WORKSHOP

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Planning of Crop and Water Management Practices

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1.0 Introduction

The adequacy of rainfall to meet the consumptive needs of crops and other consumptive and non-consumptive water needs is a basic requirement in any region. The considerable rainfall variability in space and time coupled with inadequate and uneven distribution of available water resources, particularly in drought prone areas, result in frequent crop failure and shortage of fodder and drinking water. Estimates of the magnitude and duration of water deficit/surplus are of vital importance for planning crop and water management practices in order to promote crop production both in irrigated and rainfed areas. Knowledge of rainfall and potential evapotranspiration (PET) is very useful to estimate the water availability periods for deciding the cropping pattern, water management and water harvesting practices and assessing the drought proneness of the area. Expected rainfall amount at various probability levels for different time periods, eg. monthly, weekly, etc. play an important role in estimating the water deficit/surplus at different periods.

Crop planning for an area depends upon number of factors, namely type of crop, cropping intensity, available water resources, climate, crop water requirements, method of irrigation, drainage, efficiency of the irrigation system, soil characteristics, topography, and socio-economic conditions, etc. However, in rainfed areas, it mainly depends upon the magnitude and distribution of rainfall both in space and time. Due to erratic behaviour of monsoon, generally there may be considerable variations of rainfall within the same month/week and from year to year. Thus, it is difficult to develop suitable predictive equations. Under such conditions, inspite of taking average rainfall values, models based on probability concept may serve more useful purpose.

1.1 Statistical Analysis

The random variability of hydrologic variables such as precipitation and stream flow has been recognised for centuries. The general field of hydrology was one of the first areas of science and engineering to use statistical concepts in an effort to analyse the natural phenomena. The use of statistics in hydrology provides information about various parameters and distribution of random variables as needed to design and operation of structures. These parameters and their distributions are estimated as approximations from the variable data because they can not be determined exactly.

Hydrologic data are mostly available as samples of limited sizes. Statistics enables the extraction of needed information from the available data and the characteristics of hydrologic random variables such as rainfall and runoff. Statistical estimates are numerical properties of samples and necessary in statistical modelling, for direct use in hydrology.

In any analysis of sample data, certain calculations are usually made to determine some of the basic inherent properties of the data. For instance, sample mean and variance are two statistics defining the most important characteristics of a given set of statistical data. In general, sample statistics provide the basic information about the variability of a given data set. The most useful sample statistics measure the following characteristics.

1. Central tendency of value around which all other values are clustered .
2. Symmetry or skewness of the frequency distribution and
3. Flatness of the frequency distribution.

Theses statistical properties are determined by sample statistics as mean, standard deviation, variance, coefficient of variation and skewness coefficient or symmetry. The sample mean measures the central tendency of a given data set. The standard deviation measures the dispersion of sample values around the mean. The skewness coefficient or coefficient of skewness measures the asymmetry of the frequency distribution of the data. The skewness coefficient has an important meaning since it gives indication of the symmetry of the distribution of the data. Symmetrical frequency distributions have very small or negligible sample skewness coefficient (C_s) while asymmetrical frequency distributions have either positive or negative coefficient. A small value of C_s often indicate that frequency distribution, of the sample may be approximated by the normal distribution function since $C_s = 0$ for this function.

The kurtosis coefficient measures the peakedness or the flatness of the frequency distribution near its centre. The positive value of excess coefficient indicates that a frequency distribution is more peaked around its centre than the normal distribution. The negative value of excess coefficient indicate that a given distribution is more flat around the its centre than the normal.

1.2 Probability Distribution

Probability is a constant characterising a given set of objects or incidents in a perticular period. The probability analysis of annual rainfall is useful to predict with reasonable accuracy of occurrence in different group intervals of annual rainfall. It is also possible to work out the exceedence probability of rainfall at different percentage levels.

One of the major problems encountered in hydrology is the estimation of probability levels from fairly short data. The probability can be conveniently estimated if the length of available data is more, however, the length of data available is generally very less. So the available short term data are used to fit probability distribution which is then used to extrapolate design events from the recorded events either graphically or by estimating the parameters of frequency distribution. Graphical method is having the advantage of simplicity and visual presentation but the main disadvantage is fitting of different curves by different users.

