The Importance of Rainfall in Water Resources and Agriculture

Rainfall is the fundamental driving force and pulsar input behind most hydrological processes. Since it is temporally and spatially the most variable hydrological element, an accurate estimate of gauged rainfall at a point and areal rainfall over a catchment is a basic requirement in rainfall-runoff as well as crop yield models.

In hydrology, a fundamental truism is that the rainfall-runoff process is non-linear (Figures 6.1.1 and 6.1.2), with a larger proportion of rainfall being converted to runoff as a catchment becomes wetter. This process is illustrated in Figure 6.1.1, where observed mean annual runoff (MAR) is plotted against mean annual precipitation (MAP) for catchments in Gauteng, Mpumalanga, Limpopo and KwaZulu-Natal. Similarly, the non-linear rainfall-runoff relationship is illustrated in Figure 6.1.2 for discrete one day stormflow producing rainfall events on different land uses using the SCS model (Schulze et al., 1993). Hydrological models are thus particularly sensitive to the rainfall input and any errors in rainfall estimates are amplified in streamflow simulations (Figure 6.1.2, bottom table). This implies that the success of hydrological simulation studies depends to a large extent on the precision with which the rainfall data are observed temporally and expressed spatially.

In agriculture, among the various individual climatic parameters which influence the growth characteristics of crops, certainly in South Africa, the most important is considered to be water. Limitations in water availability are frequently a restrictive factor in plant development, and water is essential for the maintenance of physiological and chemical processes within the plant, acting as an energy exchanger and carrier of nutrient food supply in solution. In any regional study of agricultural production rainfall is, therefore, of fundamental importance. Focus is invariably on the patterns of rainfall in time and over an area, by asking initially...
Section 6.1  Rainfall:  Background

- how much it rains,
- where it rains (its spatial distribution),
- when it rains (its seasonal distribution),
- how frequently it rains, and
- what the duration and intensity of rainfall events are.

In their analyses of rainfall, however, the concerns of both farmers and water resource managers go further, since they need to consider also

- how variable the rainfall is from year to year, or for a given month,
- and
- how frequently droughts of a certain level of severity are likely to recur.

The reservoir of water from which crops draw their moisture supply through the soil is derived mainly in the form of rainfall, with relatively minor contributions in South Africa from dew, fog and snow. Not all rainfall is, however, freely available to the crop through the soil, as some is intercepted by the plant before reaching the soil, part enters streams as stormflow after rainfall events (without being utilised by plants), some percolates into the deeper soil layers beyond the root zones and a portion is evaporated directly from the soil surface without being transpired through the plant.

While hydrological models (such as the ACRU model; Schulze, 1995) have become increasingly more complex and can reach high levels of computational sophistication in that many catchment physical processes can be portrayed reasonably realistically, the same does not apply to the sampling and processing of the rainfall input that "drives" the model.

Because of the sensitivity of streamflow, and to a lesser extent crop yields, to rainfall, this Section contains discussions on those aspects of rainfall to which important consideration has to be given in order to expect realistic results when applying an agrohydrological model such as ACRU. Aspects discussed therefore include:

- problems associated with rainfall estimation at a point,
- considerations regarding the spatial distribution of rainfall over a catchment,
- the question of the minimum rainfall record length required for agrohydrological modelling,
- missing rainfall records and approaches to infilling missing data,
- a suggested technique for estimating areal rainfall over a catchment, and
- sources of rainfall data and information in southern Africa.

Problems Associated with Rainfall Estimation at a Point

1. Background

The measurement of rainfall is a simple procedure provided that accuracy is not essential, as an exact measurement of rainfall is impossible to obtain owing to the random and systematic errors which occur in measuring rainfall (Schultz, 1985). As no “true rainfall amount” can be achieved, one can only attempt to improve the estimation of rainfall amounts by minimising the known errors, which are the systematic errors that are associated with the raingauge used to measure rainfall amounts.

Considerable deficiencies in raingauge measurement remain a problem and point underestimations of 20% occur frequently, with the conversion of point to areal rainfall resulting in further possible errors of between 10% and 20%, which may increase to 60% in mountainous areas (cf. review in Schulze, 1995). The fact that a majority of raingauges are usually found at lower elevations of a catchment also generally leads to an underestimation of the areal rainfall; hence errors related to raingauge networks are likely to increase the underestimation rather than cancelling it out. In order to stress the importance of the rainfall input into agrohydrological models, the accuracy of point measurement of rainfall is therefore elaborated upon below.

