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Agronomical Analysis of the Characteristics of the Precipitation (Case Study: Sabzevar, Iran)

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Abstract: In scientific agricultural planning, it is necessary to know how the precipitation occurs. This is especially important in rain-fed agriculture, because of its complete dependence on the precipitation. The occurrence of rainfall in Sabzevar, Iran has been analysed, based on daily rainfall data of fifty years. Some important agronomical parameters, such as start and end of rains, rainy periods, probability of the occurrence of wet and dry spells following a rainy and/or a dry day, maximum daily rainfall with different probabilities, cumulative ratio of the start and end of rains based on agronomical assumptions, estimation of annual and monthly rainfall and their cumulative ratios, estimation of the average number of rainy days during each month, estimation of the amount of daily rainfall in different return periods (2 to 200 years), probability of the occurrence of the number of rainy days in different months, and prediction of different dry spells, have been analysed, using SMADA and EXCEL software. All of the above characteristics, have been estimated for this station based on their agronomical importance in rain-fed agriculture.

Key words: Dry spell, rainy days, start and end of rains, Sabzevar, Iran

INTRODUCTION

The most common method of agronomical analysis of precipitation, is the collection of rainfall data of arbitrary of 5, 7 or 10 days. But most useful agronomical information is lost by adding rainfalls, especially during dry spells, at the start and end of rainfalls (Stern *et al*., 1982a,b). For agricultural experts, the essential questions about rainfall are related to the start, end and duration of rainfall, rainfall distribution throughout the year and the danger of occurrence of dry spells. Lots of research has been carried out about the subject, but a small number of them are based on daily data. The exact analysis of measuring rainfall for agricultural purposes, start with daily data. In this case lots of data should be analyzed. The daily data analysis is complicated, because there is a logical probability that there may be a day without rainfall during a precipitation period. Recent developments about the methods of daily rainfall have shown more precise prediction of the rainfall characteristics in each region (Dennett *et al*., 1984 Garbutt and Dennett, 1981; Hoogmoed and Klaij, 1990). Although the multiple-day rainfall may not be a random independent phenomenon, but experiences have showed that long-term daily rainfalls are in fact of independent phenomena (Kite, 1985). So, using suitable mathematical and statistical models, based on analysis of random independent findings can be useful in solving many problems (Alizadeh and Sarafraz, 1988).

Stern *et al*., (1981) have investigated the start of rainfalls in Western Africa with two methods: direct and model. They have found out the dependence of the start of rainfall to the latitude of the region and preference of model method upon traditional analysis. They also pointed out some obvious advantages of using daily rainfall data with respect to weekly and monthly data. The data of the start of rainfall is an important climatic variable in arid regions of the world. They also used simple methods to analyze the daily rainfall of Nigeria and India, without using computer and by fitting the long-term daily rainfall data and using normal distribution (Stern *et al*., 1982a). Then, they developed a probability model of daily rainfall, by using computer software and fitted the model, and finally, compared and analyzed the results of the model and direct methods (Stern *et al*., 1982b).

Dennett *et al*. (1983) found no correlation among rainfalls during rainy season by analyzing more than 50 years of Western African meteorological data. They could calculate conditional distributions, like probability distribution, rainfall duration and real time of the start of the rainfall, assuming independence of data. Dennett *et al*. (1984) could compare daily rainfall of each region, using rainfall regimes of 6 stations in Northern Syria and fitting the model. Probability of occurrence of rainfall and average rainfall in each rainy day was different in these regions, regularly. They extracted the data required in agricultural section from this model and pointed out that knowing the similarities and differences among points

under comparison to make recommendations about technology and suitable agricultural practices, are important.

Alizadeh and Sarafraz (1988) investigated occurrence of rainfall based on daily data of Mashhad region. For this purpose, they selected different tests and frequency of occurrences and used the most suitable of them. Annual rainfall, monthly rainfall, the start of and end of rainfall, rainfall duration, daily rainfall, consecutive number of rainy days and drying spells were calculated for different return periods. They also calculated and estimated start and end of rainfall based on agronomical definitions of the region.