Determination of probability requires knowledge of the plotting positions. Chow (1964) has summarised the different plotting position formulae like California, Hazen, Weibull, Chegodayev, Blom and Turkey. The formula proposed by Weibull has been found to be theoretically suitable for plotting the annual maximum series. Hann and Shapiro (1967) concluded that Weibull formula provides estimates that are consistent with experience. Doorenbos and Pruitt (1977) presented the steps involved in determining estimates for rainfall probabilities. It was also suggested that in case of skewed distribution, square root or logarithm of the rainfall values may be attempted. For period with little or no rainfall, the plotting position is to be modified by the following equation;

$$G_a = p + (1-p)F_a \qquad (1)$$

where G_a is the probability of occurrence and p is portion in which no rainfall occurred.

The daily annual rainfall series is divided into 52 weeks, starting from January 1. The last day of every year and last 2 days in the case of leap year are also accounted in the 52nd week. The Weibull formula is normally used to determine the rainfall probabilities at various levels e.g. 50, 60, 70, 80 and 90% for all weeks. Weibull formula can be mathematically expressed as:

$$F_a = (m/N+1)^* 100 \qquad (2)$$

where
N = total number of data items;
m = number of items arranged in descending order of magnitude; and
F_a = plotting position.

The following continuous distributions are normally used to fit the rainfall series.

Normal distribution - The normal distribution is one of the most important distributions in statistical hydrology. This is used to fit empirical distributions with symmetrical histograms or with skewness coefficient close to zero. The normal distribution enjoys unique position in the field of statistics due to its role in the central limit theorem. This theorem validates its use as an approximation to other distributions. The central limit theorem states that the distribution of sums of random variables from any distribution tends to a normal distribution as the number of terms in the sum increases.

Log normal distribution - Log normal distribution can be applied to a wide variety of hydrologic events especially in the cases in which the corresponding variable has a lower bound, the empirical frequency distribution is not symmetrical and the factors causing those events are independent and multiplicative. Chow (1964) provided a theoretical justification for the use of the log normal distribution. The causative factors for many hydrologic variables act multiplicatively rather than additively and so the logarithms of the peak flows, which are the product of these causative factors, follow the log normal distribution.

Pearson type III distribution - Pearson type III distribution is a three parameter distribution. This is also known as Gamma distribution with three parameters.

Log Pearson type III distribution - The log pearson Type III distribution has been widely used in hydrology, particularly for fitting the frequency distribution of flood data. The U.S. Water Resources Council recommended the use of Log Pearson type III distribution as an attempt to promote a uniform and consistent approach for flood frequency studies. As a result, the use of this distribution has become popular in the United States and has brought the attention of practicing engineers from Federal, State and local government as well as private organisations.

Extreme value distributions - Just as there is a family of Pearson type III distributions, each member being characterized by a value of γ there is also a family of EV distributions, each member of which is characterized by the value of a parameter denoted by k. The family can be divided into three classes, corresponding to different ranges of k values. The three classes are referred to as Fisher Tippett type 1, type 2 and type 3. They are also known as EV-1, EV-2 and EV-3 distributions. In practice, k value lie in the range-0.6 to + 0.6 For EV-1 distribution value of k is zero and for EV-2 and EV-3 - ve and + ve respectively.

1.3 Evapotranspiration and Potential Evapotranspiration

Water is essential for plant growth. It is needed for seeds to germinate, seedlings to emerge and for many plant growth functions. Water prevents the dehydration of plants, and provides the transport mechanism for plant nutrients and the products of photosynthesis. Crop yields under controlled irrigation are higher than rainfed conditions under similar climatic conditions. Because crop yields on irrigated lands are higher and more consistent than rainfed areas, irrigation plays an important role in stabilizing food and fibre production. The main objective of irrigation is to provide sufficient water to plants thereby preventing stress that may cause reduced yield or poor quality of harvest. The required timing and amount of irrigation (irrigation scheduling) is governed by the prevailing climatic conditions, type of crop and its stage of growth, soil moisture holding capacity, and the extent of root development.

