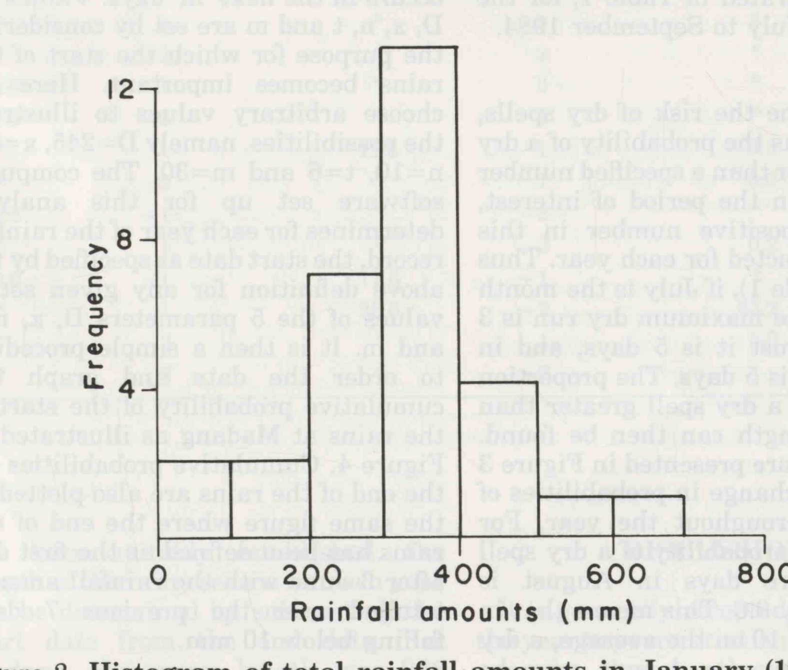


Figure 2.–**Histogram of total rainfall amounts in January (1956–1985) at Madang.**

It is also possible to obtain results on the number of raindays within a period so that rainfall intensities, measured in terms of the mean rain per rainy day, can be studied. For example, the average number of raindays in September is 11 days and the mean rain per rainy day is estimated as 10.7 mm.

Dry Spells

To investigate dry spells, it is first necessary to define what is meant by a day being dry. A day is classified as being dry if the amount of rain falling on that day is less than some threshold value. This threshold is chosen to be large enough to exclude days where the rainfall is so minimal as to be agriculturally insignificant. The choice depends on the crop-water requirements. In this analysis, a threshold value of 0.01 mm was arbitrarily chosen, and the daily observations then recoded as sequences of wet and dry days as illustrated in Table 1, for the period from July to September 1984.

To determine the risk of dry spells, defined here as the probability of a dry spell of greater than a specified number of days within the period of interest, the largest positive number in this period is extracted for each year. Thus for 1984 (Table 1), if July is the month of interest, the maximum dry run is 3 days. In August it is 5 days, and in September it is 5 days. The proportion of years with a dry spell greater than any given length can then be found. Some results are presented in Figure 3 showing the change in probabilities of dry spells throughout the year. For example, the probability of a dry spell of 7 or more days in August is approximately 0.6. This means that in 6 years out of 10 on the average, a dry spell of 7 days or longer may be expected during August.

Start and end of the rain

An event to mark the start of the rains can be determined in different ways depending on the particular application. If for instance, planting of a particular crop is never done before 1 September, and 60 mm of rain totalled over 5 days is needed for planting, then the start of the rains from the farmers' viewpoint will coincide with the first occurrence after day 245 (this is 1 September) with 60 mm rainfall or more totalled over five consecutive days. This may be considered as a false start if a dry spell of say 6 or more days occurs in the next 20 days. Thus a general definition for the start of the rains could be made in terms of (i) a start date D before which the start of the season is not considered, (ii) an event E, indicating a potential start date as the first occurrence of at least 'x' mm of rainfall totalled over 'n' consecutive days, and where (iii) the potential start is considered a false start if a dry spell of 't' or more days occurs in the next 'm' days. Values for D, x, n, t and m are set by considering the purpose for which the start of the rains becomes important. Here we choose arbitrary values to illustrate the possibilities, namely D=245, x=60, n=10, t=6 and m=30. The computer software set up for this analysis determines for each year of the rainfall record, the start date as specified by the above definition for any given set of values of the 5 parameters D, x, n, t and m. It is then a simple procedure to order the data and graph the cumulative probability of the start of the rains at Madang as illustrated in Figure 4. Cumulative probabilities for the end of the rains are also plotted in the same figure where the end of the rains has been defined as the first day after 3 June with the rainfall amount totalled over the previous 7 days falling below 10 mm.

