A REVIEW OF RAINFALL DATA FROM THE IRANIAN PROVINCE OF SISTAN AND BALOCHISTAN

M. J. Marriott and M. A. Zainudini
Built Environment Research Group
m.j.marriott@uel.ac.uk

Abstract: This paper reviews rainfall data obtained by the second author in the course of research for his MRes dissertation. Comparisons are made between information from Sistan and Balochistan, and with other published data from Oman, which are seen to follow a similar monthly distribution. Statistical analysis of the data indicates that the log-normal distribution is generally suitable for representing the annual totals of rainfall, but that the monthly totals are better represented using the Gumbel extreme value distribution. It is indicated that the monthly data are relevant to water resources considerations, and it is recommended that for flood alleviation purposes more frequent data from autographic or recording rain gauges should be sought.

1. Introduction

The area of the study is the province of Sistan and Balochistan in south east Iran, near the border with Pakistan. Data was obtained by the second author from the Water Resources Department of the Islamic Republic of Iran Meteorological Organisation (IRIMO). The capital of the province is the city of Zahedan, with the port of Chahbahar to the south on the northern coast of the Gulf of Oman. Figure 1 provides a location plan. The climate of the region is arid, with low annual rainfall on the plains of Sistan and Balochistan. Snow melt from the mountains to the north accounts for much of the river runoff.

2. Initial analysis

2.1. Annual totals

The three data sources in Table 1 show the average annual total rainfall to be of the order of 100 mm. These sources each cover over 30 years of data; some additional shorter records also showed similar totals, but have not been included in this paper. To put this in context, the UK long term average rainfall is around 1000 mm, ranging from less than 500 mm in parts of south east Essex, to over 2500 mm in western parts of Scotland, Wales and Ireland. This illustrates the arid climate of the region under study, and the following section will also show the considerable variability throughout the year.

2.2. Monthly totals

Tables 2, 3 and 4 summarise monthly data from the three sources. In analysing this data it was assumed that zero entries were genuine readings, but blanks represented missing readings. The full data are listed elsewhere (Zainudini, 2006). Table 5 has been included for comparison from Muscat, Oman (Wheater and Bell, 1983). The monthly average totals are illustrated in Figures 2, 3, 4 and 5, which show similar patterns of low rainfall from April to November, and higher totals in December, January, February and March. This pattern could be said to lie between subtropical (e.g. Aden) and Mediterranean (e.g. Athens) in the global precipitation regimes quoted by Shaw (1994) after Pettersen.

3. More detailed analysis

3.1. Probability distributions

It is useful to fit a probability distribution to data in order to enable further analysis. Guide rules suggested by Hardison (Twort et al., 2001, p.92) may be summarised as follows:

- use the normal distribution if the coefficient of variation is less than 0.25.
- use the log-normal distribution if the coefficient of skew is algebraically greater than 0.2.
- try the Gumbel distribution if neither of the above proves to be satisfactory.

The coefficient of variation is the value of the standard deviation divided by the mean. The coefficient of skew is the third moment divided by the cube of standard deviation, calculated here by Excel for a sample.

For UK rainfall, Shaw (1994, p.224) showed that annual totals are normally distributed but monthly totals are positively skewed. The log-normal distribution was recommended for monthly totals, either taking all months together, or treating totals from particular months separately. Shaw (1994, p.222) conceded that frequency analysis is more straightforward where precipitation occurs all the year round, and recommended that for highly seasonal rains it may be advisable to omit consideration of dry months. Mansell (2003, p.73) advocated the log-normal distribution for many skewed hydrological time-series. Where the observations are of extreme maximum values, he suggested using the Gumbel distribution or the Poisson distribution. Wheater and Bell (1983) used Gumbel for analysing short duration rainfall (24 hours down to 15 minutes). The first author is familiar with this approach for analysis of annual maximum flood flows (see for example Wilson (1990) for River Thames data analysed in this way), and also with applications of Poisson (Marriott, 2002).

3.2. Annual totals

It is apparent from Table 1 that the values of coefficient of variation are greater than appropriate for the normal distribution, and the positive values of the coefficient of skew suggest use of the log-normal distribution. When the logarithms of the annual totals are considered, as shown in Table 6, the coefficients of variation all reduce to less than 0.2, and the coefficient of skew values are reduced. The coefficient of skew values for Chahbahar and Balochistan are close to zero, but the Sistan logarithmic data shows a strong negative skew. For Chahbahar and Balochistan, the logarithmic values plotted reasonably linearly on normal probability paper, but the Sistan data produced a distinct curve. Chi squared tests confirmed that the log normal distribution was appropriate for the Chahbahar and Balochistan data, but that the Sistan data showed differences between observed and expected frequencies that were significant at around the 5% level, but were not significant at the 1% level. This indicates a less than perfect fit, but one that may be sufficient for practical purposes. In conclusion therefore the log-normal distribution appears generally suitably for annual data. It is noted that the Gumbel extreme value distribution also performed satisfactorily for all three data sets with correlation coefficients of R^2 = 0.87, 0.96 and 0.97 respectively.