In order to find out 'when' and 'how much' amount of irrigation is needed, it is necessary to know the consumption of water (evapotranspiration) by various crops in the field. One way to find 'when' is to observe crop indicators such as change of color or leaf angle, but this information may be too late to avoid reduction in crop yield and quality. The scientific approach to find 'when' and 'how much' would be to estimate water requirements of crops and then based on soil water balance predict 'when' and 'how much'. Researchers have investigated various ways of estimating crop water requirements by conducting experiments or developing empirical relations.

Only a small portion of the water absorbed by the root system of a plant remains in the plant tissue, virtually all is discharged to the atmosphere as vapour by a process called transpiration. This process constitutes an important phase of the hydrologic cycle since it is the principal mechanism by which the precipitation falling on land surface is returned to the atmosphere. For studying the water balance of a drainage basin, it is required to find out the evapotranspiration, a component which is combination of evaporation and transpiration. Transpiration is basically an evaporation process.

1.3.1 Estimation of Evapotranspiration

Evapotranspiration is a combined process by which water is transferred from earth surface to the atmosphere. It includes evaporation of liquid or soil water from soil and plant surfaces plus transpiration of liquid water through plant tissues expressed as the latent heat transfer per unit area or its equivalent depth of water per unit area (Jensen, 1983). Thornthwaite (1948) stipulated that soil moisture may have an effect upon the evapotranspiration and therefore suggested a term potential evapaotranspiration to define the transpiration that would occur in case of adequate supply available at all times. Jensen (1983) defined potential evapotranspiration as the rate at which water, if available, would be removed from the soil and plant surface expressed as the latent heat transfer per unit area or its equivalent depth of water per unit area. It has been found that evapotranspiration depends on the density of cover and its stage of development. Therefore, potential ET needs to be defined with reference to a particular surface cover. Some investigators in western USA have used the ET from a well-watered crop like alfalfa with 30-50 cm of top growth and at least 100 m of fetch, as representing potential ET (Jensen, 1974). Penman (1956) suggested that the original definition be modified to include the stipulation that the surface be fully covered by green vegetation. Van Bavel (1966) defined potential ET as evapotranspiration that occurs when the vapour pressure at the evaporating surface is at the saturation point. Doorenbos and Pruitt (1977) defined the effect of climate on crop water requirements by the reference crop evapotranspiration (E_{To}) which they defined as 'the rate of evapotranspiration from an extensive surface of 8-15 cm tall, green grass cover of uniform height, actively growing, completely shading the ground and not short of water.

The crop evapotranspiration depends on several crop and environmental conditions such as climate, soil moisture, type of crop, stage of growth and the extent to which plants cover the soil. Hence, in order to have accurate estimates of crop E_T it is necessary to take these factors into account. If estimates of potential E_T for a reference crop are available, the estimates of E_T for specific crops can be made using the relation,

$$E_T = K_c \, Ep \qquad (3)$$

where,

K_c = crop coefficient
E_T = actual evapotranspiration
Ep = potential or reference evaporation

Experimentally developed crop coefficients reflect physiology of the crop, the degree of the crop cover, and the reference Ep. Factors affecting the values of crop coefficient (Kc) are mainly the crop characteristics, crop planting or sowing date, rate of crop development, length of growing season and climatic conditions. For experimental determination of crop coefficients, ideally, both crop E_T and reference Ep are measured concurrently. The crop coefficient is then calculated as the dimensionless ratio of the two measurements. Crop coefficients may either be based on alfalfa or green grass. Alfalfa is normally selected for reference Ep because it has relatively high E_T rates in arid areas where there is considerable advective sensible heat input from the air. The procedure for establishing alfalfa based crop coefficient is described in detail by Jensen (1974) and Jensen et al. (1971) . Doorenbos and Pruitt (1977) have described grass based crop coefficients in F.A.O. Irrigation and Drainage paper 24. They have divided the growth period of field and vegetable crops into four stages viz. i) initial stage, ii) crop development stage, iii) mid-season stage and iv) late season state. A procedure has been described to develop crop curve i.e. distribution of crop coefficients with time for various field and vegetable crops.

A lot of work has been done on water requirement of field crops in India. For principal crops like paddy, wheat, maize, bajra, barley, groundnut, mustard, linseed, cotton and sugarcane, the water requirement/irrigation requirement for different parts of the country have been suggested in literature.