Rainfall measurements were recorded for taxation purposes in India as early as 400 BC and, since its inception, both the principles and the purpose of rainfall measurement have remained essentially unchanged (Ward, 1975).

In order to obtain rainfall data the rainfall needs to be measured. Rainfall measurements can be undertaken by numerous different methods. The most common method is the use of a standard daily non-recording
raingauge, but estimation by radar and satellite is practised as well. While radar and satellite imaging for rainfall estimates are able to provide real time, areal estimates of rainfall values, the primary source of rainfall data is still provided by the raingauge. This is so mainly because raingauges are cheap and generally reliable. Raingauge data are also available for longer time periods, which is advantageous in many respects.

2. What Sample is Actually Measured by a Standard South African Raingauge?

The actual sample of measured rainfall is minute. A standard South African 127 mm diameter raingauge, for example, takes a $0.0000001267$ sample per km$^2$. Except in very few (usually research) areas, raingauge networks of that density do not exist. What is, therefore, being sampled as the primary input into agrohydrological models is a minute fraction of the catchment's rainfall represented by the sample, which, in addition, may not even be an accurate measure of rainfall at that point.

3. How Accurately Does a Raingauge Measure Rainfall at a Point?

A raingauge is essentially an obstacle to windflow. It is therefore incorrect to assume that a raingauge reading represents the actual rainfall at the site, since rainfall is usually associated with a wind component. Point rainfall amounts are therefore essentially only indices of the true rainfall, due to catch deficiencies caused by the aerodynamic interaction of rainfall, wind, the raingauge itself and local/regional topography. Not only are there systematic errors in the sampling accuracy of the raingauges, but oversights also occur due to misreading the raingauged amounts, faulty instrumentation and to the particular measuring technique adopted.

The main factors that may affect the accuracy of the rainfall estimation at a point are depicted in Figure 6.1.3. The quantity of rainfall reaching level ground is thus invariably greater than that recorded by the raingauge – an inherent error in raingague sampling which is generally ignored. Wind is the primary cause of inaccurate sampling and under-catch is a result of the wind flow causing turbulent eddies around the raingauge orifice which deflect the rain drops. Wind accounts for about a 15% deficiency from an exposed raingauge and this aerodynamic catchment deficiency has been found by Larson and Peck (1974) to be approximately 0.6%/km windspeed.

Figure 6.1.3  Factors giving rise to catch deficiencies in point rainfall measurements (After Rodda, 1967)

Surface adhesion of the water either in the funnel or receptacle and subsequent evaporation accounts for a loss equivalent to about 4% of annual rainfall, these losses varying from 0.2 mm to 0.4 mm per rainday. Such errors are small enough individually, but nevertheless important when accumulated.

Catch deficiency can be reduced by wind shielding around the orifice of the raingauge. For example, Schulze (1975) found that at Cathedral Peak in the Drakensberg of KwaZulu-Natal, a Nipher-type windshield decreases catch deficiency by an average of 9.2%. Placement of the raingauge closer to the...
ground than the standard orifice height of 1.22 m in order to reduce turbulence is not seen as a viable proposition in South Africa, which is characterised in many regions by largely convective rainfall producing intensities which could cause in-splash when large drops disintegrate upon impacting the ground surface and the smaller droplets then splash into the orifice. Using again Cathedral Peak as an example, Schulze (1975) has shown that catch deficiency of the standard raingauge decreases by 7.3%, on average, when the raingauge orifice height is at only 0.3 m above the ground rather than at 1.22 m. Nevertheless, the greater rain catch difference, when compared with a standard raingauge in summer, must be attributed largely to in-splash associated with large rain drops from convective storms. The classic South African study on influences of raingauge elevation, protection and inclination probably remains that of De Villiers' (1980), who showed catch differences due to gauging techniques of up to 31.9% for different raingauges at one meteorological site near Durban.

Furthermore, the rainfall received on the ground not only depends on the angle of incidence of the falling drops, shown by Schultz (1981) to be a function of wind speed and drop diameter, but also on the slope and aspect of the ground surface. Thus the discrepancy between "meteorological" rain catch (i.e. measured by a vertical raingauge) and "hydrological" rain catch, (i.e. with the raingauge perpendicular to the slope face) may be as high as 4 - 11% on different aspects when rainfall is associated with storms moving in predominant wind directions, as Schultz (1981) has shown in experiments in the eastern Free State, for example.

