

The Application of Rainfall Confidence Limits to Crop Water Requirements in Dry Zone Agriculture in Sri Lanka

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Abstract : One of the more important problems in the stabilization of rainfed agriculture in the dry zone of Sri Lanka is the development of systems that would ensure an optimum use of the incident rainfall. This would principally involve : (1) a proper choice of sowing time and (2) a proper selection of sowing-to-harvest duration of crops so that there is a maximum likelihood of the rainfall satisfying the crop water demand at every stage of growth and development.

In this paper, the probability of rainfall for the growing seasons in the different regions of the dry zone have been specified by the use of 3-weekly moving totals of 1:1 rainfall confidence limits calculated according to Manning's method. It is observed that within the dry zone itself there is a significant regional differentiation in both the break of season as well as the close of season, especially for the major 'Maha' season. The manner of selecting proper sowing dates for the respective regions is indicated. By matching the crop water requirement against the 1:1 confidence limits of expected rainfall, it is demonstrated that one could select an age class for a particular crop so that its water demand fits as closely as possible with the probable seasonal supply of moisture. Predicting the adaptability and performance of individual crops to the different regions of the dry zone as well as some other practical applications are also discussed.

I. Introduction

Countries with a long established agricultural tradition are fortunate to have at their disposal the heritage of an accumulated weather lore of centuries. Indeed, through centuries of empirical observation and experience in rainfed farming in the dry zone of Sri Lanka, there has evolved a cropping calendar which, within the constraints of a subsistence economy, is observed to be quite logical as it is sound. Despite this level of development, factors such as risk at time of planting and even more at time of grain filling and maturing, especially for rainfed rice and other shallow rooted crops are often in doubt. Such risk factors may perhaps more than any other, account for the fatalistic attitudes that tend to cloud an objective assessment of occurrences in the recent run of years, which could be explained in terms of a statistically normal run of events, that may, not infrequently, tend to bunch together.

Any kind of year to year prediction of a season's rainfall is yet not possible according to our present state of scientific knowledge. However, subjecting the past rainfall data to stringent tests of statistical probability, at least such central tendencies of rainfall expectancy that are known to have a significant bearing on an inter-related range of agricultural practices could be objectively assessed.

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An important characteristic of the annual rainfall of the dry zone is its division into two well defined rainy seasons : (1) *Maha*--the major rainy season from early October to late January and (2) *Yala*--the minor rainy season from late March to late May. The mean monthly rainfall records for any dry zone station shows this bi-modal rainfall pattern with two marked dry seasons, one during February to March which is short and moderate, and the other during May to September which is long and protracted. The intensity and duration of the component wet and dry seasons themselves show minor but significant regional variations within what is broadly termed the dry zone of Sri Lanka ; and the nature of these variations do have an important bearing on the regional specialization of crops within the dry zone.

The main climatic features of the dry zone have been adequately described in several publications and therefore needs no further elaboration. For the special needs of this paper, however, the meteorological data of the dry zone research station at Maha-Iluupallama, which could be considered as representing the modal situation in the dry zone is given in Table 1.

TABLE 1. Meteorological data for Maha-Iluupallama.

Month	Mean Rainfall in	Mean Evaporation Open Pan in	Mean Temperature		Mean relative humidity	Mean daily wind mileage	Mean percentage sunshine
			Max °F	Min. °F			
Jan.	5.3	5.2	83.3	69.1	81	106	65
Feb.	1.9	5.6	87.0	69.4	74	91	75
Mar.	3.9	7.1	91.2	71.6	73	85	85
Apr.	7.4	6.8	91.6	74.4	76	93	82
May	3.9	7.0	90.8	76.4	76	190	77
June	1.1	7.2	90.0	76.4	71	264	75
July	1.5	7.5	90.8	75.9	70	243	73
Aug.	1.7	8.0	91.4	75.5	68	258	78
Sept.	3.0	8.2	91.8	75.0	68	246	74
Oct.	9.9	5.9	89.0	73.5	77	147	64
Nov.	10.5	4.6	85.8	71.4	81	79	56
Dec.	8.0	4.5	83.2	70.1	83	98	58
Total :	58.1	77.6					

One of the characteristic features of rainfed arable crops in the dry zone environment is the enormous variability in yield between years. Over a 25-year period at Maha-Iluupallama, rainfed rice yields have ranged between 74 to 8 bu/acre, while over a 12-year unbroken period, rainfed cotton yields have ranged between 1,120 to 220 lb/acre. Almost the whole of this variation in crop yields could be ascribed to the chance of obtaining a satisfactory trend of soil moisture during the growing season. Clearly, the pattern of incident rainfall and its interaction with the water consumption patterns of rainfed crops deserves a close study by such investigational techniques that are presently within our reach and capacity.

From the information that was available by 1962 on crop-water consumption patterns, rainfall expectation patterns and trends of the soil moisture profile, Abeyratne² made the following broad conclusions :

1. There is a good chance in most years for the successful cultivation of 4-month or shorter duration crops under rainfed conditions in the Maha season.
2. The cultivation of rainfed Yala crops at least in the northern dry zone may be possible if proper water conservation methods are used and if the fields are kept free of weeds.
3. The only long aged crops that will survive the dry season are the very deep rooted ones such as pigeon pea (*Cajanus cajan*) when planted in the Maha season.

Considerable advances have been made during the recent decade in the study of soil-plant-water relationships and soil-water energy characteristics in our dry zone environment. This paper presents our contemporary state of inter-related information in this field in order that agricultural scientists and policy makers could formulate a reliable and objective approach to the development of rainfed agriculture in the dry zone.

The initial sections of this paper deal with the main parameters of the subject : (1) the confidence limits of rainfall, (2) water consumption patterns of crops and (3) soil-water energy relationships. The latter sections discuss the matching of crop-water requirements with rainfall expectancy and the practical applications that arise from this study.

2. Confidence limits of expected rainfall

In tropical regions in particular, it has been clearly demonstrated that the mean monthly rainfall, even when derived from a large number of years, is at best an unreliable guide to the variation in rainfall with which the agriculturist must contend. In an analysis of the dry zone rainfall made in 1953, Farmer³ drew attention to this, and he has shown that the median and other percentile values afforded a more reliable measure of rainfall expectancy.