1.3.2 Water requirement

A rational planning and management of water resources is not possible without comprehensive assessment of the need and availability of water. It includes the irrigation water requirement, domestic water requirement, industrial water requirement and water requirement for livestock.

1.3.2.1 Irrigation water requirement

The estimation of water requirement of crops is one of the basic needs for crop planning of any irrigation project and rainfed areas. Water requirement may be defined as the quantity of water, regardless of its source, required by a crop or diversified pattern of crops in a given period of time for its normal growth under field conditions at a place.

The irrigation water requirement for a crop depends upon the irrigation need of crop, the area occupied by the crop and losses in the water distribution system. Irrigation water requirement, IR is given by

$$IR = WR - ER + Losses \qquad (4)$$

where,

WR= Crop water requirement, and
ER= Effective rainfall.

1.3.2.2 Crop water requirement

Crop water requirement may be defined as the quantity of water, regardless of its source, required by a crop for its normal growth under field conditions at a place. Crop water requirement may be formulated as follows:

WR = Evapotranspiration + application losses + special needs

Application losses include the loss of water during water application. These losses are unavoidable losses. Special needs include water required for land preparation, transplanting, leaching, etc.

1.3.2.3 Effective rainfall

Some part of the total water requirements of crop may be met by rainfall. Effective rainfall is that part of rain which enters the root zone and remains there as soil moisture. Crop water needs can be fully or partly met by rainfall. A part of total rainfall may be lost by surface runoff, deep percolation and evaporation. In case of rainfall of high intensity only a part of the rain enters and is stored in the root zone and the quantity of effective rain is low. Frequent light intensity rains on an area are more effective for meeting the crop water requirement. With dry soil surface and little or no vegetative cover, rainfall upto 8 mm/day may be lost totally by evaporation. For rains of 25 mm to 30 mm per day with low percentage of vegetative cover, only 60 percent of it is contributes as effective rainfall.

A number of empirical formulae can be used for estimating the effective rainfall. The formula developed under a given set of conditions may not be applicable for different conditions elsewhere. However, in this study, consumptive use/precipitation ratio method developed by soil conservation service of USDA (1969) has been adopted. In this method, monthly effective rainfall is related to monthly consumptive use as presented in table 1. The soil water storage capacity in the crop root zone at the time of irrigation is assumed to be equal to 75 mm.

1.4 Objective of the Study

The main objective of the study is to evolve a strategy for contingency crop planning and water management practices to promote crop production in rainfed areas based on the magnitude and duration water deficit and surplus.

The study involves the following steps:

1. Sample statistical analysis
2. Estimation of weekly probability of exceedence at 50, 60, 70, 75, 80 and 90% levels for the study area using suitable statistical distribution.
3. Identification of principal crops swon in the area and estimation of consumptive use of each crop different stages of growth.
4. The adequacy of rainfall to meet the consumptive use of crops is worked out in accordance with probability of exceedence level and effective rainfall for the crop.
5. Evolve a crop contingency plan and management strategy for the study area with crop types and rainfall probabilities.

2.0 Study Area

In the present study, two districts namely, Raichur and Koppal were selected. However, until recent past both the districts were together called as Raichur district. Undivided, Raichur district was between latitude 75° 50' and 77°40', longitude 15° 10' 16° 32' and a geographical area

13,88338 Hectares. The whole district was encompassed by Thungabhadra and Krishna rivers acting as a doab. About half of geographical area of the district was contributing catchment for Thungabhadra river and rest half contributing to the Krishna river. The divider of Thungabhadra and Krishna basins lies within the district. Out of nine taluks in the district, five taluks namely Gangavathi, Koppal, Kustagi, Sindhanur and Yalberga comes under newly constituted district Koppal district. Koppal, Yelberga and Kustagi taluks are considered to be rainfed areas. Raichur, Deodurga, Manvi and Lingasugur taluks are in the divided Raichur district. Except Lingasugur taluk, all other taluks in newly constituted Raichur district considered are as rainfed areas. Both the districts come under north-eastern and north dry zones of Karnataka state. The location map of the study area presented in the figure 1.