"True" rainfall is a function of meteorologically measured rainfall, slope gradient and aspect, average storm direction and angle of inclination of rainfall. This Section has, to this point, merely highlighted that the primary input into daily agrohydrological models is already an inadequately sampled point index rather than an absolute value, before the spatial representation of rainfall over a catchment has even been considered.

Raingauge Networks

1. A Brief History of Rainfall Monitoring over South Africa

According to Lynch (2004), one of the first accounts of heavy rain in South Africa, from Jan van Riebeeck's journal, dates back to 22 - 23 July 1652 when the garden at the fort in Cape Town was washed away and the packing shed in the fort was 150 mm under water (The Chief Director, 1990). The earliest recording station, with records dating back to 1850, is the Royal Observatory (SA Weather Service rainfall station Number 0020866 W) in Cape Town. The second oldest active rainfall station, Ufumba (0375383 W), which is located approximately 20 km north of Hluhluwe in KwaZulu-Natal, has records that date back to 1865, while a still active rainfall station opened in Clanwilliam, in the Western Cape, around 1869. By 1880 South Africa had more than 100 active daily recording stations and this number increased to a maximum of 3 841 in 1938, with a steady decline in the number of rainfall stations both in the RSA and neighbouring countries since then, but more pronounced after 1980 (Figure 6.1.4).

![Figure 6.1.4](image_url) 

Figure 6.1.4 Analysis of active rainfall stations in South Africa and neighbouring countries (Lynch, 2004)

2. General Design Considerations of Raingauge Networks

A network of raingauges across a region or country should be designed so as to be sufficiently adequate to represent the spatial variability of the rainfall...
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within that region. Raingauge network design must account for the systematic variation in rainfall over an area as well as the random errors incurred when extrapolating from gauged to ungauged points. Point values of rainfall in mountainous terrain, for example, display considerable spatial variability and, ideally, dense raingauge networks are needed there to obtain a meaningful measure of areal rainfall in these hydrologically important areas of generally high runoff generation. Design criteria of raingauge networks may be summarised as needing to consider:

- the number of raingauges required,
- the location of these gauges, and
- the length of operation.

Despite well documented design recommendations, most countrys’ raingauge networks are inadequately developed and have often expanded somewhat haphazardly to reflect a number of influences such as costs of installation, costs of maintenance, a lack of appreciation of the value of accurate rainfall (and thus runoff) estimates, historical patterns of agricultural or industrial (rather than hydrological/water resources) development within a country and frequently also of inaccessibility. Careful planning is therefore required for a minimum permissible/acceptable network.

The dilemma is that some sort of information on the rainfall distribution is required before a network can be established. Ideally, therefore, a dense primary network should be installed to collect the data to justify the adequacy of a secondary network which would then be the permanent installation. It should be borne in mind that the error in estimating the rainfall at any ungauged point increases the further the point is from the site of measurement, particularly if much of the rain falls as convective storms which are, at least partially, random in their location. A dense network of raingauges is, therefore, required to obtain a reliable estimate of the areal rainfall.

The effect of network density is shown by Linsley et al. (1982) in Figure 6.1.5, where the resulting estimated spatial distribution of a rainfall event is displayed. The area illustrated in this diagram is the Muskingum catchment in Ohio, USA. Two totally different isohyetal patterns are obtained from the two networks of raingauges for the same event. The sparse network is not able to account for the spatial variation in the rainfall and thus excludes much detail on the map. Dense networks are not common; therefore, network planning requires the placement of raingauges in strategic positions to measure the areal rainfall adequately.