The arithmetic mean that is usually calculated directly from rainfall figures does not take into account the inherent skewness of the raw data that results from a disproportionately large amount of the rain falling in heavy tropical downpours thereby raising the level of the mean much above the normal amount of rain received or expected. Thus, unless account is taken of the skewness of the frequency distribution of the rainfall where the mode is lower than the mean, estimates of rainfall expectancy made directly from raw data could be quite misleading.

Frequency distributions were constructed from weekly records of the past 50 years rainfall for selected dry zone stations using the class interval of one fourth the approximate standard deviation. It was observed that except for the weeks that fell within the month of November, the distributions in respect of all other periods were positively skew. Even monthly rainfall values as subsequently reported by Alles³ show a non-normal positively skewed distribution. Clearly, any statistic derived from such distributions will give a distorted measure of the real values.

Several methods are available for transforming skew data to give approximately normal distributions. The method proposed by Manning⁷ has been directly used in this study. Briefly this involves summing up the daily total rainfall for each year into 52 standard weeks so as to give an even run of data which may be subject to analysis. 3-weekly moving totals are used for several reasons indicated in subsequent sections of this paper. The data is then transformed by the function $y = \log(x + c)$ where the size of the constant c varies inversely with the degree of skewness. The rainfall patterns are thus presented in a form free from the distortion imposed by the skewness of the actual data. Manning⁸ observes that "from this transformed data the concept of rainfall expectation at selected levels of probability could provide a completely objective and reliable estimate of rainfall to be expected so as to assess long-term crop risk which is not apparent when means alone are used."

The real need in agriculture is for a precise estimate not merely of the average expected rainfall, but the limits within which this expected rainfall will occur. These limits can be calculated for any level of probability from the transformed data and are known as *fiducial* or *confidence* limits. A confidence limit may therefore be defined as an estimate of the chance of obtaining a value for a given statistic that falls within prescribed limits. For agricultural purposes, the limits within which rainfall may be expected to lie in 3 years out of 4, namely 75% fiducial probability or 1:1 confidence limits are considered adequate.

The 1:1 rainfall confidence limits calculated on a monthly basis for Mahalluppallama from a 20-year run of unbroken rainfall records are given in Table 2. In statistical terms, the rainfall for a particular month will be greater than the lower confidence limit value in 3 years out of 4; and similarly it will be less than the upper confidence limit value in 3 years out of 4. Expressed in this manner, it is of more direct relevance to agricultural problems than the mean monthly values quoted in Table 1.

TABLE 2. Confidence limits (1:1) for monthly rainfall at Maha-Illuppalama (20 years).

Month	Lower confidence limit (in)	Upper confidence limit (in)
Jan.	2.3	8.0
Feb.	0.3	2.9
Mar.	0.6	4.2
Apr.	3.0	8.7
May	1.5	5.6
June	0.3	2.1
July	0.1	1.8
Aug.	0.3	2.5
Sept.	0.2	3.1
Oct.	3.5	9.1
Nov.	5.5	13.4
Dec.	5.1	14.3

The trends of rainfall expectation during the progress of the season are as important to the agriculturist as the break of season and the close of season. A graphical method of presenting these processed rainfall confidence limits that would capture in a single diagram the main elements of the seasonal cycles would be the most pertinent. To this end, a diagram of the 1:1 rainfall confidence limits could be drawn to a convenient scale with the rainfall on the vertical axis and with weeks along the horizontal axis. Figure 1 shows the 1:1 confidence limits of 3-weekly moving totals that have been worked out from a 50-year run of data for the rainfall station Anuradhapura which is located very close to Maha-Illuppalama. According to the data presented in Figure 1, for a particular week one quarter of the values should fall above the upper limit as shown in the upper curve, and one quarter below the lower limit as shown in the lower curve.

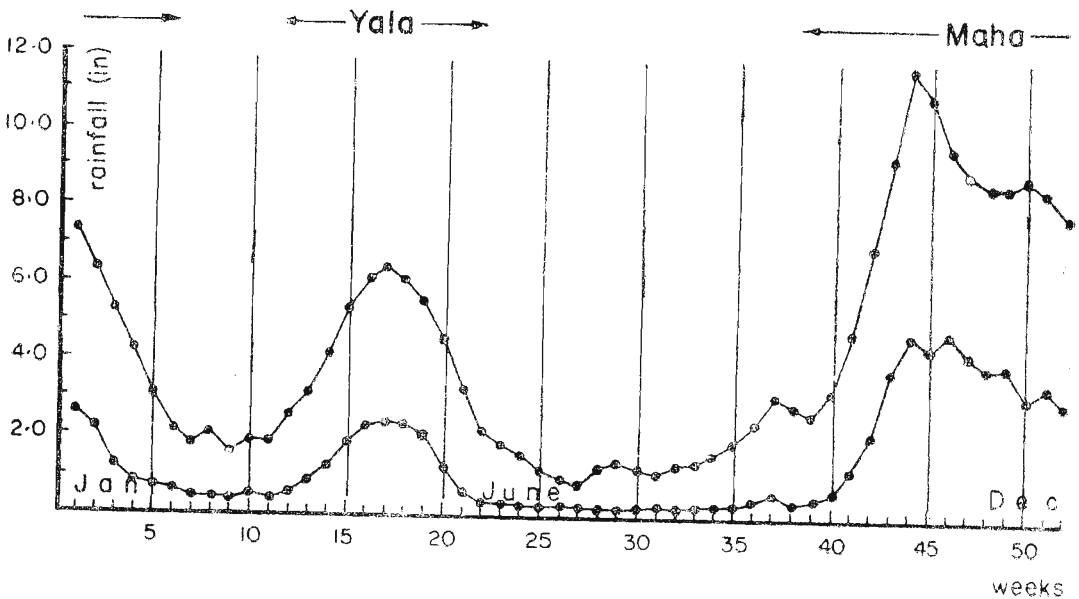


FIGURE 1. 1:1 Confidence limits of 3 weekly moving totals of Anuradhapura rainfall (Minimum expectation for 3 years in 4 given by lower limit)

Therefore, for any one 3-weekly period, the total rainfall is likely to exceed the lower limit in 3 years out of 4, or in other words the minimum expectation for 3 years in 4 is given by the lower limit. Similarly, the total rainfall for the same 3-weekly period will not exceed the upper limit in 3 years out of 4. For example, in the 3-weekly period represented by the 15th week in Figure 1, the rainfall (3-weekly total) will exceed 1.8 inches in 3 years out of 4, and it will also not exceed 5.3 inches in 3 years out of 4.