3. 0 Methodology

The basic aim of the study to find out the adequacy of rainfall to meet the consumptive needs of principal crops grown in the study area. The considerable rainfall variability in space and time coupled with inadequate and uneven distribution of available water resources in raifed areas. Therefore statistical analysis has been carried out to find out the distribution of rainfall in space and time. Estimate of the magnitude and duration of water deficit and surplus are of vital importance for planning crop and water management practices to promote crop production both in irrigated and rainfed areas. The estimation of probability exceedence at different percentage levels and consumptive use of crops in the study area has been carried out to estimate the magnitude and duration of water deficit and surplus.

3.1 Sample Statistics

Two raingauge stations namly Raichur and Devadurg for Raichur district and three rain gauges namely Koppal, Yelburga and Kustagi for Koppal taluk were used for the statistical anlysis of weekly rainfall over the selected study area. Daily rainfall data 22 years(19**-19**) have been analysed for mean, standard deviation, variance, coefficient of variability, and coefficient of asymmetry.

3.2 Probability Analysis

Weekly rainfall data for 22 years (19**-19**) for both Raichur and Koppal districts have been analysed for estimating expected rainfall at different probability levels. For planning crop and water management practices water deficit/surplus using Gauss, Lognormal, Gumble Pearson Type -III and Weibul formula. Lognormal and Weibul have been found to give better consistancy in estimating the probability levels. In the present study, Weibul formula has been used to estimate the probability levels. The daily annual rainfall series was divided into 52 weeks, starting from January 1. The last day of every year and last 2 days incase of leap year were also accounted in the 52nd week. The Weibul formula was used to determine the rainfall probabilities at various levels, e.g. 50, 60, 70, 80 and 90% for all weeks. Different steps involved in this analysis are,

a. Tabulation of weekly data

b. Arrangement of weekly data in descending order.

Thus if x_1, x_2, x_3, ...x_n are the original unordered observations then the ordered observations to be denoted x_1, x_2, x_3, ...x_n are such that x_1,>> x_2,>> x_3, >>, ...x_n assigning serial numbers, m, to weekly data thus m=1 for the largest magnitude and every successive data in the descending order is assigned as 2, 3, 4,...,m.

c. determination of plotting position, Fa by use of equation (2).

d. For periods with little or no rainfall use equation (1)

e. Plot values of F_a or G_a on X- axis and the rainfall sequences on Y- axis on arithmetic probability paper.

f. Determination of magnitude of rainfall for 50, 60, 70, 80, and 90% probabilities.

Rainfall at 50, 60, 70, 80and 90% probability levels for all the weeks have been given in tables 4 and 5 for study areas.

Different weightages were assigned to normal distribution, log normal distribution and square root distribution to determine the mixed distribution. Based on chi-square test, it was found that lognormal distribution fits better as compared to normal and square root distributions. Rainfall for different probabilities for all weeks was determined from probability graphs and corresponding values are worked out. The fitted distribution and probability of exceedance equation for both Raichur and Koppal Taluk has been worked out.

3.3 Estimation of Consumptive Use

The consumptive use a crop depends upon the type and stage of growth, soil moisture, soil type and environmental conditions such as climate. Factors affecting the crop coefficient (K) are mainly the crop characteristics, crop planting and sowing date, rate of crop development, length of growing season and climatic conditions. For the present study, crop coefficients were taken as given by Water Management Division, Department of Agriculture, Irrigation, Govt. of India, 1971.

Monthly pan evaporation data of Kustagi for Koppal district and Yermuras for Raichur district from 1990 to 1998 were used to estimate the monthly potential evapotranspiration of principal crops grown in the study area. The potential evapotranspiration of each principal crops were estimated under rainfed. The variation of potential consumptive use under probability levels of 50%, 60%, 70%, 80%, and 90% and its deficit/surplus of rainfall at all probability levels have been estimated.

4.0 Results And Discussion

4.1 Statistical Distribution of Rainfall

(a). Raichur District

Annual rainfall in Raichur district ranges from 430.00mm to 1020.00mm. Normal rainfall is estimated for 22 years 732.5 mm with standard deviation 163.11 mm, coefficient of variation +0.223 and coefficient of asymmetry +0.445. The overall situation of rainfall distribution over the years has been found to be reasonably dependable as probability of occurrence of 75% and 50% normal rainfall were estimated as 87 and 100 per cent respectively.