Adiku *et al.* (1996) investigated rainfall variations in two Savana regions of Ghana. They estimated dry and wet spells using 20 years rainfall data of each region, also pointed out that a complete answer to basic questions, like suitable conditions for rain-fed crop production which needs water balance in each region, including the capacity of crop water requirement in the soil, is necessary. Rainfall variations at the beginning of plant growth season and also in the middle of the season (less than crop water requirement), causes less growth and as a result in yield reduction. For this reason, although the single rains make the soil enough wet for plant sowing, but these events may occur along with dry spells (Rastegar, 1993). Even in the regions with high rainfall, the single events may have severe storms and a considerable loss of rainfall in the form of surface runoff. So, decisions about the start of crop production and yield management after a rainfall, must be made with more precision (Hoogmoed and Klaij, 1990). Also, in the regions with high rainfall after a long dry spell, plant growth and development may be prevented (Stern *et al.*, 1981). For this reseason, classification of different rainfall regimes is an important factor in the research and development of agriculture (Stern *et al.*, 1982 a, b).

Rastegar (1993) determined that the threshold of rain-fed agriculture is 250 mm rainfall. The determination has a high necessity in rain-fed regions. It is obvious that long-term data is more suitable for precise estimation of agronomic parameters.

Determination of probability of occurrence of rainy and dry spells after each dry or rainy days in Sabzevar is necessary, due to the kind of climate and importance of rain-fed crop production in the county. Because of the high number of long-term daily rainfall data, their analysis is difficult. On the other hand, time and struggle for inputting the daily rainfall data into computer, for using software are considerable too. The main work of this research is possible summarizing a great volume of data, without ignoring any important information. The statistical period is 50 years, although Stern *et al.* (1982a) pointed out that 10-year data gives logical results. This research, is a suitable method to achieve practical results to assess the dates of preparing farm land and the time of sowing in rain-fed agriculture. The direct method of analysis in daily rainfall occurrence, includes determination and estimation of agronomical characteristics of precipitation in a region.

The aims of this research are:

- Collection of long-term daily rainfall data from Sabzevar meteorological station.
- Extracting important agronomical parameters such as:

The data of start and end of rainfall and their cumulative ratio based on agronomical assumptions.

Rainfall duration.

•Estimation of the average number of rainy days in each month.

•Estimation of daily rainfall with different return periods (from 2 to 200 years).

•Maximum 24-hour rainfall with different return periods.

•Probability of occurrence of consecutive rainy days in different months.

• Forecasting of occurrence of different dry spells.

MATERIALS AND METHODS

The main materials of this research are the meteorological data of Sabzevar station, obtained from Iranian Meteorological Organization. The data includes, raw daily, monthly and annual rainfall, the geographical characteristics of this station (longitude of 57°43′, latitude of 36°12′ and Mean sea level of 977 m).

To determine the most suitable statistical distribution for rainfall data, Residual Sum of Squares (RSS) is used:

$$RSS = v\ (Qe - Qo)^2/(n-m).$$

where Qe is the actual value, Qo is the estimated value, n is the number of data and m is the number of parameters of types of statistical distributions (Alder and Rasler, 1990). The most suitable distribution is the one with the least RSS (Shokohi, 1999). Annual rainfall is obtained and by using SMADA software, the annual rainfall with different return periods are calculated. The same procedure is used for annual rainfall.

The start of rainfall can not be obtained easily for agronomical aspects, because the rain does not start in a predetermined time. Besides, the first precipitation, is not the start of it. Perhaps after a rainfall, a long dry spell occurs, so that the agronomic effect of the rainfall is also lost. In this research the start of the rainfall is based on the following 3 assumptions (Alizadeh and Sarafraz, 1988):

- The first day after September 23 with cumulative rainfall of at least 25 mm.
- The first day after September 23 with cumulative rainfall of at least 20 mm and next rainfall occurs in less than 15 days.
- The first 10-day duration after September 23, in which the cumulative rainfall is 15 mm or more.

In all above assumptions, the starting date of investigation is September 23. Then the dates of starting the rainfall are investigated statistically. To define probability the Wiebull formula (p = m/ (n+1)) is used which gave the best results in previous studies (Alizadeh and Sarafraz, 1988).

The end of rainfall is also the parameter that its definition is difficult in arid region of the word. This definition should be in complete relationship with the definition of the start of rainfall. In this study, the end of precipitation, is the last date of precipitation after March 21 and after that the dry spell is over 20 days (Alizadeh and Sarafraz, 1988). In other words, the first occurrence of a specific dry spell is obtained after last rainfall in a specified date.

When satisfactory definitions of the start and end of rainfall exist, the rainfall duration for each year or its long-term averages in each region, is obtained by deduction of the date of end of rainfall from its date of start. Rainfall duration is actually showing the start and end of rainfall in each water year (Sept-Sept) and long-term estimation of it is carried out with different probabilities.

The rainy day is defined as a day in which the amount of rainfall is 1 mm or more. During precipitation period, all days are not rainy and the probability of occurrence of rainfall is not equal in each day. Occurrence of rainfalls are very indetermined during precipitation period.