3-weekly moving totals of 1:1 confidence limits of rainfall have been worked out from the past run of unbroken data for 19 rainfall stations in the dry zone, 7 in the intermediate zone and 6 in the wet zone. The locations of these rainfall stations and the number of years of unbroken rainfall records from which the rainfall confidence limits have been calculated are shown in Figure 2. For the scope of discussion within this paper it would be sufficient to consider 15 rainfall stations from the dry zone proper, as well as 3 rainfall stations from the intermediate zone. The 1:1 rainfall confidence limits diagrams that have been constructed for the foregoing 18 rainfall stations are shown in Figures 3, 4 and 5 respectively.

3. Water consumption patterns of crops

Every crop requires during its growing season, a certain quantity of water which varies with the different stages of growth and development. The water consumption pattern of a crop within a growing season is therefore a more meaningful parameter of crop water requirement than the overall total consumptive use value, especially when estimating the probability of obtaining the desired distribution of rain through the duration of the cropping season.

The seasonal trends of moisture consumption in respect of the more important crops as measured during the Maha season at the dry zone research station Mahalluppallama have been reported earlier.¹¹ It was observed that the consumptive use of water by crops varied at different stages of growth, the evapotranspiration increasing with increasing leaf cover over the duration of the crop. The monthly evapotranspiration values (E_t) for maize and cotton were compared with values of free water surface evaporation (E_o). It was observed that starting with a value of 0.63, the ratio E_t/E_o steadily rises with increasing leaf cover of the crop until it reaches a peak value of 0.95 for maize. In the case of cotton, this ratio of E_t/E_o could exceed 1.0 and attain a peak value of 1.4 at the 5th month of growth.

More recent studies that were conducted under irrigation on the Reddish Brown Earths during the long dry season by Sivanayagam¹² indicate very similar trends of increasing evapotranspiration with increasing leaf cover, and he has further observed that the duration of peak water use was short for maize, whereas for groundnut and other leguminous crops the peak water use period was less pronounced but extended

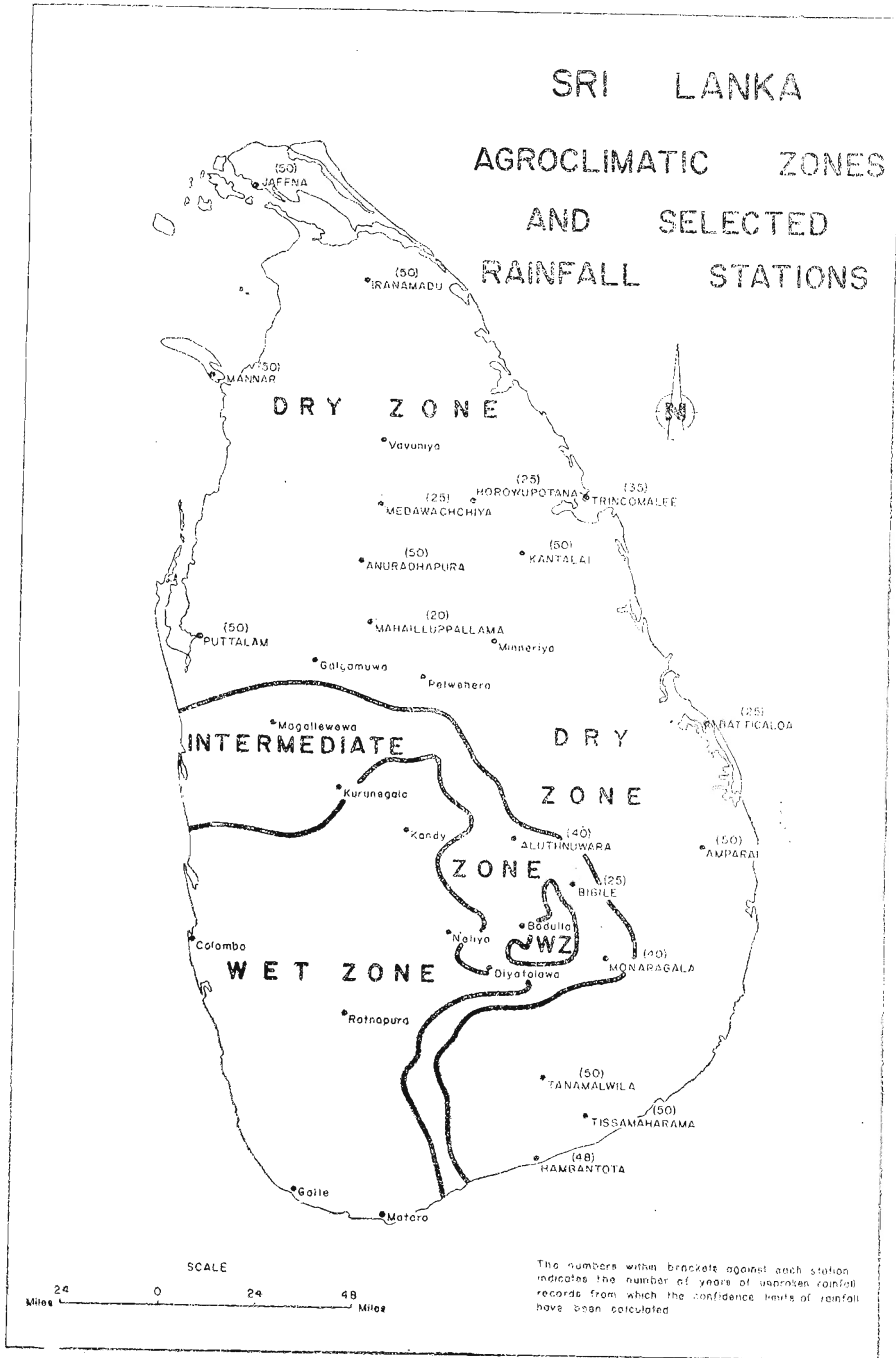


FIGURE 2.