Rainfall distributed from April to December with maximum occurring during the months of July, August and September. Weekly rainfall values were used for the statistical distribution. Mean weekly rainfall ranges from 0 to 42.09mm. Most of the rainfall normally occurs between June to October. It can be observed that standard deviation ranges from 1.1 to 54.82, coefficient of variation from 0.8 to 3.14 and coefficient of asymmetry 1.67 to 6.28 in all the rainfall weeks. It implies that the distribution of rainfall is highly scattered and not dependable on weekly basis.

The weekly probability levels were estimated by Weibull plotting positions, 50% probability ranginges from 0 to 31.56mm of rainfall, 60% probability 0 to 26.74mm rainfall, 70% probability 0 to 21.93mm rainfall, 80% probability 0 to17.11mm rainfall, and 90% probability 0 to 12.41mm rainfall.

(b) Koppal

Annual rainfall in Koppal taluk ranges from 351.00mm to 943.00mm. Normal rainfall was estimated for 22 years 592.89mm with standard deviation 150.061mm, coefficient of variation +0.253 and coefficient of asymmetry +0.506. The overall situation of rainfall distribution over the years has been found to be reasonably dependable as probability of occurrence of 75% and 50% normal rainfall were estimated as 93 and 100 per cent respectively.

Rainfall is distributed from April to December with maximum occurring during the months of July, August and September. Weekly rainfall values were used for the statistical distribution. Mean weekly rainfall ranges from 0 to 42.33mm. The most of the rainfall normally occurs between June to October. It can be observed that standard deviation ranges from 6.26 to 45.73, coefficient of variation 0.72 to 2.81 and coefficient of asymmetry 1.44 to 5.62 in all the rainfall weeks. It indicates that the distribution of rainfall is highly scattered and not dependable on weekly basis.

The weekly probability levels were estimated Weibull plotting positions, 50% probability ranges from 0 to 33.01mm of rainfall, 60% probability 0 to 29.39mm rainfall, 70% probability 0 to 23.78mm rainfall, 80% probability 0 to19.16mm rainfall, 90% probability 0 to 14.41mm rainfall.

Rainfall for both the districts follow almost same pattern and reasonably dependable on annual basis. However, it is highly erratic in nature on weekly basis.

In both the study areas (Raichur and Koppal), different probability levels have almost the same ranges of rainfall values inspite of higher rainfall in Raichur district. It indicates homogeneity in pattern of scattering and distribution of rainfall for both the districts. However, exceedence probability of rainfall at different levels namely 50%, 60%, 70%, 80% and 90% are higher in the case of Koppal.

Ranking and weighed transformation distribution relationships were established. The correlation coefficients are ranging from 0.64 to 0.97 in case of Koppal district, whereas it is ranging from 0.58 to 0.98 in the case of Raichur. However, in most of the cases, coefficient of correlation was estimated to be around 90%. Therefore, the established relationship cans be used to find the weekly rainfall corresponding to different percents of exceedence probability.

4.2 Variation of Monthly Rainfall probability and Consumptive Use of Crops

(a) Raichur

Even at the status of normal rainfall, there is about 200mm of deficit in rainfall to meet the water requirement of paddy crop. At this present scenario, paddy crop can only be grown in Raichur district with provision of extra irrigation sources.

The monthly variation of rainfall at different probabilities and consumptive use of jowar, maize and bajra in the kharif season. Under normal conditions of mean rainfall, it is just sufficient to meet water requirement the crops (jowar, maize, bajra).

The monthly variation of rainfall at different probabilities and consumptive use of redgram, horsegram and copea in the kharif season. In the present crop calendar for these crops, later part of the cropping period has to be supplemented by irrigation either surface water resources or groundwater resources depending upon the availability. If this alternative is not feasible, crop calendar may have to be shifted to one or two months in advance for these crops..

The monthly variation of rainfall at different probabilities and consumptive use of castor, soyabean and niger in the kharif season. Under normal conditions of mean rainfall, it is just sufficient to meet water requirement of these crops.