3.3 Monthly totals

It may be seen from Tables 2, 3 and 4 that the high coefficient of variation and coefficient of skew values suggest that the log-normal would be more appropriate than the normal distribution. However, it is also apparent that every month includes entries with zero rainfall recorded, and examination of the full data shows that around half of the monthly entries indicated zero rainfall, rather more in the case of Chahbahar. Some entries are blank, for example around the time of the Iranian revolution, and these have been omitted, which accounts for some differences in the numbers of years of data for different months.

The dry months of April to November do not lend themselves to this type of analysis, as the majority of entries are zero. The wetter months also have the problem of several zero values, which when included in the logarithmic data do not facilitate analysis. The logarithmic data also did not plot particularly linearly on normal probability paper. The Gumbel extreme value distribution was therefore tried, and found to perform better in this context. An example is shown in Figure 6 of the Chahbahar January data. Note that a slightly different formula for the trendline was produced by the method of moments. Reasonable results were also obtained by this method for February, March and December (R^2 values of 0.85, 0.85 and 0.77 respectively), but not for the dryer months.

4. Data for different purposes

Having discussed the data in detail, it is worth reflecting on the use for this data, and also to consider the data requirements for other purposes too.

The monthly totals, and the calculations in the previous section, are clearly more relevant to water resources purposes than to flood alleviation calculations, although months with particularly high totals may well corresponded with times of flooding.

Monthly data may be used to predict the likely future levels of reservoirs such as those formed by dams fed by natural catchments. Monthly data is derived from daily records. Depending on the size of the catchment and its time of concentration, daily rainfall data may be of use when considering flood alleviation, but shorter duration data would be much more useful for this purpose. For the Oman flood study (Wheater and Bell, 1983), durations down to 15 minutes were used to undertake a rainfall intensity-duration-frequency analysis. To obtain such shorter duration data requires recording or autographic devices such as the tipping or tilting bucket raingauge (for details see for example Shaw (1994) or Mansell (2003)).

It should be mentioned that the analysis for this paper assumes that the time series data is stationary, with no consideration of long term trends. Another use of long term hydrological data could be to investigate such effects, either due to local causes such as urbanisation, or wider issues such as global warming.

5. Conclusions

The monthly rainfall data that have been obtained give a realistic description of the arid climate in Balochistan, and clearly illustrate the times of the year when rainfall is more or less likely. It is concluded that the log-normal distribution may be used to analyse annual data, but that the Gumbel extreme value distribution is preferable for monthly data from the wet months. The dry months are not amenable to this type of analysis.

It is also concluded that if progress is to be made with flood study work, or with analysis of rainfall information for flood alleviation purposes, then shorter duration data would need to be sought.

6. References

Mansell M.G., *Rural and Urban Hydrology,* Thomas Telford, London, 2003.

Marriott M.J., "Probability of Flooding", *The Mathematical Gazette,* Volume 86, Number 507, Note 86.81, November 2002, pp.506-509.

Shaw E.M., *Hydrology in Practice,* third edition, Chapman & Hall, 1994.

Twort A.C., Ratnayaka D.D., Brandt M.J., *Water Supply,* fifth edition, Arnold 2000, reprinted by Butterworth-Heinemann, 2001.

Wheater H.S., Bell N.C., "Northern Oman flood study", *Proceedings of the Institution of Civil Engineers,* Part 2, Volume 75, September 1983, pp.453-473.

Wilson E.M., *Engineering Hydrology,* fourth edition, Macmillan, 1990

Zainudini M.A., *MRes Dissertation (in preparation),* University of East London, 2006.