To estimate the daily rainfall, the amount of rainfall during rainy days in statistical period, is used and by statistical analysis, the amount of rainfall with different return periods is calculated.

Maximum daily rainfall is obtained from data of each year and by using statistical analysis and most suitable statistical distribution, the maximum 24 h precipitation with different return periods were calculated.

The consecutive rainy days of each year (1-day, 2-day, 3-day, ...) were prepared from existing data and after statistical analysis, the probability of occurrence of consecutive rainy days were estimated.

Study of distribution of dry spells, is an important part of detail analysis of daily rainfall data. The danger of occurrence of dry spell affects most agricultural decisions especially in rain-fed agriculture. To do research about dry spells, first a threshold is defined, which less than that, a day is called dry. In this study, a dry day is a day with rainfall of 0 to 1 mm. This definition is in direct relationship with agronomic uses of the amount of rainfall. With this situation, even in days that rainfall is not measurable, the plant is able to use it and the amount of evapotranspiration decreases considerably in that day (Alizadeh and Sarafraz, 1988). The dry spells can have any period. This is possible by looking at raw meteorological data (during rainy period of each year) and analysis of them. From the data, the number of dry spells from 1 to 20 days are obtained for the statistical period and after statistical analysis, the probability of occurrence of different dry spells are obtained.

RESULTS AND DISCUSSION

In all steps of this investigation, SMADA (for 200 data), EXCEL (for more data), Wiebull probability formula and most suitable statistical distribution based on RSS, have been used.

Table 1 shows an estimation of annual rainfall with log-Pearson Type III as the best statistical distribution. Annual mean rainfall in usual years (50% probability) is 183 mm and in high water years (100 years return periods) is 373 mm. Therefore if the minimum amount of annual rainfall for rain-fed agriculture is 300 mm, the chance of success in this region is only about 6%.

Table 2 shows monthly rainfall with different return periods. The minimum monthly rainfall is in summer months and the maximum in February.

From Fig. 1 the highest amount of rainfall occur between February and March As it can be observed from Fig. 2 starting from water year (Sept-Sept) the amount of rainfall increases gradually and after about 9 months reaches to its maximum. In other words, there is no rainfall in 3 months of the year and is completely dry.

Table 1: Estimation of annual rainfall of Sabzevar with different return periods

Return period (year)	2	3	5	10	25	50	100	200
Rainfall (mm)	183	211	241	276	317	346	373	400

Table 2: Estimation of monthly rainfall in Sabzevar (mm) with return periods of 2 to 200 years

	Return periods							
Months	2	3	5	10	25	50	100	200
Oct.	3	5	9	14	23	33	44	58
Nov.	8	11	16	24	36	47	60	74
Dec.	20	28	37	49	64	76	87	99
Jan.	26	38	51	65	78	85	90	93
Feb.	24	32	43	58	80	99	119	141
Mar.	34	46	58	72	90	103	116	128
Apr.	23	33	44	57	70	78	85	90
May	8	14	22	34	51	65	80	95
June	1	2	4	6	12	17	25	34
July	0	1	1	3	6	9	15	22
Aug.	0	0	0	1	2	4	6	9
Sep.	0	0	1	2	3	5	7	10

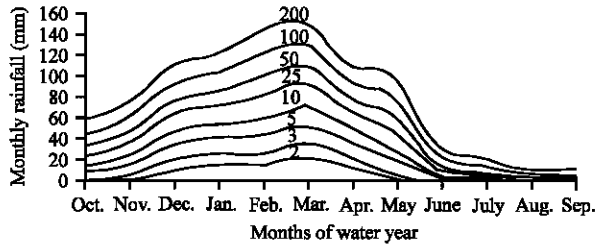

Fig. 1: Variations of Sabzevar monthly rainfall with different return periods of 2 to 200 years

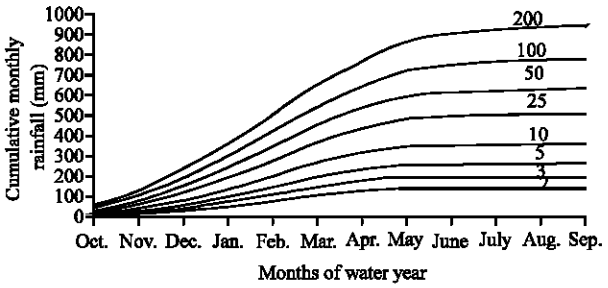

Fig. 2: Cumulative monthly rainfall of Sabzevar with different return periods of 2 to 200 years

As it can be seen from the Table 3 start of usual rainfall in Sabzevar is 13th of December based on first assumption, 10th of December based on second assumption and 5th of December based on the third assumption. Alizadeh and Sarafraz stated that the first assumption is more suitable than the start of rainfall based on first assumption. In this case, for Sabzevar with probability of 20%, 24 November, with probability of 80%, January 2 will be the dates of the start of rainfall. As a result, the dates of the start of rainfall in Sabzevar is November 14 to December 26. The results based on first assumption are shown Fig. 3 (probability the dates of start of rainfall).