Once the start and end of the rains

Table 1.–**Daily rainfall measurements for 1984 at Madang, together with dry/wet sequences. Positive numbers show sequences of dry days and negative numbers show sequences of wet days.**

JULY		AUGUST		SEPTEMBER	
Rainfall (mm)	Dry/Wet State	Rainfall (mm)	Dry/Wet State	Rainfall (mm)	Dry/Wet State
0.4	−1	*	4	2.0	1
*	1	*	5	*	1
2.4	−1	0.2	−1	*	2
0.6	−2	22.2	−2	21.0	−1
2.0	−3	*	1	0.6	−2
0.8	−4	*	2	*	1
*	1	*	3	*	2
1.8	−1	6.8	−1	*	3
0.4	−2	1.0	−2	*	4
1.0	−3	4.6	−3	5.6	−1
*	1	*	1	*	1
0.2	−1	*	2	*	2
*	1	*	3	21.8	−1
*	2	0.2	−1	*	1
9.6	−1	*	1	4.6	−1
*	1	0.8	−1	0.2	−2
1.2	−1	*	1	23.6	−3
*	1	21.8	−1	49.2	−4
8.8	−1	4.6	−2	*	1
*	1	*	1	*	2
*	2	*	2	*	3
5.6	−1	*	3	*	4
1.0	−2	*	4	*	5
*	1	11.8	−1	3.0	−1
*	2	*	1	3.0	−2
0.4	−1	*	2	*	1
*	1	*	3	0.2	−1
10.0	−1	17.6	−1	*	1
*	1	26.6	−2	33.2	−1
*	2	*	1	5.0	−2
*	3	*	2		

has been suitably established, the length of the rainy season for each year can be determined by subtracting the start date from the end date. For Madang, the mean length was 266 days.

DISCUSSION

It is generally accepted that much of the year to year variation in crop yields may be due to the variability of rainfall. The results presented here

Figure 3.–**Probability of dry spells in 30-day periods, estimated as the observed proportion of years in which a dry spell of at least 4, 7 and 10 days occurred in the 30 days following each date plotted.**

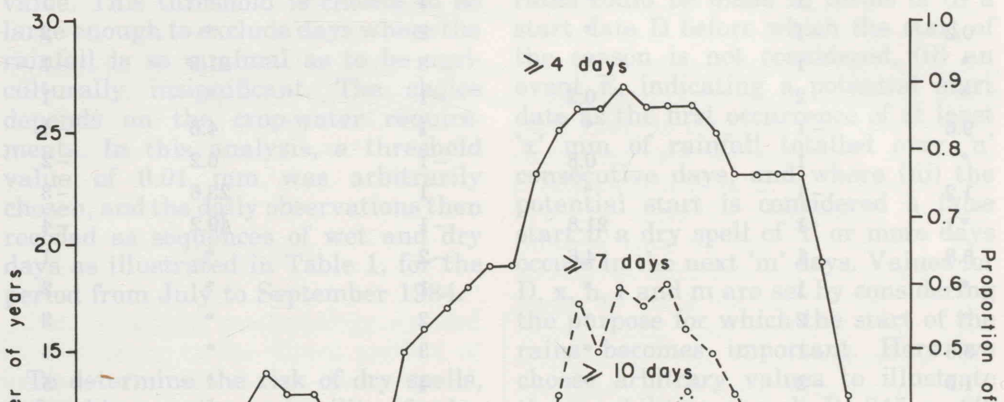
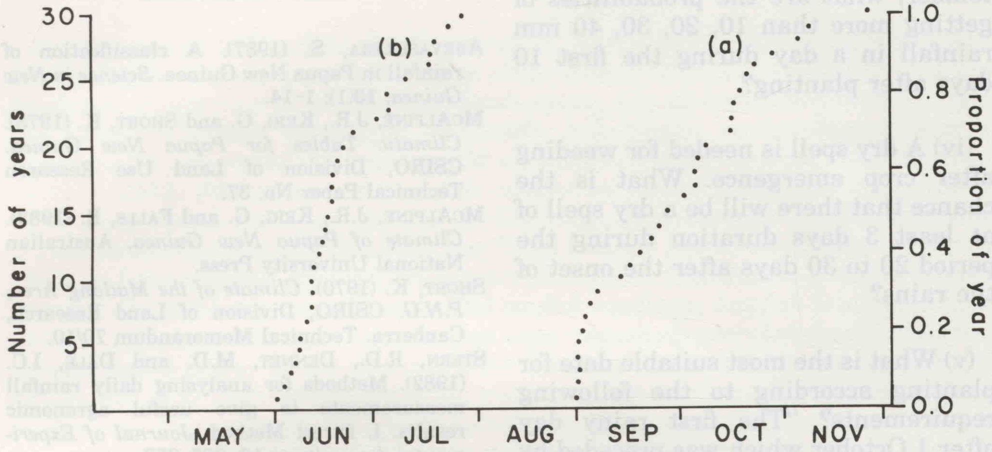


Figure 4.–**Cumulative probability of the start and end of the rains at Madang.**
(a) Start of the rains: First day after 1 September with rainfall of 60 mm or more totalled over 10 consecutive days, but with no dry spell of 6 or more days in the next 30 days.
(b) End of the rains: First day after 3 June with less than 10 mm of rain totalled over the previous 7 days.



show that many questions of agricultural importance can be studied through a comprehensive analysis of daily rainfall measurements. At least this level of detail is required to investigate many aspects of the distribution of rainfall at a site, particularly in relation to the risk of dry spells and the start and end of the rainy season. The latter is clearly of importance when a suitable planting date is to be determined for a particular crop. Farmers often plant their crops with the onset of the rains, but they should be made aware of the risks involved in planting at particular times of the year. An adequate definition for the start of the rains in terms of the crop-water requirements will allow the farmer to plant his crop at a time when the risk of inadequate rain during the initial stages of crop growth is minimal.