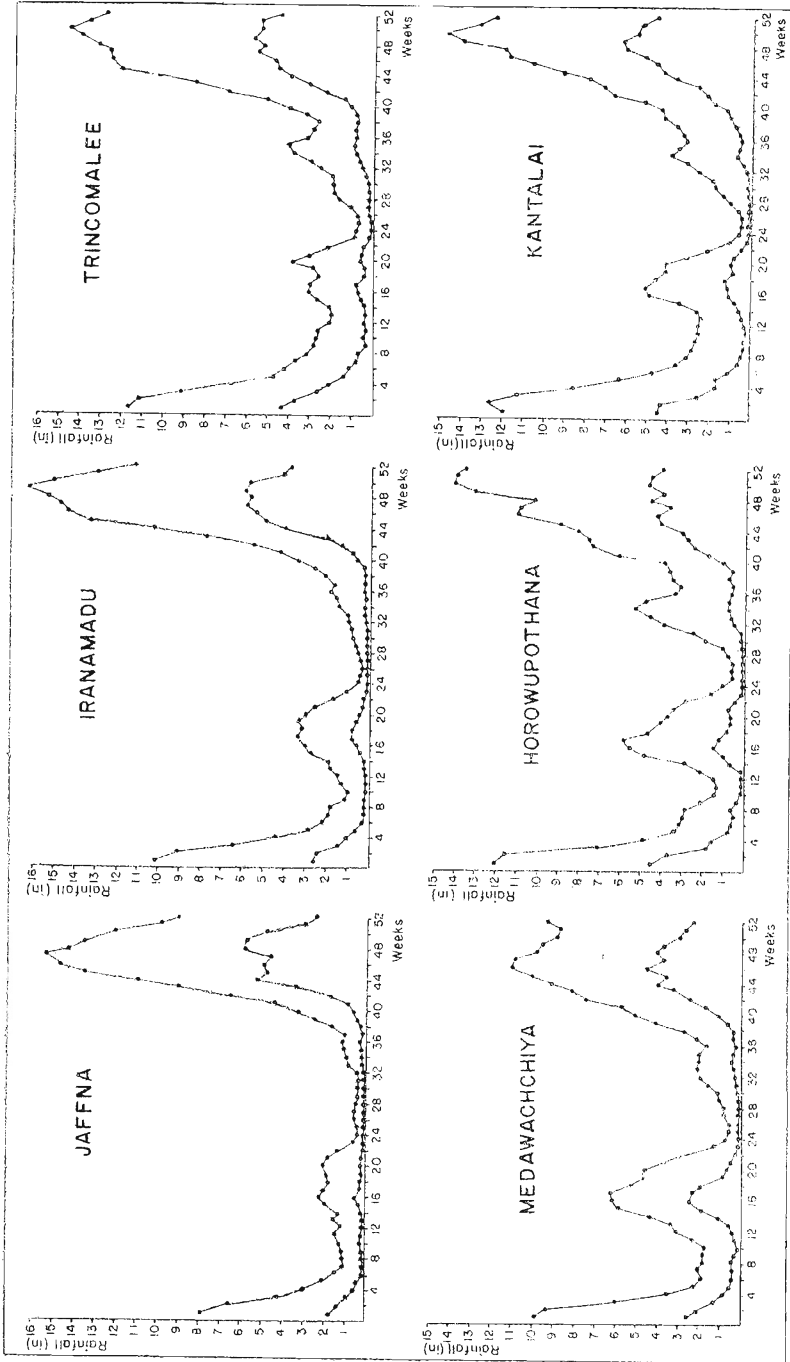


FIGURE 3.

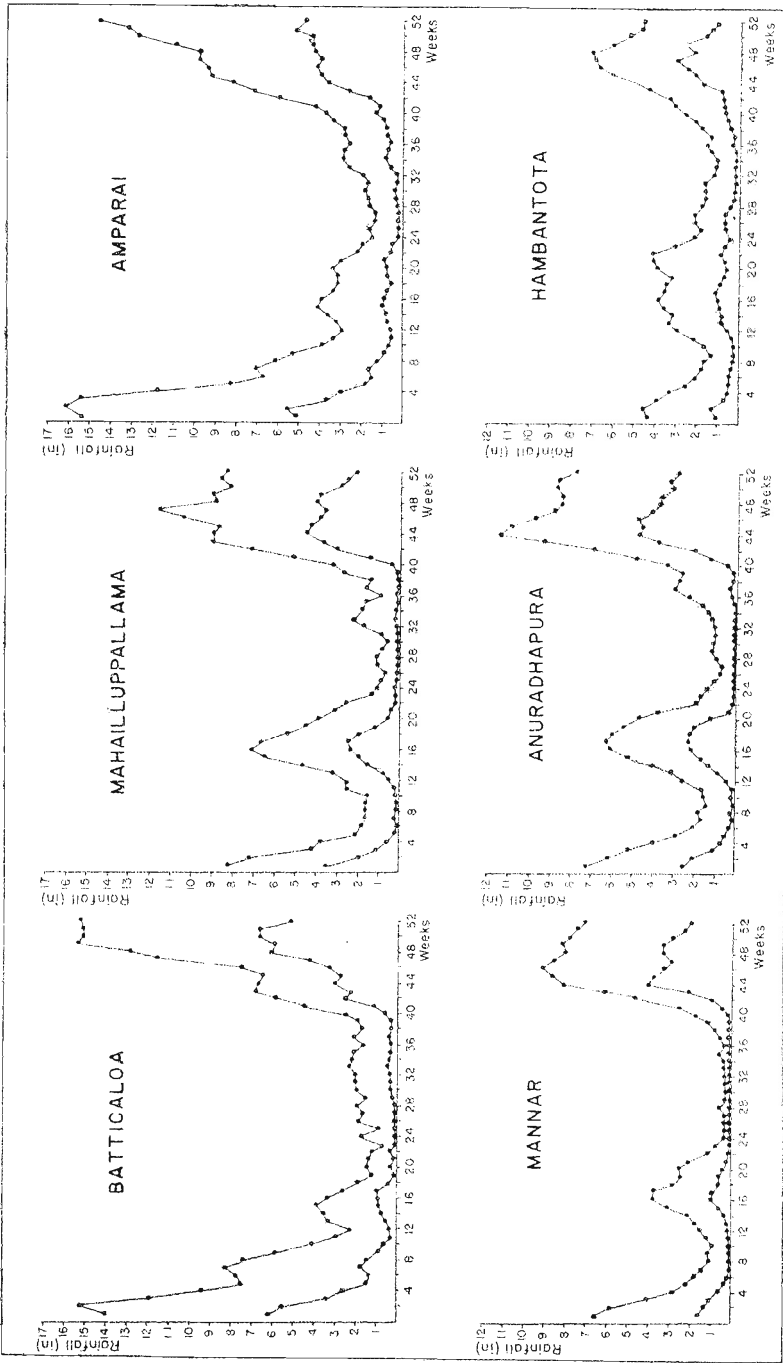


FIGURE 4.