The monthly variation of rainfall at different probabilities and consumptive use of groundnut, sesame and sunflower in kharif season. Under normal condition of mean rainfall it is just sufficient to meet all crops. However, for the rainfall below normal mean, then water has to be supplemented by other sources.

The monthly variation of rainfall at different probabilities and consumptive use of blackgram, greengram and avare in the kharif season. Under normal conditions of mean rainfall it is just sufficient to meet water requirements of these crops. In the months of June and July, even 50% of probability rainfall can meet the required crop water requirement for avare and blackgram. However, in the months of August and September, if the rainfall is below 50% probability level, then water has to be supplemented by other sources. In the case of greengram, 50% of rainfall probability can also just meet the water requirement.

The monthly variation of rainfall at different probabilities and variation of consumptive use of jowar, maize and wheat in the rabi season. It can be seen from the figure that under the present crop calendar, it is not possible to grow any of these crops additional application of water from other sources. Initial part of the growing season can be met by rainfall if it is under normal rainfall category. Under such cases, either cropping calendar has to be changed or irrigation water has to be drafted from other sources.

The monthly variation of rainfall at different probabilities and variation of consumptive water requirement for linseed, soyabean, and sunflower in the rabi season. It can be seen from the figure that under the present crop calendar, it is not possible to grow any of these crops without additional application of water from other sources. Initial part of the growing season can be met by rainfall if it is under normal rainfall category. Under such cases, either cropping calendar has to be changed or irrigation water has to be drafted from other sources.

The monthly variation of rainfall at different probabilities and consumptive water requirement for bengalgram in rabi season. It can be seen from the figure that under the present crop calendar, it is not possible to grow the crop without additional application of water from other resources. Initial part of the growing season can be met by rainfall if it is under normal mean rainfall. Under such cases, either cropping calendar has to be changed or irrigation water has to be drafted from other sources.

The monthly variation of rainfall at different probabilities and variation of consumptive water requirement for greengram, groundnut, and sesame in the summer season. It can be seen from the figure that, it is not possible to grow these crops without supplemental irrigation by surface or groundwater resources.

The monthly variation of rainfall at different probabilities and consumptive water requirement for copea and sunflower in the summer season. It can be seen from the figure that, it is also not possible to grow all these crops without supplemental irrigation by surface or groundwater groundwater resources.

(b) Koppal

The monthly variation of rainfall at different probabilities and variation of consumptive water requirement for rice in the kharif season. As can be seen from the figure, even at the status of normal rainfall, there is about 250mm of deficit in rainfall to meet the water requirement of paddy crop. At this present scenario, paddy crop can only be grown in the district with provision of extra irrigation sources.

The monthly variation of rainfall at different probabilities and variation of consumptive use of jowar, maize and bajra in the kharif season. Under normal conditions of mean rainfall, it is not sufficient to meet water requirement of these crops (jowar, maize, bajra). However, if the crop calendar can be shifted by one month later, then the most of the crop water requirement can be met under normal mean rainfall conditions.

The monthly variation of rainfall at different probabilities and variation of consumptive use of redgram, horsegram and copea in the kharif season. In the present crop calendar for these crops, it is just sufficient to meet the crop water requirement of horsegram and copea. However, for redgram later part of the cropping period needs to be supplemented by either surface water resources or groundwater resources depending up on the availability. Otherwise, crop calendar may be shifted to one or two months in advance than the existing practice.

The monthly variation of rainfall at different probabilities and variation of consumptive use castor, soyabean and niger in the kharif season. Under normal condition of mean rainfall it is not sufficient to meet water requirements of these crops (castor, soyabean, niger). However, if they shift the crop calendar by one month later, the magnitude of water deficit can be reduced under normal rainfall condition. Alternative measures are to be adopted to meet the crop water requirement of these crops.

The monthly variation of rainfall at different probabilities and variation of consumptive water requirement of groundnut, sesame and sunflower in the kharif season. Under normal condition of mean rainfall it is not sufficient to meet water requirements of these crops (groundnut, sesame, sunflower). However, if they shift the crop calendar by one month later, the deficit of crop water requirement can be reduced under normal rainfall condition. Alternative measures are to be adopted to meet the crop water requirement of these crops.

