Iran Agricultural Research, Vol. 23, No. 2 and Vol. 24, No. 1
Printed in the Islamic Republic of Iran, 2004 and 2005
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“Research Note”

A Simple Model for Prediction of Annual Precipitation in the Southern and Western Provinces of I. R. Iran

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ABSTRACT- Dryland agriculture plays an important part in the agricultural production of the southern and western provinces of I. R. Iran. Since it utilizes precipitation directly, it is considered an optimal method of water use. The purpose of this research was to develop a simple model for the prediction of annual (water year) precipitation in southern and western provinces of I. R. Iran, so that dryland farming can be properly planned in these areas. The relationships between annual precipitation and the duration of 37.5, 42.5, and 47.5 mm of precipitation since the onset of autumn ($t_{37.5}$, $t_{42.5}$, and $t_{47.5}$) were analyzed using simple regression for all stations in the study areas. The results showed that $t_{47.5}$ had higher correlation with the annual precipitation than $t_{37.5}$ and $t_{42.5}$. Furthermore, $t_{47.5}$ was inversely related to the annual precipitation for all stations in the study areas. Among different parameters such as mean of annual precipitation, P_{ma} (mm), elevation, longitude, and latitude of the stations, the mean of annual precipitation was the most appropriate one to be included in a linear multiple regression model along with $t_{47.5}$ to estimate annual (water year) precipitation, P_a (mm) as follows:

Southern provinces

$$P_a=-1.83\ t_{47.5} + 0.76\ P_{ma} + 228.3, \qquad R^2=0.71$$

Western provinces

$$P_a=-1.88\ t_{47.5} + 0.94\ P_{ma} + 146.8, \qquad R^2=0.76$$

These models were validated by using data from the study areas not used for model development. The regression analysis showed a high correlation with a slope of approximately one between the predicted and observed values.

Keywords: Annual rainfall, Dryland farming, Rainfall prediction, Rainfall modeling

INTRODUCTION

Dryland agriculture is an important part of the system of agricultural production in the southern and western provinces of I. R. Iran. Under these conditions, assuring some degree of yield stability to the farmers has become a priority for agricultural management systems.

The demand for food and agricultural production is doubled with population growth

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approximately every 25 years, but precipitation is extremely variable, and unpredictable, and does not show such increasing rate. For example in Bajgah area, the mean annual precipitation is about 400 mm while actual precipitation might be as little as 175 mm or as much as 500 mm (5). However, farmers demand a narrow range of precipitation probabilities for the approaching season. This providence is helpful for more rational and productive decisions to be made for cropping management. For example, it would be extremely helpful if one knew (with an acceptable degree of probability) that this season's precipitation will vary from 175 to 400 mm, or 400 to 500 mm, rather than 175 to 500 mm.

Levels of predictability similar to that suggested above do indeed exist in Mediterranean-type precipitation patterns right across the regions from Morocco to Jordan (12, 13) and West Africa (10), and mansoon precipitation of eastern Kenya (14). These studies indicate a significant relationship between the date of onset of precipitation and annual amount of precipitation (3, 4, 10, and 11).

Different procedures have been used to predict rainfall. Complicated neural network based models were used to forecast seasonal rainfall for Shiraz (Fars province, I. R. Iran) by Setoodeh *et al.* (9). Their results indicated a slope of 0.62 for the line showing the relationship between model output and measured values, which was different from the 1:1 line with the slope of one.

For the study areas, dryland wheat production was found to be low; less than one t/ha due to unpredictable precipitation and no fertilizer use. The prediction of annual precipitation can develop information to alleviate these problems, and guidance can be provided to farmers both for reduced-risk selection among alternative crops to plant (barley instead of wheat), and for improving their levels of input, particularly fertilizers, to match precipitation levels for yield maximization per unit of water more closely. Similar studies have been reported by Rees *et al.* (7, 8).

A key concept in defining the date of onset of the rainy season for crop production is that precipitation accumulated in the surface soil layer must be sufficient to penetrate beyond the seedling depth so that it can germinate the seed and fulfill the needs of the young seeding until further precipitations are assured. This could be determined by a simple soil-water balance to store 30 mm of precipitation in the soil surface layer (12). Furthermore, a monthly precipitation of 37.5 mm was reported as a risky precipitation for marginal areas by Newman (6). This value was related to the annual (water year) precipitation for a province in the southwest of I. R. Iran (2); however, this correlation was not investigated in western and southern provinces where there are considerable areas of dryland farming.

The present study was conducted to show similar predictability to those of Mediterranean-type climates for the southern and western provinces of I. R. Iran with different amounts of precipitation for the onset of the rainy season.

MATERIALS AND METHODS

The locations of study areas are shown in Fig. 1. The southern study area is located between the longitude of 50°, $15^{'}$ and 55°, $45^{'}$, and the latitude of 27°, $15^{'}$ and 31°, $30^{'}$. The western study area is located between the longitude of 46°, $19^{'}$ and 51°, $31^{'}$, and the latitude of 30°, $13^{'}$, and 36°, $03^{'}$. The mean annual precipitation of the regions varied between 120 to 650 mm for the southern provinces with Mediterranean -Sudanian precipitation and 257 to 850 mm for the western provinces with Mediterranean precipitation .

The daily precipitation for 66 and 75 meteorological stations with a data period greater than 20 years in the southern and western provinces were used, respectively. The source of rain for the western area is usually a weather front from the Mediterranean region, while the source of rain for the southern area are fronts from Mediterranean and Sudanian regions.

For simplicity, the onset of the rainy season was determined by the accumulated precipitation of 37.5 mm (as a risky monthly precipitation, reported by Newman (6)), 42.5 mm, and 47.5 mm from the beginning of fall (September, 23) as the number of days from September 23 ($t_{37.5}$, $t_{42.5}$, $t_{47.5}$). The value of rainfall for the onset of the rainy season was somewhat increased (i.e., 42.5 mm, and 47.5 mm) for the sake of reducing the risk. Furthermore, the annual precipitation for the water year (October to September) was also recorded for the same period of data.

The homogeneity of the recorded data (onset days and annual precipitation) was examined by “running test” (reported in (1)). The simple and multiple linear regressions were used to investigate the relationship between the annual (water year) precipitation and onset days, the mean of annual precipitation, station position (longitude and latitude) and elevation, and a simple model was then proposed. To validate the proposed model, the data of five and seven stations of the southern and western provinces were used and the annual precipitations were predicted (Table1).

RESULTS AND DISCUSSION

The results of run test indicated that the data were homogeneous. The relationships between annual precipitation and $t_{37.5}$, $t_{42.5}$, and $t_{47.5}$ for all stations showed that they were related inversely for most of the stations and $t_{47.5}$ gave the greatest correlation coefficients. The reciprocal relationship between annual precipitation and $t_{47.5}$ for southern and western provinces are shown in Figs. 2 and 3. The relationships obtained from a mutual duration of data from 1973-74 to 1992-93 for southern and from 1970-71 to 1989-1990 for western provinces, are as follows:

$$P_a = 1/[5.55 \times 10^{-5}\, t_{47.5} - 1.28 \times 10^{-3}] \qquad R^2=0.40,\ SE=2.29 \times 10^{-3},\ n=954,\ p<0.001 \qquad [1]$$

$$P_a = 1/[1.4 \times 10^{-4} + 3.935 \times 10^{-5}\, t_{47.5}] \qquad R^2=0.34,\ SE=1.72 \times 10^{-3},\ n=840,\ p<0.001 \qquad [2]$$

in which P_a is the annual precipitation, mm, and $t_{47.5}$ is the precipitation onset days from the beginning of the water year, day. The dashed curves in Figs. 2 and 3 show the confidence intervals of 95 and 99%. These results indicated that for later onset of precipitation in the fall, the annual precipitation amounts will be smaller. As indicated in Figs. 2 and 3, for a particular t, i.e., 80 d for t=47.5 mm, the values for P_a varied from 180mm to 800mm for southern areas. This large variation is justified by the difference in the average annual rainfall in different locations in the study area. These findings are similar to those reported by Stewart (12, 13) for Morocco to Jordan and by Sivakumar (11) for West Africa.

Table1. Meteorological station parameters for validation

Provinces	Station	Longitude	Latitude	Elevation (m)	Years of record
Southern	Badamak	52°, 15	30°, 15'	1730	23
	Jahanabad Cheshmeh	53°, 51	29°, 43'	1580	27
	Baraghan	52°, 01	30°, 13'	2100	23
	Ghalat	52°, 19	29°, 48	2080	24
	Lanfarjan Karzin	53°, 06'	28°, 26"	700	24
Western	Aligudarz Dargazin	49°, 41'	33°, 24'	1972	8
	(Hamadan)	49°, 04'	35°, 21'	1870	15
	Holaylan	47°, 03'	33°, 44'	870	13
	Marivan	46°, 10'	35°, 30'	1465	11
	Sangtrash	48°, 34	33°, 14'	1584	16
	Eslamabad (Gharb)	46°, 36'	34°, 06'	1285	16
	Sarpou Zahab	45°, 52'	34°, 27'	550	10

For further analysis using the same series of data, the multiple relationships between annual precipitation (P_a, mm), and the mean of annual precipitation (P_{ma}, mm) and $t_{47.5}$ were obtainedfor southern and western provinces as follows:

Southern provinces

$$P_a=-1.83\ t_{47.5} + 0.76\ P_{ma} + 228.3 \qquad R^2=0.71,\ SE=87.8,\ n=780,\ p<0.001 \qquad [3]$$

Western provinces

$$P_a=-1.88\ t_{47.5} + 0.94\ P_{ma} + 146.8 \qquad R^2=0.74,\ SE=90.5,\ n=840,\ p<0.001 \qquad [4]$$

The multiple linear regressions between annual precipitation, station elevation and position (longitude and latitude) were not as good as Eqs. [3] and [4] (R^2 less than 50% and 65% for southern and western provinces, respectively), therefore, their equations are not shown. The coefficients of the mean of annual rainfall (0.76 and 0.94 for southern and western provinces, respectively) are somewhat different for the two study regions.

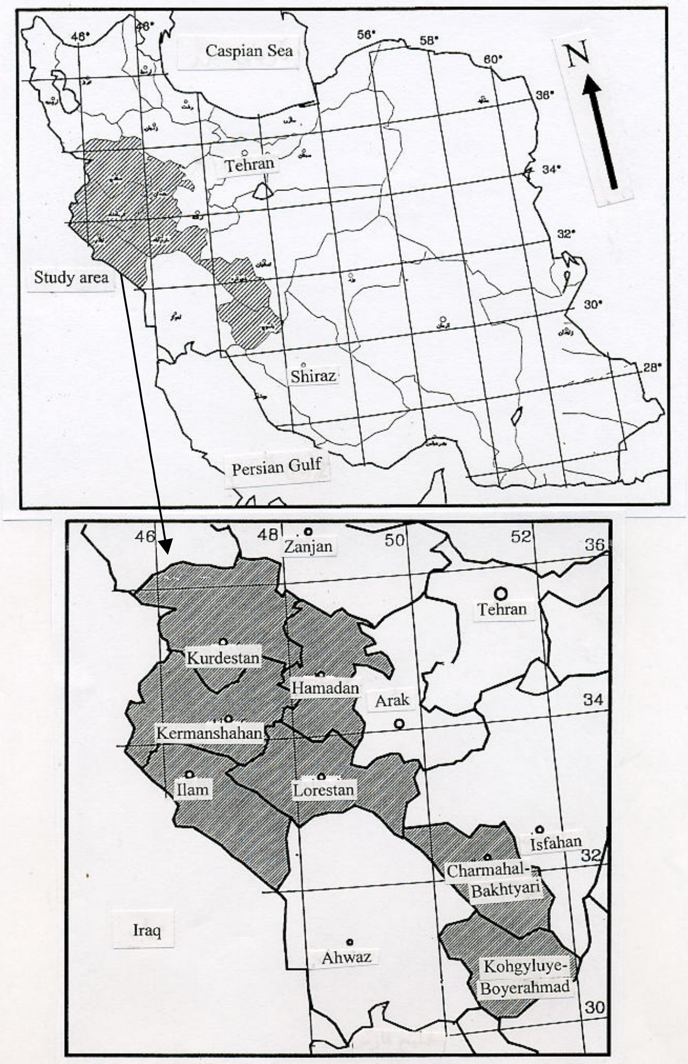

Fig.1. Location of the study areas.

This might be due to the fact that the range of annual rainfall for the western region (100-1300 mm) is larger than that for the southern region (100-800 mm). Furthermore, the larger coefficient (0.94) is accompanied by a smaller intercept (146.8 mm). Similar analysis was performed for the Khuzestan province in the southwest of I. R. Iran by Ghasemi and Sepaskhah (2). The coefficient for $t_{42.5}$ (1.89) is similar to those for the study regions, and the value of the coefficient for P_{ma} (0.86) was less and more than those for western and southern regions, respectively.

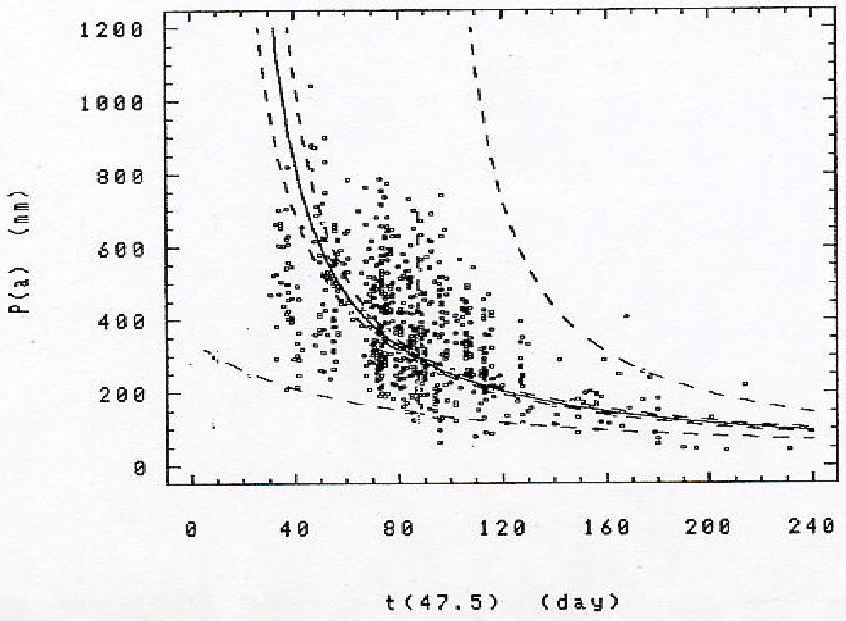

Fig.2. Reciprocal relationship between annual precipitation and t47.5 for the southern province.

Dashed curve show the 95 and 99% confidence intervals.

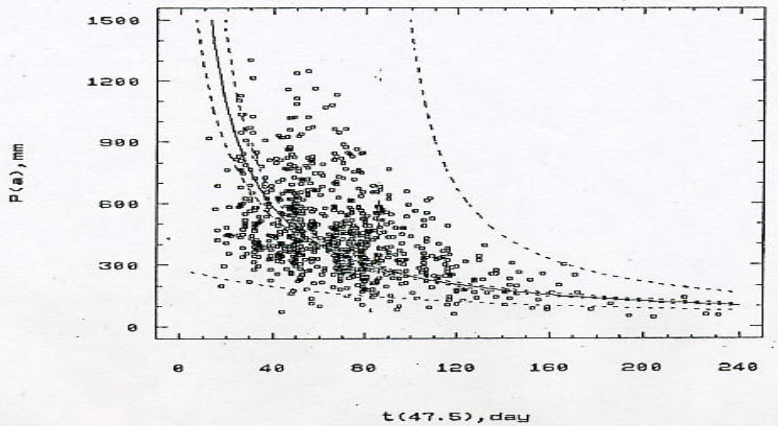

Fig.3. Reciprocal relationship between annual precipitation and t47.5 for the western province.

To validate the proposed models, the data of five and seven stations in southern and western provinces were selected (Table 1) and their annual precipitations were estimated according to Eqs. [3] and [4]. The results are shown in Figs. 4 and 5. The linear relationships between observed (Y) and predicted (X) annual precipitations are as follows:

Southern provinces

$$Y=1.05\ X \qquad R^2=0.95,\ n=92,\ SE=112.9,\ p<0.001 \qquad [5]$$

Western provinces

$$Y=1.01\ X \qquad R^2=0.95,\ n=84,\ SE=108.3,\ p<0.001 \qquad [6]$$

The line in Figs. 4 and 5 is the 1:1 with a slope of one. The F test was used to compare the slopes of Eqs. [5] and [6] with the slope of the 1:1 line (one). The slopes are not significantly different from one. These results indicate that the proposed simple models (Eqs [3] and [4]) are valid for the prediction of annual precipitation, using the mean annual precipitation and $t_{47.5}$ for the study areas.

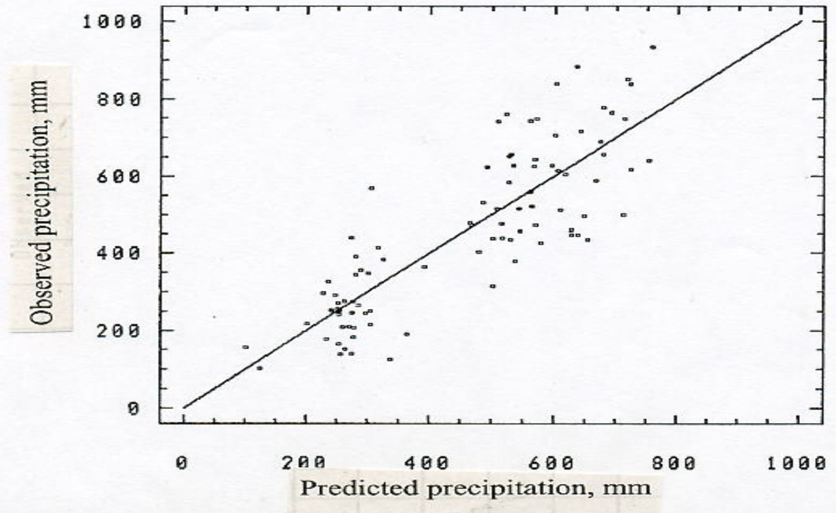

Fig.4. The relationship between observed and predicted annual precipitations for five stations in southern province.

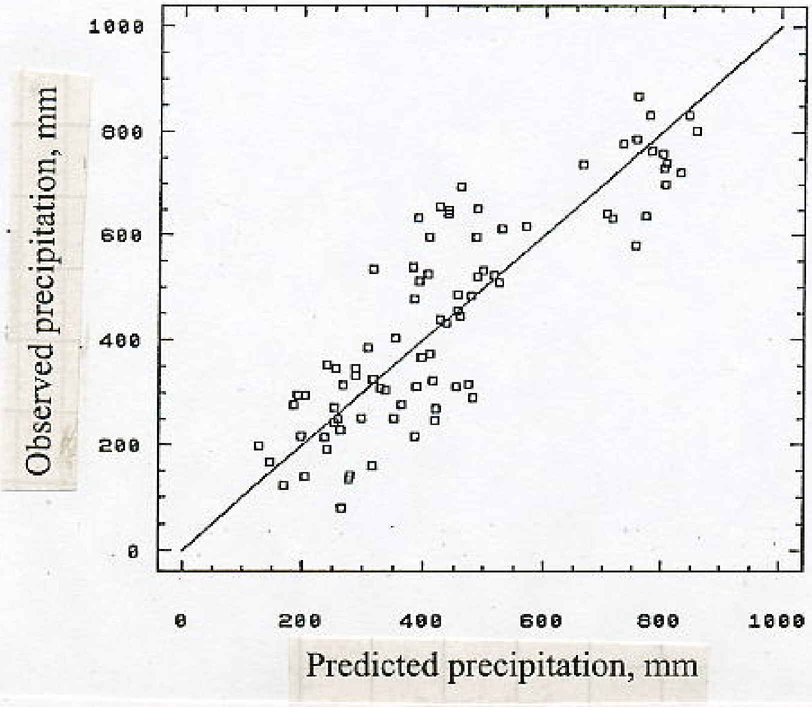

Fig.5. The relationship between observed and predicted annual precipitations for seven stations in western provinces.

CONCLUSIONS

Among different onset precipitation parameters the $t_{47.5}$ was better related to the prediction of annual precipitation by using the mean of annual precipitation. Among different parameters such as the mean of annual precipitation, station elevation and position (longitude and latitude), the mean of annual precipitation was preferred to be included in the simple model for annual precipitation prediction. Finally, two simple models were proposed for annual precipitation prediction in the southern and western provinces of I. R. Iran.

ACKNOWLEDGEMENT

This research was supported in part by project No. 76-AG-1022-608of Shiraz University Research Council.

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