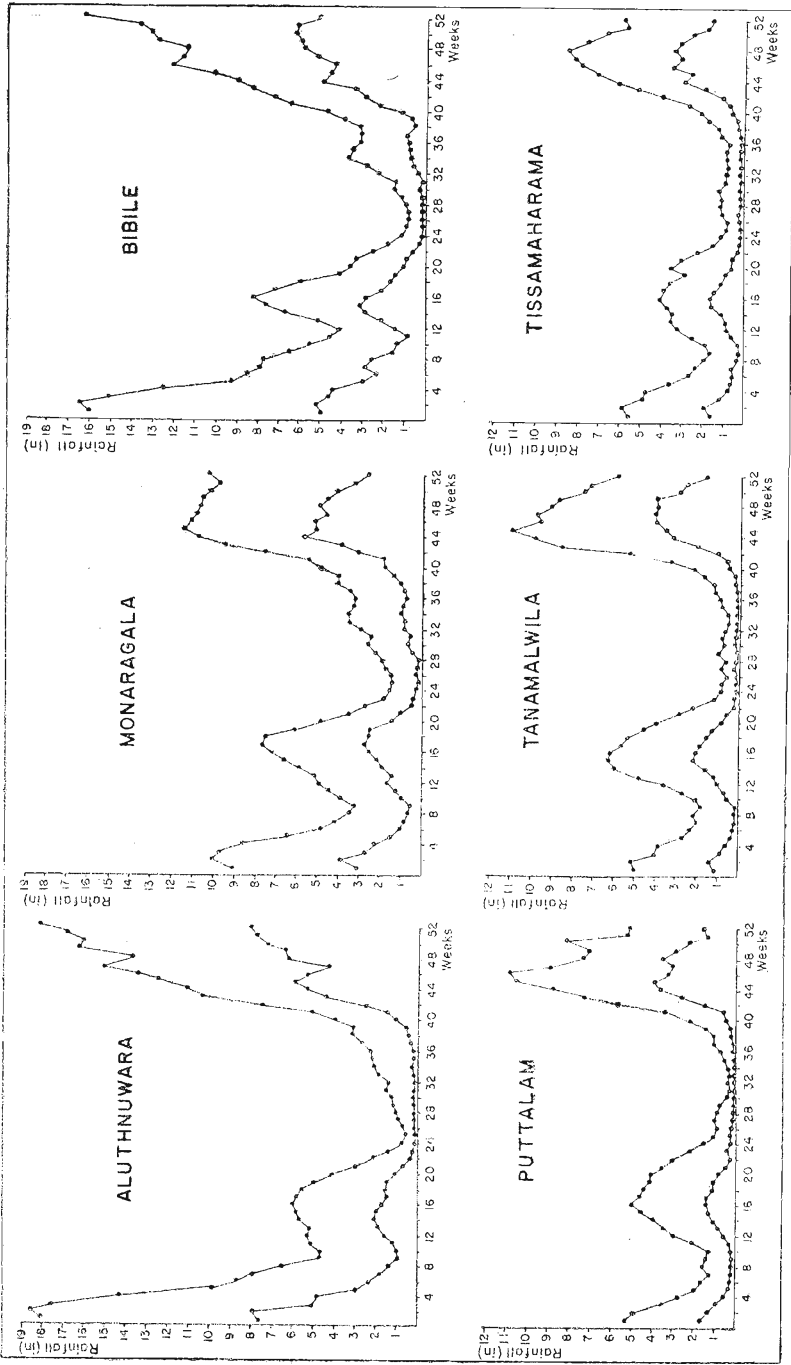


FIGURE 5.

over a longer period. It was also observed that the ratio E_t/E_o in respect of maize reaches a peak value of 1.1 when irrigated at 50% depletion while when irrigated at 75% depletion this ratio reaches a peak value of 0.9. In the case of groundnut and other leguminous crops it was observed that this ratio reaches a peak value of 0.85 when irrigated at 50% depletion, while when irrigated at 75% depletion it reaches a peak value of 0.68. Evapotranspiration values in respect of rice grown under irrigated conditions have also been reported by Murakami and Vignarajah.⁹

From the data that is presently available at Maha-Iruppallama on the water consumption patterns of crops, it is possible to construct a modal water consumption pattern curve for a 120-day Maha cereal crop as well as a 70-day Yala legume crop. Since cereal crops such as rice and maize give maximum yields at soil moisture tensions corresponding to 50% depletion, the modal curve for a Maha cereal crop was constructed for evapotranspiration values obtaining for a low value of soil moisture tension. Since legume crops give maximum yields at soil moisture tensions corresponding to 75% depletion, the modal curve for a Yala legume crop was constructed for a high value of soil moisture tension. Such a modal curve for the water consumption pattern of a crop constructed on a 3-weekly moving total basis is referred to as a *crop water template* in this paper. Figure 6 shows this template for a Maha cereal crop as well as for a Yala legume crop. This template could be superposed on the 1:1 rainfall confidence limits curve drawn on the same scale with a view to matching the crop to the rainfall sequence so that there is a maximum likelihood of adequate water supplies during crop growth and development.

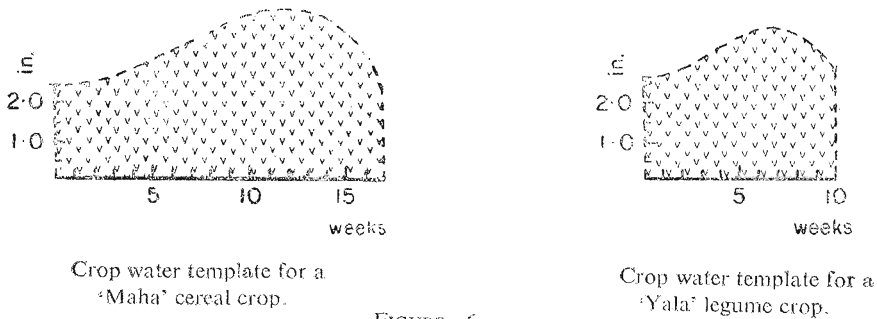


FIGURE 6.