Kelbe (1987) states that correlation analysis is often used to describe the adequacy of networks, and he compared the inter-station correlation of daily rainfall events with the distance between the raingauges near Bloemfontein in the Free State. The influence of the characteristic dimensions of the rainfall fields are shown in Figure 6.1.6. Convective systems display a sharp decay in correlation with distance between raingauges (as in February, Figure 6.1.6) whilst frontal events result in a more gradual reduction in correlation (as in June, Figure 6.1.6). The observed existence of extreme gradients and a generally discontinuous behaviour leads to the conclusion that any interpolation technique will not show great accuracy in the case of convective rainfall. Considering that Schulze (1975) accepted an inter-station correlation coefficient for daily rainfall of 0.9 as sufficient for given raingauge spacings in research catchments, vastly different networks are required to describe a convective and a frontal rainfall event. The Free State (and much of South Africa in general) is an area where much of the

Figure 6.1.5 Isohyletal maps of an event showing the effect of network density on the apparent storm pattern (After Linsley et al., 1982)
Figure 6.1.6 Inter-station correlation decay with the increasing distance between stations in the Free State (After Kelbe, 1987)

rain falls in summer in the form of convective storms; therefore, a close raingauge spacing would be essential in that region.

Because of the generally high degree of association between rainfall and altitude, consideration has to be given for network design to be based on a stratification based on altitude intervals. Furthermore, meteorological factors such as storm size and direction can be dominant factors in determining the effectiveness of a network. It must be noted that these procedures only indicate the total number of raingauges required in each strata for reliable rainfall estimates, and that the choices of strategic gauge positions thus still remain subjective.

Seed (1992) classified raindays over a 150 km x 150 km area centred on Carolina/RSA into dry, scattered rain and general raindays and found there were, on average, 20 general raindays per summer over the area. Only a few days of widespread heavy rainfall were found to provide the bulk of the annual mean areal rainfall over large catchments. Since, in such situations, even fairly sparse gauge networks are expected to perform rather well, the implication for hydrologists is that over large catchments the intermittency of rain fields on isolated and scattered raindays is less of a problem than appears initially. This conclusion does not necessarily hold true for small catchments, however (Maaren, 1984).

Considerations Regarding the Spatial Distribution of Rainfall over a Catchment

1. Background

The problems associated with the spatial variation in rainfall and errors in calculating representative areal values and their effect on simulated streamflow have been considered by many researchers. For example, the use of a single rainfall record in a Quaternary Catchment can probably at best predict the peak discharge of that catchment to within 20% of the true value. Similarly, the use of a non-representative set of raingauges can also result in poor streamflow predictions. These points highlight the importance of preserving the spatial rainfall input and incorporating, ideally, some sort of distributed rainfall input into catchment models such as ACRU, even when the total rainfall depth at a raingauge is considered not to be in serious error.

The most important considerations in determining areal rainfall rely on the quantification of those factors which influence the spatial distribution of rainfall, especially the physiographic characteristics of a catchment. Mountain ranges, local topography and other physiographic features, as well as the prevailing synoptic conditions influence the occurrence and the spatial distribution of rainfall. The variations of rainfall with altitude, slope, aspect, exposure, steepness or areal location have been investigated widely, particularly using various forms of multiple regression techniques, and for southern Africa have been documented, inter alia, by Whitmore (1972), Schulze (1979), Hughes (1982), Dent, Lynch and Schulze (1989) and Lynch (2004).

2. Altitude

Rainfall over an area may vary considerably as a consequence of even relatively small differences in altitude. Whitmore (1972) stressed that over South Africa, for example, the elevation change over an area, rather than
altitude per se, would give a better indication of the role that relief plays in the distribution of rainfall. The escalation in rainfall with rising altitude was shown by Schulze (1983), working in KwaZulu-Natal, to be the result of both an increase in the magnitude per rainfall event, as well as an increase in the number of rain-bearing events.

Even small terrain features may play an important role in enhancing rainfall, with relatively small hills of the order of 50 m above the general ground level having been known to cause an increase of 25% in rainfall amounts by causing the formation of low level feeder clouds with droplets too small for independent rainfall, but large enough to be coalesced by rain falling from above (e.g. Storebo, 1964). Thus, an appreciable variation in rainfall, especially under frontal systems, may occur over relatively small areas.

3. Continentality

Continentality, i.e. a measure of the distance inland from a coast or the position of a site with respect to the source of moisture, was found by Whitmore (1972) to account for 22% of the variation in MAP in the Western Cape region. The further inland a moisture laden air mass must travel, the more likely it is that the precipitable water will be reduced due to the orographic effect of previous upliftings. The bias in the distribution of rainfall on windward vs leeward slopes, with a flatter gradient of rainfall increase on the windward side as the moisture-laden air ascends, cools and condensation can take place, the rainfall peak occurring before the altitude peak and the steeper decline of rainfall on the leeward side as a result of less precipitable water remaining and air heating up when it is descending, is illustrated well by Schulze (1979) for the Drakensberg region between KwaZulu-Natal and Lesotho (Figure 6.1.7).