Based on the Table 4 the rainfall in Sabzevar is considered ended after May 1. Table 5 shows the forecasting of rainfall duration with different probabilities. As the rainfall usually starts from December 12 and ends on May 1, the rainfall period is forcasted as 140 days. The period is variable in each year and analysis of the results are shown in Table 5. It can be observed from the table that rainfall period with 50% probability is 138 day and with 90% probability, at least 104 days of rainfall occurs each year.

Table 6 shows that, the rainy days are 34 days in each year, which is about 1 to 6 days in a month. Maximum rainfall occurred in March (6 days).

Table 7 shows an estimation of daily rainfall with different return periods. The average daily rainfall of Sabzevar (usually with 50% probability) is 3 mm

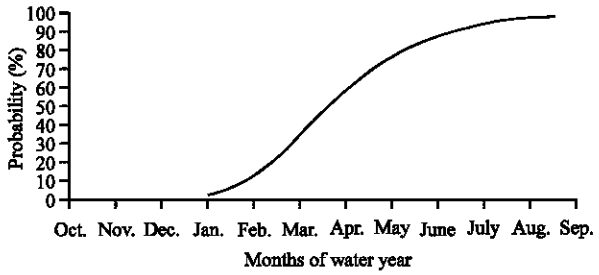

Fig. 3: Cumulative ratio of the dates of start of rainfall in Sabzevar based on first assumption.

Table 3: Estimation of the dates of start of rainfall in Sabzevar with different probabilities

	The dates of start of rainfall		
Probability %	First assumption	Second assumption	Third assumption
10	October 31	October 31	October 21
20	November 24	November 19	November 16
30	December 2	November 30	November 26
40	December 9	December 4	December 1
50	December 12	December 10	December 5
60	December 14	December 14	December 11
70	December 21	December 19	December 23
80	January 2	December 24	January 7
90	January 16	January 13	January 30

Table 4: The dates of ends of rainfall in Sabzevar with different probabilities

Probability (%)	10	20	30	40	50	60	70	80	90
The dates ends of rainfall	Apr. 3	Apr. 13	Apr. 20	Apr. 26	May 2	May 8	May 15	May 24	June 4

Table 5: Forecasting of rainfall period in Sabzevar with different probabilities

Probability (%)	10	20	30	40	50	60	70	80	90
Rainfall period (day)	184	166	156	146	138	130	122	114	104

Table 6: Estimation of the average number of rainy days in each month in sabzevar

Months	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
No of rainy days	1	2	4	5	5	6	5	3

Table 7: Estimation of the amount of daily rainfall (mm) in sabzevar with different returns period(mm)

Return periods (period)	2	3	5	10	25	50	100	200
Daily rainfall	3	5	8	13	18	22	27	30

(2-year return period). The average changes from 3 mm to 30 mm for 2-year and 200-year return periods, respectively.

Table 8 shows an estimation of maximum 24 h rainfall with different return periods. In agricultural projects and even in urban wastewater systems, maximum 24 h rainfall is used for calculation of design rainfall (Alizadeh and Sarafraz, 1988). It can be observed from Table 8 that usual maximum 24 h rainfall is 23 mm and for

Table 8: Estimation of maximum 24-hr rainfall in Sabzevar (mm) with different return periods

Return periods	2	3	5	10	25	50	100	200
Maximum 24-h rainfall (mm)	23	26	29	33	37	41	44	46

Table 9: Probability of occurrence of consecutive rainy days in Sabzevar in different months

Consecutive rainy days	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Year
1	73	71	68	66	64	64	69	7868	68
2	24	23	25	26	28	26	21	1924	24
3	3	5	5	7	6	6	7	26	6
4	0	1	2	1	1	3	3	12	2
5	0	0	0	0	1	1	0	00	0
6	0	0	0	0	0	0	0	0	0

100-year designs, 44 mm is estimated. Table 9 shows that rainfall in Sabzevar is one-day during a year mainly (68%). In 24% of cases, the rainfall occurs in 2 consecutive days and in 6% of cases, it falls in 3 consecutive days. The chance of occurrence of rainfall with 4 consecutive days and more, is low (2%). The probability of 5 consecutive day rainfall in Sabzevar is about 0%.