4. Soil-water energy relationships, infiltration and run-off characteristics

Attention has been drawn in a previous paper¹⁰ to certain special features of the soil-water energy relationships of some soils of the dry zone. This section considers the soil-water energy relationships pertaining to three of the more important soil regions of the dry zone as represented by the Reddish Brown Earths (RBE), the

Non Calcic Brown soils (NCB) and the Red Latosols (RL). The morphological and laboratory analytical characteristics of the different great soil groups of the dry zone are dealt with in a recent publication.⁴

Moisture retention characteristics have been determined for the diagnostic horizons of the soil profiles on samples collected from a very large number of profile description sites during a 12-year programme of soil survey investigations. Using the pressure membrane and pressure plate apparatus, measurement of water retention from 15 bar to 0.1 bar have been carried out on core samples as well as on disturbed samples. This data has been processed into a set of modal values of moisture properties by Joshua⁶ and these are given in Table 3. From the modal depths and other characteristics of the individual soil series that have been mapped out in the respective areas of the dry zone, the moisture storage capacity of the different soil regions could now be properly defined.

TABLE 3. Moisture properties of dry zone soils.

Soil	Field capacity moisture %	Wilting point moisture %	Available moisture	
			% by wt	in/ft.
Reddish Brown Earths (RBE)	22 (18—24)	13 (9—15)	9 (8—12)	1.71
Noncalcic Brown Soils (NCB)	8 (6—10)	2 (1.5—3)	6 (4—7)	1.16
Red Latosols (RL)	14 (16—12)	7 (5—8)	7 (6—9)	1.21

Note: The figures within brackets denote the range of values measured.

The RBE can store approximately 1.7 in of available moisture in a 12 in depth of soil or approximately 1.1 inches in an 8 in depth of soil. On this basis, 1.0 in of cumulative rainfall over a 11-day period would be sufficient for the germination requirements of crops during the first half of October. Similarly, for the NCB and RL 1.0 in of cumulative rainfall over a 8-day period would be sufficient for the germination requirements during the first half of October.

An estimate of the total amount of available moisture that can be stored in a soil could be obtained by multiplying the modal depth of the soil profile by the available moisture content/ft of the respective soil. A 4 ft depth of a RBE could therefore store 6.8 in of available moisture when the whole profile is wet to field capacity.

Apart from the quantity of moisture than can be stored in the soil, it is desirable to have some measure of the frequency with which rainfall would be lost as surface run-off during the season. The quantity of rain that will be lost as surface run-off

will depend on (a) the infiltration capacity of the soil ; (b) its state of moisture at a certain time ; and (c) the intensity of rain at this particular time. Infiltration rates of dry zone soils have been determined by the ring infiltrometer for a very large number of sites. The modal values of the minimum infiltration rates work out to 1 in/h for RBE, 7in/h for NCB and 15 in/h for RL. These values represent the steady infiltration rate after a lapsed time of approximately 4 h. Initial infiltration rates could be 5 to 10 times higher.

For the RBE, when the profile is moist, any quantity of rain in excess of 1 in/h will therefore be lost as surface run-off, while when the profile is dry it could accept up to 3 to 4 in of rainfall/h during the initial stages. There could be appreciable run-off during the early Maha season only if very high rainfall intensities are experienced such as 2 inches in 30 or 40 min. The RL can easily accept rainfalls of this intensity without any run-off being experienced.

Comparing the moisture storage characteristics of the RBE with the 1:1 rainfall confidence limits for Anuradhapura, it could be inferred that the central tendency would be for a significant proportion of the rain to be lost as surface run-off during November and December. This also coincides with the period when the tanks or reservoirs in this region fill up rapidly. On the other hand, in the Latosol region represented by Pattalam, Mannar and Iranamadu even the peak rains of November and December can be completely accepted by the soil without any run-off occurring. In this region a greater part of the excess rain will be discharged as deep percolation into stream flow and underground aquifer re-charge.

5. Fitting sowing dates and crop water requirements to rainfall expectancy

The problem of choosing the correct sowing date for rainfed crops is, in fact, of fundamental importance if one wants to ensure high yields. From experimental evidence at the dry zone research station Maha-Iluppallama, Abeyratne¹ concludes as follows : "Time of sowing trials have clearly brought out the fact that the dry zone is no exception to the general rule that in any system of rainfed arable agriculture time of sowing has a great influence on yields of annual crops." Based on the results of field experiments and also using traditional experience as a guide, optimum sowing times were defined for different groups of crops, and these have proved valid for the rainfall patterns around Anuradhapura and Maha-Iluppallama. It would indeed be desirable to establish the optimum sowing times for the rest of the dry zone regions using the rainfall confidence limits as a guide.

The dilemma of the agriculturist in rainfed farming is quite often as to whether he should sow with the first arrival of rain for the season with some expectancy of the minimum rainfall that would be needed to raise the soil moisture to an adequate level for germination, or whether he should wait for the approximate date that is

usually accepted by traditional experience. In other words, he is interested in the risk to crop establishment that would be associated with a particular date of sowing. Since the week before as well as the week after sowing are as crucial as the actual sowing period, it is appropriate to express the suitability for sowing of each week as a 3-weekly total of the week before, that week and the week following.

A reliable index of the true break of the Maha season would be the point at which the lower confidence limit curve shows a sharp upward trend. For Anuradhapura this occurs between the 39th and the 40th week, namely between 29 September and 6 October (Figure 1). By the 41st week there is a 75% chance of a 3-weekly total of 1.3 in of rain, while by the 42nd week there is a 75% chance of a 3-weekly total of 2.2 in of rain. As observed earlier in the soil-water energy characteristics for RBE (Section 4), adequate levels of soil moisture for germination will be fulfilled at the values of rainfall expectancy reported above. The 1st week of October could herefore be considered a very reliable choice of sowing date for this region, and in fact the past 25 years experience at Maha-Iluppallama has confirmed that this sowing date has been the most successful for rainfed rice, cotton and maize. Similarly, the optimum sowing dates for the other dry zone regions could be quite objectively determined from the rainfall confidence limits diagrams of the respective rainfall stations in conjunction with the moisture characteristics of the soil.

Apart from taking advantage of the optimum sowing date, it should also be ensured that the water demand of the crop during its growth and development should fit as closely as possible with the probable water supply in a definite proportion of years such as 3 out of 4. By matching the crop water template against the rainfall confidence limits curve, it would be possible to estimate the maximum likelihood of the rainfall satisfying the crop water demands especially at those periods of its development when insufficient moisture would have its most serious effect on crop yield.

The crop water template of a 120-day cereal crop is superposed on the 1:1 rainfall confidence limits diagram for the duration of the Maha season for the rainfall stations of Anuradhapura and Amparai respectively in Figures 7(a) and 7(b).