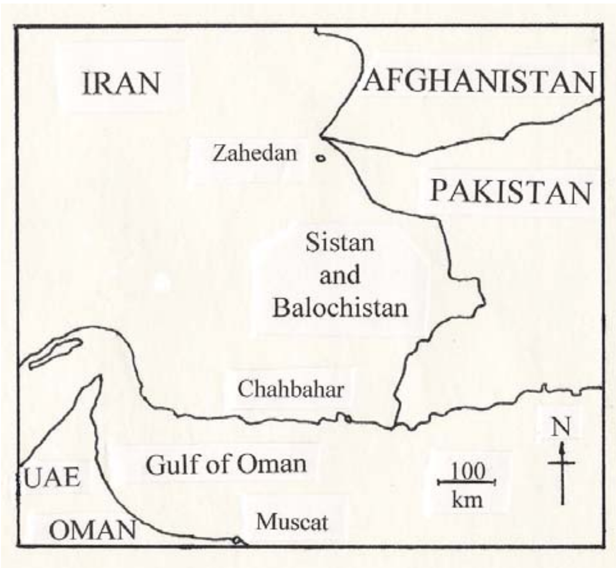

Figure 1: Location plan

Location	Period	Full data years	Annual rainfall / mm					
			max.	min.	Mean	standard deviation	coeff. of variation	coeff. of skew
Chahbahar	1963-2000	33	538.8	19.2	118.3	102.3	0.9	2.6
Balochistan	1951-2000	50	196.1	33.6	94.5	44.4	0.5	0.5
Sistan	1964-2000	37	285.8	4.6	111.7	59.2	0.5	0.5

Table 1: Annual total rainfall data

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Years of data	35	35	35	36	36	36	37	36	36	35	34	33
Maximum/mm	95.2	196.6	89.3	44.4	1.0	10.0	51.0	24.0	29.0	166.6	57.8	158.9
Minimum/mm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean/mm	27.3	27.2	16.9	4.3	0.1	0.4	5.6	1.9	0.8	4.8	5.0	20.9
St.deviation/mm	27.7	44.1	25.3	11.0	0.2	1.7	13.1	4.9	4.8	28.2	12.1	39.6
Coeff. of variation	1.0	1.6	1.5	2.6	4.2	4.3	2.3	2.6	5.9	5.9	2.4	1.9
Coefficient of skew	0.9	2.4	2.0	3.0	4.1	5.4	2.6	3.4	6.0	5.9	3.2	2.5

Table 2: Monthly total rainfall data from Chahbahar

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Years of data	50	50	50	50	50	50	50	50	50	50	50	50
Maximum/mm	90.1	79.1	114.1	56.0	28.0	7.0	26.0	15.4	2.0	38.0	42.4	85.4
Minimum/mm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean/mm	22.9	18.4	17.0	11.9	4.7	0.5	1.5	0.6	0.1	2.6	4.1	10.2
St.deviation/mm	21.0	19.1	19.7	13.7	7.8	1.3	5.3	2.8	0.4	7.4	9.2	16.3
Coeff. of variation	0.9	1.0	1.2	1.1	1.6	2.8	3.4	5.0	3.4	2.9	2.3	1.6
Coefficient of skew	1.0	1.3	3.0	1.3	1.7	3.7	3.9	4.9	3.5	3.6	3.4	3.4

Table 3: Monthly Rainfall data from Balochistan

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Years of data	37	37	37	37	37	37	37	37	37	37	37	37
Maximum/mm	85.1	80.6	150.8	32.4	21.6	27.0	82.2	32.0	34.0	31.0	19.0	85.9
Minimum/mm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean/mm	21.7	22.4	20.3	5.6	1.9	3.1	12.1	5.0	1.3	2.2	1.8	14.2
St.deviation/mm	21.5	24.1	29.3	7.9	5.1	6.5	19.3	8.7	5.7	7.0	4.7	21.3
Coeff. of variation	1.0	1.1	1.4	1.4	2.7	2.1	1.6	1.7	4.6	3.2	2.6	1.5
Coefficient of skew	1.1	1.1	2.8	1.6	3.0	2.8	2.0	2.0	5.5	3.5	2.9	2.3

Table 4: Monthly Rainfall data from Sistan

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Years of data	63	64	62	63	61	61	60	61	61	60	61	60
Maximum/mm	143.0	98.6	70.4	98.3	8.9	64.0	37.1	14.7	0.0	44.5	77.2	171.2
Mean/mm	31.2	19.1	13.1	8.0	0.4	1.3	1.0	0.4	0.0	2.3	7.2	22.0
St.deviation/mm	38.9	25.1	18.9	20.3	1.4	8.3	4.9	2.1	0.0	7.6	15.1	35.1
Coeff. of variation	1.3	1.3	1.4	2.5	3.7	6.3	5.1	4.6	0.0	3.3	2.1	1.6

Table 5: Monthly Rainfall data from Muscat (after Wheater and Bell, 1983)

Location	Period	Complete years	Natural logarithm of annual rainfall / mm					
			maximum	minimum	mean	standard deviation	coefficient of variation	coeff. of skew
Chahbahar	1963-2000	33	6.289	2.955	4.504	0.738	0.16	0.08
Balochistan	1951-2000	50	5.279	3.515	4.434	0.493	0.11	-0.13
Sistan	1964-2000	37	5.655	1.526	4.508	0.785	0.17	-1.86