4. Aspect

Another important consideration in the spatial distribution of rainfall is aspect, particularly in association with direction of rain-bearing wind.

5. Rainfall Type

Because of the marked seasonal variation in rainfall type in southern Africa, with predominantly frontal systems occurring in winter and convective storms in summer, it must be stressed that these two systems will not necessarily be affected by the same topographic and meteorological conditions. Frontal systems are far more extensive and uniform than the isolated convectional systems. Hence, rainfall type is another factor influencing the areal distribution of rainfall.

It is aspects such as the above that require careful forethought in preparation of rainfall input for agrohydrological models in order for the rainfall to be representative of a catchment, particularly in a physiographically heterogeneous catchment, or when using rainfall data which may be non-representative of the catchment's true rainfall. The latter may be either because the gauge is located non-representatively, or the network is distorted, or the record lengths of rainfall are not long enough and they are possibly from a non-representative or non-stationary time series.
The Question of Length of Rainfall Record for Agrohydrological Modelling: How Long Is Long Enough?

This vexing question is a crucial one modellers frequently ask themselves in the context of agrohydrological risk analysis and planning, even more so when using a multipurpose daily model such as ACRU.

Relatively little research has been undertaken on "how long is long enough" with regard to daily rainfall data sets used in agrohydrological risk modelling. Considerably work has, however, been published on suggested minimum length of record regarding statistical stability of annual and monthly rainfall totals, and that may be taken as a guideline to minimum record lengths appropriate for use in models.

If, for example, a 50 year annual rainfall record were to be selected for an agrohydrological simulation run, that duration would at the same time

- satisfy any bias which could be induced by short (say 10 years) record lengths being influenced unduly by a particularly wet or dry spell of years especially where, for example, in southern Africa "quasi" periodic fluctuations with approximately 20 year oscillations have been reported by many researchers (e.g. Tyson, 1987), because a 50 year period would then include at least two such "cycles". A 50 year record length would, furthermore;
- satisfy the international agreement of using a minimum base period of 30 years, as recommended by the World Meteorological Organisation.

However, the minimum useable record length will also vary regionally within South Africa. On the premise that variability of rainfall is generally higher in areas of low rainfall (Schulze, 1983) and that the use of short term records can bias estimates of MAP significantly, semi-arid areas are likely to require longer record lengths for hydrological risk analysis than wetter areas. This was confirmed statistically by Lynch and Dent (1990), who found that a minimum annual rainfall sequence of any 15 year moving "window" in the wetter eastern regions of South Africa, and 35 years in the more arid west, was sufficient to ensure that the mean annual rainfall for that length of record was within 10% of the long term mean 90% of the time.

From the above research findings, it is surmised that for daily agrohydrological modelling the minimum record lengths required be about double those for MAP, but with the assumption that a 50 year daily record would be acceptable throughout South Africa. Based on the infilling and record extension techniques applied by Lynch (2004), as summarised in Section 2.2 of this Atlas. Figure 6.1.8 shows that the distribution of rainfall stations in South Africa with record lengths exceeding 50 years generally provides an adequate network of stations in the region, except in certain critical areas such as Lesotho (a major source of water resources for South Africa) and the former homelands areas within South Africa (where rural development schemes require planning), where there appears a dearth of stations with long records.

Other Problems Associated with Daily Rainfall Records which are of Importance in Agrohydrological Modelling

Apart from errors of daily rainfall measurement at a point and over an area, and those induced by using short records, users need to be made aware of the following problems with regard to daily rainfall records:
• **The Standard Rainfall Day**
  The standard rainfall day begins and ends at nationally determined times; in South Africa it is 08:00. In recording the previous day’s rainfall at 08:00, many characteristics of individual storm events which may be occurring at that time of day may be lost because standard non-recording gauges are read only once a day. This may lead to misinterpretations and under-simulations, particularly of the more crucial “extreme” events and in long duration events.

• **Date Phasing**
  Furthermore, some observers record the 08:00 rainfall against the previous day’s date (which is correct), while others inadvertently record that rainfall against that day’s date, i.e. one day out of phase. While date phasing may not be a serious error when statistics are computed, it becomes a serious hydrological error when the runoff from an upstream catchment is generated with rainfall from an incorrect date and is merged with the runoff from a downstream catchment which is computed using rainfall from the correct date.