The monthly variation of rainfall at different probabilities and variation of consumptive water requirement of blackgram, greengram and avare in kharif the season. Under normal conditions of mean rainfall, it is just sufficient to meet water requirements, of greengram but not sufficient to meet water requirement of avare and blackgram. However, crop calendar for these crops (avare and blackgram) is sfifted by one by one month later, their crop water requirement can be met under normal rainfall conditions. However it is necessary to take alternative measures to meet the crop water requirements of these crops under the existing crop calendar.

The monthly variation of rainfall at different probabilities and variation of consumptive water requirement of jowar, maize and wheat in the rabi season. It can be seen from the figure that under the present crop calendar, it is not possible to grow any of these crops without additional application of water from other sources. Initial part of the growing season can be met by rainfall if it is under normal rainfall category. Under such cases either cropping calendar has to be changed or irrigation water has to drafted from other sources.

The monthly variation of rainfall at different probabilities and variation of consumptive water requirement of linseed, soyabean, and sunflower in the rabi season. It can be seen from the figure that under the present crop calendar, it is not possible to grow any of these crops without additional application of water from other sources. Initial part of the growing season can be met by rainfall if it is under normal rainfall category. Under such cases either cropping calendar has to be changed or irrigation water has to be drafted from other sources.

The monthly variation of rainfall at different probabilities and variation of consumptive water requirement of bengalgram in the rabi season. It can be seen from the figure that under the present crop calendar, it is not possible to grow the crop without additional application of water from other sources. Initial part of the growing season can be met by rainfall if it is under normal rainfall category. Under such cases, either cropping calendar has to be changed or irrigation water has to be drafted from other sources.

The monthly variation of rainfall at different probabilities and variation of consumptive water requirement of greengram, groundnut, and sesame in the summer season. It can be seen from the figure that, it is not possible to grow these crops without supplemental irrigation by surface water or groundwater resources.

The monthly variation of rainfall at different probabilities and variation of consumptive water requirement of copea and sunflower in the summer season. It can be seen from the figure that, it is also not possible to grow these crops without supplemental irrigation by surface water or groundwater resources.

5.0 Conclusions and Recommendations

The following conclusions and recommendations have been drawn from the study.

1. The annual rainfall distribution over the years are reasonably dependable.
2. The distribution of rainfall is highly scattered in respect of spatial and temporal and not dependable on weekly basis.
3. Nearly 75 to 80 % of the annual rainfall are received during the monsoon season (June to September) associated with temporary dry spells in between causing damages to kharif crops with an average annual rainfall 592 to 732mm. The erratic behavior of monthly rainfall distribution has been observed for both Raichur and Koppal districts. Therefore, it is difficult to develop prediction equations for rainfall. Under such a situation, instead of taking average rainfall values, models based on probability concept may serve as more useful purpose.
4. The established relationships for Raichur and Koppal districts for different weeks can be used to find the weekly rainfall corresponding to different percents of exceedence probability.
5. Longer periods of daily rainfall data may be used to estimate better consistent probability to make more reasonable crop planning.
6. Tables 14, 15, 16 and 17 show the recommended crop calendar with alternative measures to be taken for better management of water resources. These suggestions are applicable only under normal rainfall condition. However, under 50%, 60%, 70%, 80%, and 90% exceedence probability levels, water requirement of crops need to be supplemented either by groundwater sources or by surface water sources.
7. Paddy crop can not be grown under only rainfed conditions in both Raichur and Koppal districts. Otherwise, about 250mm of irrigation water is additionally required to grow paddy crop in Raichur and Koppal areas.

8. There is a need to change the cropping pattern and crop calendar. Under the existing distribution of rainfall, cropping pattern for Koppal and Raichur districts are the recommended.
9. Shifting of crop period may not always be suited as there may be overlapping of Kharif, Rabi and summer crops. In such cases, shorter period, high breed variety crops may be adopted.
10. Estimation of weekly crop water requirement is suggested for all principal crops as one month is a relatively long period when compared to entire crop growth period. This would provide useful information for evaluating climatic potential for deciding suitable cropping pattern more effectively.
11. In the present expected rainfall distribution, the chances of growing rabi and summer crops in the study areas are not favourable.
12. Water and soil moisture conservation measures are recommended to improve the agricultural practices in Raichur and Koppal districts.

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