Table 6: Natural logarithms of annual total rainfall data

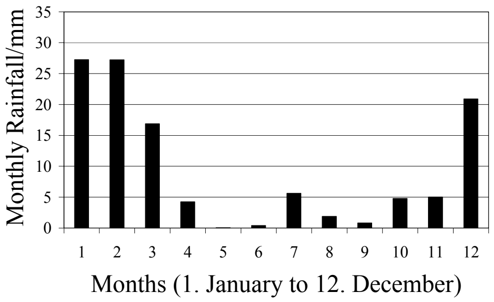

Figure 2: Chahbahar monthly mean rainfall totals

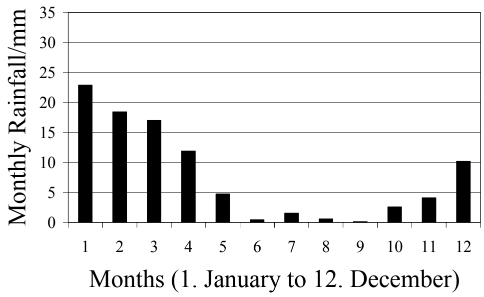

Figure 3: Balochistan monthly mean rainfall totals

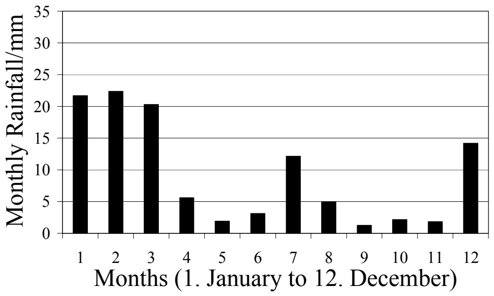

Figure 4: Sistan monthly mean rainfall totals

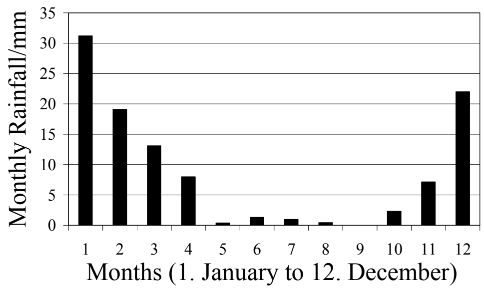

Figure 5: Muscat monthly mean rainfall totals

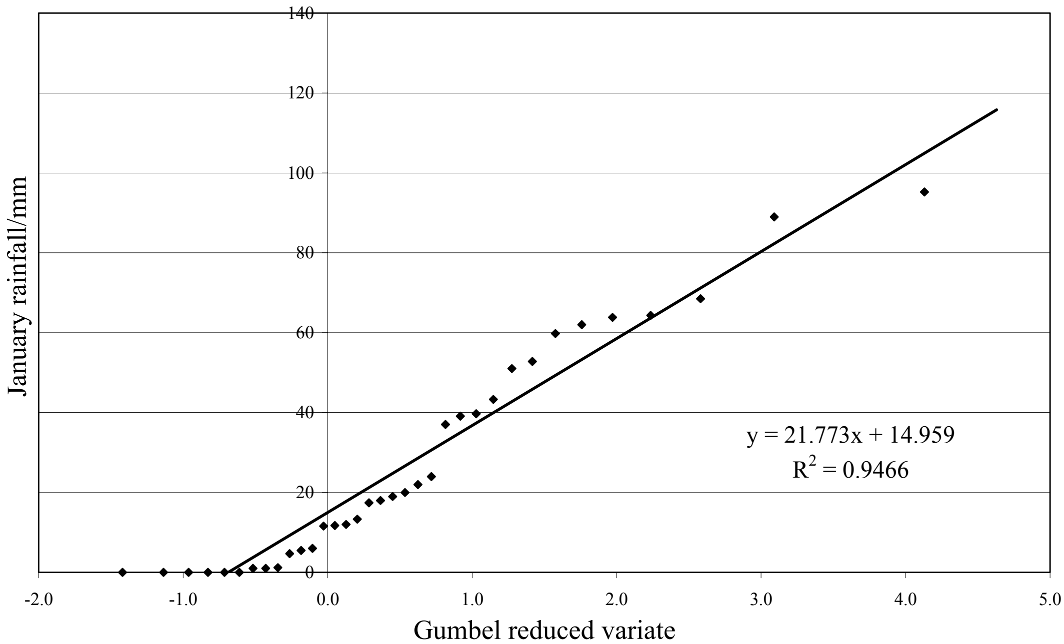

Figure 6: Chahbahar January data