• **Human Error**
  The vast majority of rainfall stations are operated by volunteers and it is possible for human errors to occur in reading and recording rainfall. There is no objective means of checking for such errors. Schulze (1979) found that at certain stations in the Drakensberg area, for example, it became quite obvious by careful manual perusal of the daily rainfall records when the operators’ annual leave was taken.

• **Errors in Data Capturing**
  The South African Weather Service, for example, cautions against data capturing errors and claims about 95-98% accuracy in the data acquired from them.

• **Extreme Events**
  These are of primary concern in hydrological modelling. In an analysis of events in South Africa recording in excess of 200 mm per day, Dent, Lynch and Schulze (1989) found that of 3 500 such events on the official data files only 1 300 could be verified beyond any doubt when checking was undertaken against concurrent daily rainfall at nearby stations, and the remaining 2 200 so-called extreme events had to be considered as being suspect, often a result of a keying-in gremlin.

• **Fog**
  In many high lying areas fog may play a major role in hydrological response. Fog contributions are not recorded by standard raingauges.

Schulze (1979) and Schmidt and Schulze (1989) have reviewed the contribution of fog measurements by special fog interceptors, and report that in many mountainous areas so-called fog catch may in fact exceed total rainfall recorded.

### Missing Rainfall Records and Approaches to Infilling Missing Data

Missing records can severely limit the use of rainfall data. In continuous daily simulation modelling, for example, the models cannot function without a continuous daily dataset.

Following on previous research in South Africa on so-called data “patching” (e.g. Zuccini and Adamson, 1984; Adamson, 1987; Dent et al., 1989), a number of infilling algorithms were used in the research by Lynch (2004) and a complete list, with discussion on advantages and disadvantages of each, is contained in his full report. Four infilling techniques were selected and infilling of missing values more than doubled the size of the South African daily rainfall information base up to 2000 (Table 6.1.1), which consists of 105 753 218 daily observed values with 236 154 934 infilled values. The total size of the observed and infilled rainfall database is thus 341 908 152. The infilling process has also increased the size of the annual database considerably from an initial 5 118 stations with more than 15 years of complete record to 9 641 stations that have more than 15 years of record.

### Table 6.1.1

<table>
<thead>
<tr>
<th>Infilling Technique</th>
<th>Number of Daily Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expectation Maximisation Algorithm</td>
<td>113 869 517</td>
</tr>
<tr>
<td>Median Ratio Method</td>
<td>40 823 148</td>
</tr>
<tr>
<td>Inverse Distance Weighting</td>
<td>81 451 381</td>
</tr>
<tr>
<td>Monthly Infilling Technique for &lt; 2 mm</td>
<td>10 888</td>
</tr>
<tr>
<td>Total</td>
<td>236 154 934</td>
</tr>
</tbody>
</table>

### A Suggested Technique for Estimating Areal Rainfall

1. **A Brief Overview of Previous Work in South Africa**

Areal rainfall at the subcatchment scale can be estimated using satellite or radar systems, but raingauge networks still provide the bulk of the historical

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rainfall data to hydrologists throughout the world. The accuracy of areal rainfall estimated from point measurements depends on the representativeness of the point measurements, the spatial variability of the rainfall, the size of the catchment, duration of rainfall as well as the method used to estimate the areal distribution from the point measurements.

A review in Schulze (1995) found that classical methods such as the Thiessen polygon (Thiessen, 1911), isohyetal or inverse distance square methods performed inconsistently and could yield errors in areal rainfall of over 100%. Trend surface analysis, a form of multiple regression approach, was found to estimate areal rainfall successfully at annual and monthly levels, also in mountainous areas, but less so for daily estimates over a catchment (Schulze, 1976). Again at annual and monthly levels, Dent et al. (1989) and Lynch (2004) went one step further and used a combination of multiple regression analysis plus linear interpolation of residuals to generate gridded images of median monthly rainfall for southern Africa. However, caution is expressed by Whitmore (1972), that non-orographic rainfall is not reflected accurately by multiple regression methods, although on the whole that method describes areal rainfall adequately.