It is observed that for the Anuradhapura rainfall there is a 75% probability that the rainfall alone could satisfy the crop water requirements up to a period corresponding to approximately the 50th week or the 51st week; and beyond the 51st week there is only a 50% probability that the rainfall alone could satisfy the crop water requirements. While a deeper-rooting cereal crop such as maize could make good any deficiency in rainfall after the 51st week by drawing upon the soil moisture reserves beyond the 1 ft depth of soil, a shallow rooting cereal crop like rice will have to rely mainly on the supply of moisture by rainfall. There is a 50% chance that a rainfed rice crop would experience conditions of moisture stress during its last few weeks of growth (Figure 7(a)) and the experience at Maha-Iluppallama over

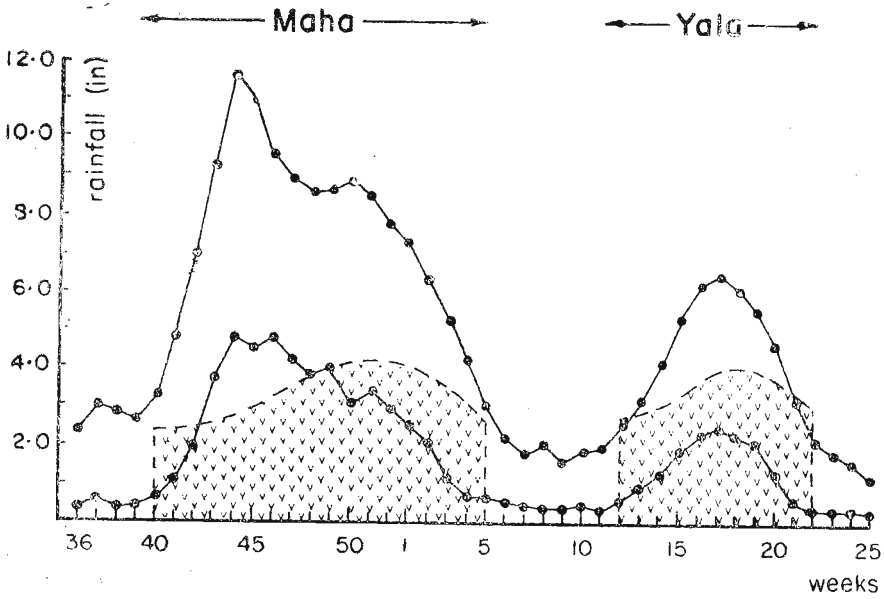


FIGURE 7 (a). Matching the crop water template of a Maha cereal crop and Yala legume crop with rainfall confidence limits of Anuradhapura.

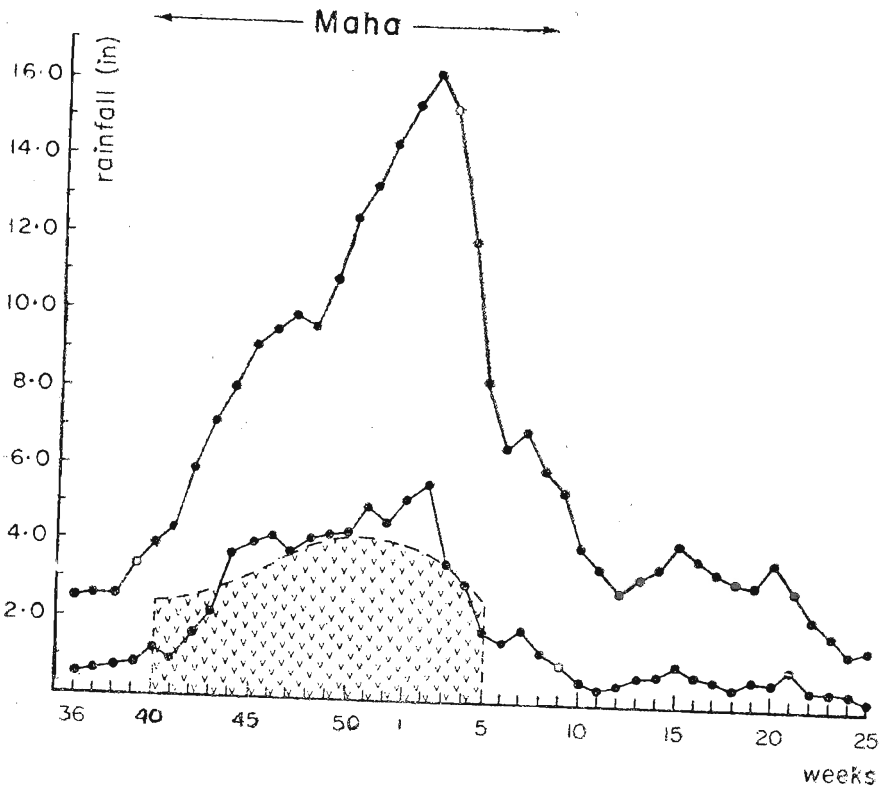


FIGURE 7 (b). Matching the crop water template of a Maha cereal crop with rainfall confidence limits of Amparai.

the past years confirms this observation in that the failure of the rainfed rice crop has always resulted from a deficiency of rainfall after around the 3rd week of December; and this has occurred with a frequency of approximately 4 years out of 10. On the other hand, for the Amparai rainfall (Figure 7(b)) there is a 75% probability that the rainfall alone could satisfy the crop water requirement for the whole duration of the period from sowing to harvest for a 120-day rainfed rice crop. It is therefore evident that a rainfed rice crop of sowing-to-harvest duration of approximately 4 months has a better chance of success in the Amparai and Batticaloa regions of the dry zone than in the Anuradhapura region. It is also clear that a shorter duration rice variety of approximately 95 to 100 days duration from sowing to harvest would be more appropriate for the Anuradhapura and adjacent regions.

As commonly experienced in several years, good crops of maize and cotton from early sowings can get adversely affected by heavy rains midway during the season. Abeyratne¹ has observed that depressions in certain crop yields, and even outright crop failures have occurred mainly on account of excessive rain during certain stages of the Maha season rather than on account of drought. This hazard of excess rain is reflected in the rainfall values represented by the upper confidence limits curve. Figures 4 to 5 show that this hazard of excess rain during the Maha season is least marked for Hambantota, Tissamaharama, Puttalam and Mannar. For all other stations, there is a significant chance of experiencing catastrophic rains during the months of November and December, and sometimes even during early January in the eastern region.

Superposing the crop water template for a 70-day Yala legume crop on the rainfall confidence limits for the Yala season of Anuradhapura (Figure 7 (a)) it becomes evident that there is only a 50% probability that the rainfall alone could satisfy the crop water requirements during this period. Furthermore, even this chance of 50% obtains only for those stations in the north central region, the intermediate zone and the area around Tanamalwila. It could also be demonstrated that a sowing-to-harvest duration not exceeding 70 days gives the best fit of crop duration with the rainfall expectancy for Anuradhapura for the Yala rainfed season.

6. Discussion and some practical applications

One of the more important problems in the intensification of agricultural production in the dry zone is the development of methods for ensuring that the best use is made of the incident rainfall, or "of every drop of rain that falls on the land" according to an ancient edict of Sri Lanka, historically associated with irrigation construction and irrigated rice culture. In rainfed agriculture, however, this involves the choice of crop and its management so that its yield is as high as possible from the water that is made available by rain as well as by soil moisture reserves. Having specified the probability of rainfall during the growing season, and with a knowledge of the

water requirements of crops during their growth, the main strategy would therefore be to tailor the crops to rainfall and adjust their management to the available sequences of soil moisture. Choosing or breeding crops whose water demands fit as closely as possible with the probable moisture supply and selection of proper sowing dates would therefore constitute the central strategy in the optimum exploitation of the rainfall resource.

The manner of choosing the proper sowing date for Anuradhapura has been outlined in Section 5. Applying the same approach to the other stations it can be established that the proper sowing dates for the stations representing the north central, north western, northern and eastern regions of the dry zone would be around the 40th week, with the exception of the area around Medawachchiya—Horowpatana-Kantalai which would be approximately 7 to 10 days earlier. For the southern region of the dry zone it would be around the 41st week, while for the area around Hambantota-Tissamaharama it would be approximately 7 to 10 days later. For stations in the intermediate zone, the proper sowing date would be around the 39th week or even slightly earlier as in some areas around Moneragala. It can thus be observed that within the dry zone itself there is a significant regional differentiation in the break of season which ranges from the 38th to the 42nd week. While traditional experience bears out this pattern of regional differentiation in broad terms, it has not been hitherto specified in a form that could be of strategic meaning to the agronomist and the plant breeder.

Similarly, the close of season could be reliably specified by the rainfall confidence limits diagrams; and the sowing-to-harvest duration for the different regions of the dry zone could be defined with a greater degree of precision than hitherto defined by using arithmetic means of rainfall. In some rudimentary form there has taken place, over the years, some kind of selective adaptation of the age class of both old and new crops to the different regions of the dry zone. This has, however, not been matched by a conscious breeding programme that has taken into account the variability of rainfall characteristics in the different regions, except at the research stations in the north central and southern region of the dry zone which have been mainly specific to their own environments. This paper demonstrates that the age class of a shallow rooting cereal crop like rainfed rice will have to be tailored to the particular region in such a manner whereby its water requirements are met solely by the incident rainfall and with little or no contribution by soil moisture reserves. On the other hand, in choosing the age class of a deeper rooting cereal crop like maize one could take into account both rainfall as well as contributions from soil moisture reserves. It could be demonstrated that the sowing-to-harvest duration for maize would be approximately 135 days for the intermediate zone and the eastern dry zone, while for the north central dry zone the present 115 day varieties would be quite appropriate.

The likelihood is that good crops resulting from the optimum time of sowing may in some years be lost by torrential rains during the middle or latter part of the season. This is a hazard that is particularly marked on the RBE where both the surface discharge and the downward drainage of surplus water is quite sluggish. It is less serious a hazard on the NCB while on the RL it presents little or no problem to management because of the high infiltration rate of the soil. The periods that correspond to the maximum likelihood of the occurrence of these catastrophic rains in the different regions of the dry zone are clearly revealed in the rainfall confidence limits diagrams. Advantage could, at the same time, be taken of the spell immediately following this period of maximum hazard to establish short duration deep rooting crops that may be harvested into late Maha.

A better feature of the Yala rainfall, despite its inadequacy to match the evapotranspiration demand of crops by rainfall alone, is the absence of this hazard of crop damage by excess rainfall. Residual soil moisture reserves from the Maha season can make a useful contribution to augment this inadequacy of rainfall in the RBE soil regions. Assuming a rooting depth of 3 ft, a RBE could contribute up to a total 5 in of available soil moisture which would help to satisfy this deficiency to some extent. Furthermore, some short age legume crops and sorghum are capable of giving good yields at high values of soil moisture tension or less ideal soil moisture conditions. The cultivation of Yala rainfed crops in the intermediate zone, the north central region and around the Tanamalvila area on the RBE soils is therefore quite feasible if the supporting management measures such as weed control, moisture conservation and optimum spacing are adopted. The appropriate sowing-to-harvest duration of crops for each of these regions could be reliably estimated from the rainfall confidence limits diagrams and the soil moisture characteristics of the particular region.

This paper has demonstrated that the patterns of rainfall expectancy have a very important bearing on the regional specialization of crops within the dry zone. Taking this factor in conjunction with our presently available knowledge of the soil moisture characteristics of the different soil regions of the dry zone, it would be possible to predict the adaptability and performance of individual crops to the different regions of the dry zone. For example, cotton which has hitherto been grown as a rainfed crop almost exclusively in the Hambantota-Tissamaharama area could be equally well extended to the red latosol areas in Mannar and Puttalam as a rainfed crop. Further, the sequences of rainfall and soil moisture that are considered desirable for the cultural operations and maturing of a rainfed sugarcane crop obtain in a satisfactory measure within the intermediate zone.

Selective allocations of areas for particular crops on the basis of a maximum chance of success is also rendered possible by the approaches outlined in this paper. Even the periods of minimum hazards to dry season irrigated crops by chances of

unseasonal rains can be reliably assessed by a study of the rainfall confidence limits. Similarly, the least number of irrigations that would be needed for irrigated crops during the Maha season could also be objectively determined by examining the rainfall confidence limits diagrams.

Some further applications that are not considered in this paper but could profitably engage the attention of other workers in related areas of study would be those concerned with (a) crop insurance planning ; (b) water resources planning ; and (c) the selective allocation of our total water resources to rainfed, semi-irrigated and irrigated farming in the dry zone. Although the full extent of all problems concerning the interaction between rainfall and crop water requirements is still not perfectly understood, these latest research findings are set out here in the hope that this new knowledge will become assimilated into agricultural practice.

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