One prerequisite however is for agricultural researchers to appreciate the wide range of questions that can be answered, and phrase such questions precisely. Some possiblities are given below.

(i) What is the average date for the beginning of the rainy season? This event is defined as the first day after 15 October that rainfall reached 50 mm totalled over 5 consecutive days. What is the probability that this event will occur 5, 10, 15 or 20 days earlier or later than this average date?

(ii) What is the average date for the end of the rains? This is defined as the first day after 1 April with less than 20 mm rainfall totalled over 5 days, and remaining below 10 mm in the next 2 days. What is the probability that the end date will occur 5, 10 or 15 days earlier or later than the average date?

(iii) If planting is done on 1 September, what are the probabilities of getting more than 10, 20, 30, 40 mm rainfall in a day during the first 10 days after planting?

(iv) A dry spell is needed for weeding after crop emergence. What is the chance that there will be a dry spell of at least 3 days duration during the period 20 to 30 days after the onset of the rains?

(v) What is the most suitable date for planting according to the following requirements? "The first rainy day after 1 October which was preceded by 3 consecutive days having a total of more than 40 mm of rain with (a) no dry spell of 5 or more days in the next 20 days, and (b) no dry spell of 2 or more days in the flowering period from 20 October to 30 October."

These illustrate some of the questions that can be answered with access to daily rainfall records and using the computing software that has been set up on the UPNG computer. The daily records from 1956–1970 for stations listed in the Appendix are also available, and results of the type presented in this paper can be produced for interested researchers on provision of the daily records for the post 1971 period.

ACKNOWLEDGEMENTS

We sincerely thank J.R. McAlpine and his team at CSIRO, Australia, for the supply of computerised daily rainfall records, and the Tropical Agricultural Meteorology group at Reading University, United Kingdom, for supplying the software to pick specific rainfall events. Thanks are also due to the National Weather Office in Port Moresby for allowing access to their rainfall records.

REFERENCES

ABEYASEKERA, S. (1987). A classification of rainfall in Papua New Guinea. *Science in New Guinea*, **13**(1): 1–14.

MCALPINE, J.R., KEIG, G. and SHORT, K. (1975). *Climatic Tables for Papua New Guinea.* CSIRO, Division of Land Use Research Technical Paper No. 37.

MCALPINE, J.R., KEIG, G. and FALLS, R. (1983). *Climate of Papua New Guinea.* Australian National University Press.

SHORT, K. (1970). *Climate of the Madang Area, P.N.G.* CSIRO, Division of Land Research, Canberra. Technical Memorandum 70/10.

STERN, R.D., DENNET, M.D. and DALE, I.C. (1982). Methods for analysing daily rainfall measurements to give useful agronomic results. I. Direct Method. *Journal of Experimental Agriculture*, **18**: 237–253.

APPENDIX

(a) Stations for which computerised daily rainfall records are available from 1956 to 1970.

1. AIOME	19. FINSCHAFFEN
2. AITAPE	20. GARAINA
3. AIYURA	21. GIZARUM
4. AMBUNTI	22. GOROKA
5. ANGORUM	23. HENGANOFI
6. AWELKON	24. ITIKINUMU
7. BAINYIK	25. KAIAPIT
8. BAIYER RIVER	26. KAVIENG
9. BANIARA	27. KANDRIAN
10. BAMU	28. KEREMA
11. BEREINA	29. KIKORI
12. BOGIA	30. KIUNGA
13. BULOLO	31. LAE
14. BWAGAOIA	32. LUMI
15. DARU	33. MADANG
16. DOGURA	34. MENDI
17. ERAP	35. MENYAMYA
18. ERAVE	36. MINJ

37. MOMOTE
38. MT. HAGEN
39. NAMATANAI
40. POMIO
41. POPONDETTA
42. PT. MORESBY
43. RABAUL
44. SAIDOR
45. SAMARAI
46. SOHANO
47. TAPINI
48. TARI
49. TIMBUNKI
50. TUFI
51. VANIMO
52. WABAG
53. WAU
54. WEWAK

(b) Stations for which computerised daily rainfall records are available from 1971 to 1985.

1. ERAVE
2. JINJO
3. KAVIENG
4. KIETA
5. LAE
6. MADANG
7. MOMOTE
8. PT. MORESBY
9. RABAUL
10. VANIMO