It must be borne in mind that spatial averaging of areal precipitation results in decreasing mean rainfall depth with increasing area, which may be accounted for by an areal reduction factor (ARF). Figure 6.1.9, for example, shows that the higher the rainfall intensity at a point is and the larger the area of a catchment under consideration, the lower the ARF. If, for example, the rainfall intensity recorded at a point was 100 mm/h and that point was to represent rainfall over a catchment of 50 km², then the point rainfall should be reduced to 84% of the recorded daily point rainfall.

2. A Recommended Technique For Estimating Daily Areal Rainfall in South Africa: The Driver Station Approach

There is no perfect technique for estimating areal rainfall, for the "best" technique will depend on

- the size of catchment under consideration,
- the topography of the catchment (low relief or mountainous area),
- the availability of input data required by the various techniques, and in particular

Figure 6.1.9 Areal reduction factor (ARF) for short duration storms over South Africa, derived from storm-centred data showing precipitation depths equalled or exceeded (Hydrological Research Unit, 1972)
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The type of problem for which the simulation is to provide results, be it for design (planning) or for operational hydrology.

One approach to preparing daily areal rainfall values discussed in more detail and assessed is the so-called “driver station” approach, which has been used in the South African Quaternary Catchments Database (cf. Section 2.3) to undertake simulations with the ACRU model (Schulze, 1995).

The driver station approach is carried out according to the following steps:

- A representative station selected to "drive" the hydrological response of a catchment or subcatchment is chosen according to the following criteria:
  - it is as close as possible to, or within, the catchment or subcatchment
  - its altitude is representative of the catchment's mean altitude
  - it has a long continuous record with a minimum of missing or suspect data and
  - where data are missing, the next best driver station (according to the above criteria) is used to estimate the missing rainfall.

- The median monthly precipitation of the driver station is compared to the median monthly precipitation of the catchment, which can be estimated from the one arc minute raster of median monthly precipitation developed for South Africa by Lynch (2004) and described in Section 2.2 of this Atlas. From the comparison of the driver station and catchment median monthly precipitation values, month-by-month precipitation adjustment factors can be derived and input, in the case of the ACRU model, into the ACRU Menubuilder.

Disadvantages

The main disadvantage lies in an oversimplified representation of daily areal rainfall. One can question if, say, a 100 - 200 km² large catchment's areal rainfall can be represented realistically by a single raingauge. If no rainfall is recorded at the driver station, the method presumes that no rain has fallen on that day anywhere in the catchment. Alternatively, if a heavy rainfall event has been recorded for a particular day, the method assumes that this heavy rainfall event, which might have resulted from a small cell convective storm, occurred over the entire catchment.

Sources of Rainfall Information for Use in South Africa

Daily rainfall in the South Africa, Lesotho and Swaziland is monitored extensively and the data are collated by a number of organisations. The South African Weather Service (SAWS) and the Agricultural Research Council (ARC) are the principal collectors and custodians of daily rainfall data banks in the RSA. Other sources are the Department of Water Affairs and Forestry, national and provincial parks boards, organised agriculture and in particular the South African Sugarcane Research Institute (SASRI), municipalities and mines. In addition, a large number of individuals record daily rainfall, but do not submit these data to any of the aforementioned organisations.

Daily rainfall has, historically, been recorded at approximately 12 000 stations in southern Africa (Lynch, 2004). Up to the year 2001 these rainfall data were collated, quality controlled and disseminated by the Computing Centre for Water Research (CCWR). With the closure of the CCWR no common point of rainfall data access is any longer available in South Africa. However, a CD with quality controlled rainfall data for South Africa may be obtained from the Water Research Commission as part of the rainfall report by Lynch (2004).

Conclusions

Rainfall is the major driving force to responses in the agrohydrological system. This Section has therefore highlighted the importance of accurate rainfall as an input to agrohydrological models by examining the problems
inherent in obtaining realistic daily point and catchment rainfall estimates under the premises that

- one should not accept rainfall data in blind faith at face value,
- in an agrohydrological model "garbage in" results in "garbage out" with respect to rainfall, and
- agrohydrological response is probably more sensitive to rainfall than to any other climatic input.

References (In the sequence in which they appear in this Section, with the full references given in Section 22)

12. The Chief Director (1990)
17. Whitmore, J.S. (1972)
22. Storebo, P.B. (1964)
28. Thiessen, A.H. (1911)
30. Hydrological Research Unit (1972)

Citing from this Section of the Atlas

When making reference to this Section of the Atlas, please cite as follows: