551.586 : 633 : 551.573

ESTIMATION OF CROP YIELD FROM ARID KUTCH (GUJARAT) REGION USING ACTUAL EVAPOTRANSPIRATION THROUGH CLIMATIC WATER BUDGETING

1. Yield estimation of various kharif crops, *viz.*, groundnut, pulses and sorghum in Kutch district of Gujarat State is worked out for the period 1970-1984 by fitting reciprocal hyperbola and Hoerl function. The Hoerl function indicates that maximum yield of groundnut (10.6 q/hec), kharif pulses (5.5 q/hec) and sorghum (4.2 q/hec) can be obtained at water use of 465, 357 and 327 mm respectively under rainfed condition. Suitability and performance of these models are also discussed for estimation of crop yield.

2. Large area of arid Kutch region (2.4 lakh hec) is under rainfed cultivation of groundnut, kharif pulse (greengram and moth bean) and sorghum crops. As a result of low and erratic rainfall over the region (Singh *et al.* 1990) the yield variability of groundnut, kharif pulses and sorghum is very high being of the order of 44.5, 53.4 and 83.9 % respectively (Singh *et al.* 1991). Thus yield prediction of these crops using climatic data is of a great concern for economic planning and for adopting timely relief measures in the area. Therefore, in this study empirical yield prediction models are developed to estimate crop yield at harvest using the information on Actual Evapotranspiration (AET) obtained through climatic water balance.

3. *Material and method* — Daily rainfall data of Kutch district (12 raingauge stations) for the period of

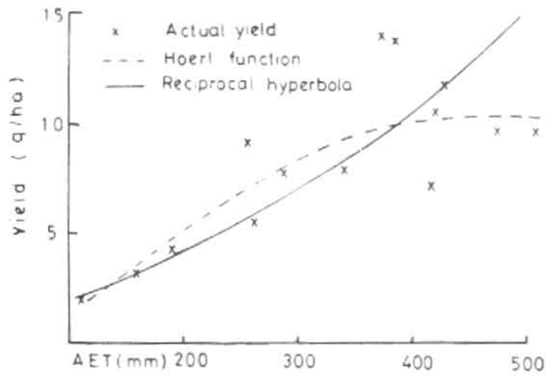

Fig. 1. Relationships between groundnut yield and water use

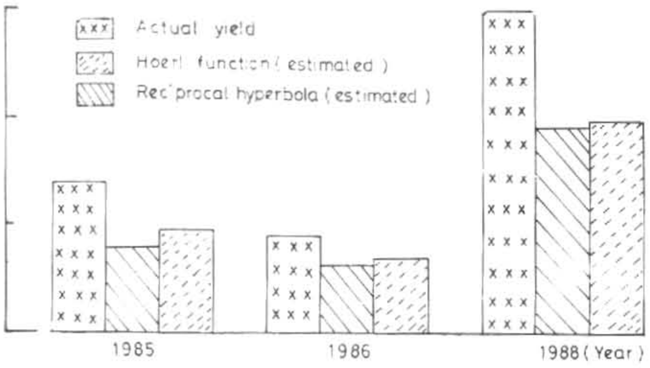

Fig. 2. Comparison of actual and estimated yields of groundnut

1970-1988 were used in weekly water balance computation. Potential Evapotranspiration (PE) values computed by Rao *et al.* (1971) through Penman's formula are used in the water budgeting. The weekly AET for each of the stations and for individual year were worked out using climatic method of water budgeting (Thornthwaite and Mather 1955). The water holding capacity of the soil profile (1m depth) was assumed to be 150 mm. The commencement of crop growing season under rainfed farming was assumed as first week of the cropping season when AET exceeded half the value of PE. The total water used (AET) during the each growing season (1970-1988) by the crop was computed taking into consideration length of growing season of 9, 16 and 18 weeks for kharif pulses, sorghum and groundnut respectively.

Various mathematical functions (Singh and Ramakrishna 1992) were fitted to the yield data (1970-1984) of groundnut, kharif pulses and sorghum using computer software "Curvefit" prepared by Thomas (1986) based on method developed by William (1985).

4. *Results and discussion*—Among various mathematical equations fitted, reciprocal hyperbola of the form $Y = X/(A \times B)$ and Hoerl function of the form $Y = A \times B^X \times X^C$ represented the yield-water use relationship better and explained higher percentage of variation in yield of various rainfed kharif crops of the region, where, Y is crop yield (q/hec), X is water use (AET) and A, B and C are regression constants.

4.1. *Groundnut* — Using the rainfall data of Kutch region for the period of 1970 to 1984 and groundnut yield, the best association between groundnut yield (Y) and crop season AET (X) was found by fitting reciprocal hyperbola of the following type :

$$Y = X/(-5.04 \times 10^{-2} \times X + 57.71) \quad (1)$$

with

$r = 0.9626$, significant at 0.1% level and d.f. = 13.

Using same data, Hoerl function was also fitted to predict the groundnut yield. The equation obtained is as follows :

$$Y = 1.37 \times 10^{-5} \times 0.99^X \times X^{2.64} \quad (2)$$

with

$r = 0.9294$, significant at 0.1% level and d.f. = 13.

Eqn. (2) explains less variation (86%) in yield compared to the above reciprocal hyperbola (93%) equation. However, Hoerl function was found to predict a realistic maximum yield (10.6 q/hec) at 465 mm of water use. With increase values of AET the model predicts that groundnut yield decreases, thus, showing that any excess water use will result in lower Water Use Efficiency (WUE) by the crop. This decrease in yield may be because of the susceptibility of crop to pest and disease or prolongation of vegetative phase when more quantum of soil water is available to groundnut plant. Whereas predicting yield with Eqn. (1) becomes unrealistic when water use is more than 550 mm (Fig. 1). Hence predicting groundnut yield using Eqn. (2) (Hoerl function) represents and provides more meaningful estimations than reciprocal hyperbola for conditions of higher water regime (when AET exceeds 550 mm) during periods of high rainfall over the region.

4.2. *Kharif pulses* — The predictive equations of reciprocal hyperbola and Hoerl function type once again give the best fit between yield and water use by kharif pulses.

Following regression equations were obtained :

$$Y = X/(-0.19 \times X + 101.20) \quad (3)$$

with $r = 0.8718$ significant at 0.1% level, and

$$Y = 3.31 \times 10^{-6} \times 0.99^X \times X^{2.94} \quad (4)$$

with $r = 0.8638$ significant at 0.1% level.

Estimated yields by both the Eqns. (3) and (4) are almost same up to crop water use of 250 mm, where after gradual difference occurs in the yields. The difference in estimated yield by these two equations increase abruptly when crop water use exceeds 300 mm. Hoerl function predicts maximum yield of 5.5 q/hec at 357 mm of seasonal evapotranspiration and afterwards yield predicted show a slow declining trend, whereas predicted yields by reciprocal hyperbola increase further with water use and become unrealistic for the region when crop water use exceeds 350 mm indicating that response of Hoerl function for yield prediction is more appropriate for kharif pulses also in the region.

4.3. *Sorghum* — Hoerl function gave best fit between sorghum yield (Y) in q/hec and crop water use (X) during growing season (mm). The same is obtained as follows :

$$Y = 6.44 \times 10^{-19} \times 0.97^{X} \times X^{9.04} \quad (5)$$

with r=0.9252 significant at 0.1% level and d.f. = 12.

This model predicts optimum yield (4.2 q/hec) of sorghum at 327 mm of crop evapotranspiration. Similar value of crop evapotranspiration is also reported by Sahu and Sastry (1992) in their study of water requirement from Junagadh district of Saurashtra (Gujarat) region. Beyond this value of AET, the predicted sorghum yield remains stagnant or starts decreasing probably because of crop susceptibility to pest and diseases due to high rainfall over the region. The equation fitted to the actual yields obtained in the region confirms this feature for Kutch region where the yield levels of sorghum are very low. In contrast, reciprocal hyperbola type function fitted to the data provides the following regression equation :

$$Y = X/(-5.56 \times X + 1853.0) \quad (6)$$

with r= 0.8075 significant at 0.1% level and d.f.=12.

The predictive value of this equation is very poor. Also, for conditions of more than 350 mm of water use, it predicts negative yield which is meaningless. Hence for predicting sorghum yield from the Kutch region Hoerl function only can be used successfully.

4.4. *Prediction performance of models* — To validate the performance of these models, predicted yield of groundnut using reciprocal hyperbola and Hoerl function was compared with actual yield data of three independent years 1985, 1986 and 1988 (Fig. 2). It can be seen from the figure that Hoerl function [Eqn. (2)] predicts closer to the actual value than by using reciprocal hyperbola. In case of kharif pulses both reciprocal hyperbola and Hoerl function and in case of sorghum, Hoerl function only predicted closely the actual observed yield. Thus, Hoerl function, in general, showed better results over a large range of (low and high) moisture regimes indicating that it has capacity as a predictive equation for crop yields in Kutch region.

5. *Conclusions* — The study brought out that Hoerl function can successfully be used for the estimation of productivity of groundnut, kharif pulses and sorghum in Kutch region. Reciprocal hyperbola is useful for prediction of only groundnut and kharif pulse yields. Its response to predict yields is low during below normal rainfall years as well as under high moisture availability conditions.

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