Daily rainfall data can be recorded as wet and dry days series (positive number for wet and negative number for dry periods). This has been done for all statistical period years and the results are shown in Fig. 4. In the Fig.4 the probability of occurrence of different dry spells can be observed. From the Fig. 4 it can be concluded that with 20% probability there is a dry day after one day raining, but with 4% probability, after each rain, a 9-day dry spell may occur.

As the distribution of cumulative probability of occurrence of dry spells gives better results about occurrence of them, Table 10 is produced for cumulative distribution of dry spells. The dry spells are longer than 4 days. The probability of occurrence of dry spell for over 6 days is 32% and for 10 days, it is 16%

Figure 5 shows probability of occurrence of dry spells after each rainy day. The variations of dry spell after each rainy day are not regular, which can be observed from Figure 5 obviously. In this Fig. 5 the probabilities of dry spells equal to or greater than 1, 3, 5, 7, 10 and 15 days, after each rainy day in different months of the year are drawn. For example in March, probability that after a rainy day, 3 dry days occur is about 16% and in 84% of cases, the next rainfall occurs in less than 3 days, whereas, the same probability is about 9% is November.

In Fig. 6 the probability of occurrence of rainy days, equal to or greater than 1, 2 and 3 days after each day of dry spell throughout the year has been estimated and drawn. For example in March, after each day of dry spell, there is 18% probability that next day is rainy and this rain continues for more than one day, whereas, in the same

Table 10: Probability of occurrence of dry spells in Sabzevar

Dry spell period exceedence (%)	Probability of exceedence (%)	Probability of non-period (day)
1	81	19
2	67	33
3	56	44
4	48	52
5	40	60
6	32	68
7	28	72
8	24	76
9	20	80
10	16	84
11	14	86
12	13	87
13	10	90
14	8	92
15	7	93

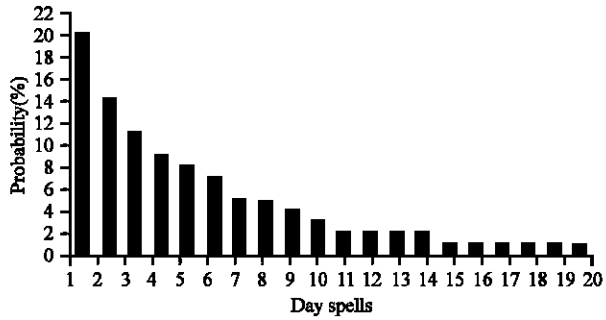

Fig. 4: Probability of occurance of different spells in Sabzever

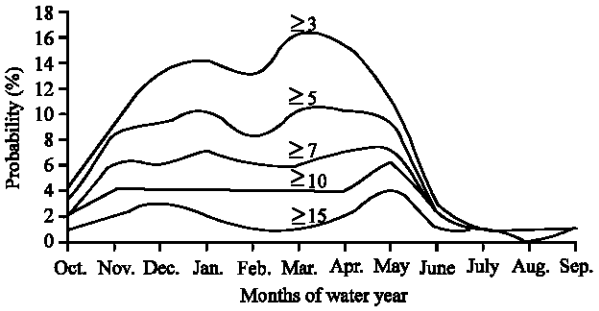

Fig. 5: Probability of occurrence of dry spells after each rainy day in Sabzevar

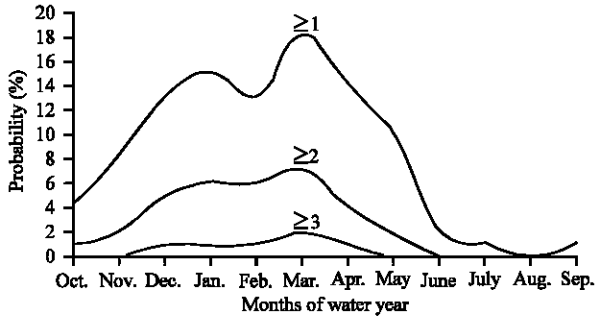

Fig. 6: Probability of occurrence of rainy periods after each dry day in Sabzevar

month, the probability that after each dry day, the rainfall occurs for 3 consecutive days is 7% and probability that rain after dry spell, continues for at least 3 consecutive days is only 2%. In March, the probability of occurrence of at least one rainy day has increased and this means that the dry spells are short in this month.

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