Mausam, (1983), **34**, 3, 275-280

633.11:632.11(545)

Estimation of wheat yields over Punjab using district and State models

G. APPA RAO

Drought Research Unit, Meteorological Office, Pune

(*Received 27 November 1981*)

सार – जलवायु संबंधी निदर्शों की सहायता से पंजाब राज्य और उसके चार जिलों में गेहूं की उपज पर जलवायु एवं प्रौद्योगिकी के प्रभाव का अध्ययन किया गया है । जलवायु के प्रमुख उपादानों का पता लगाया गया और उनकी भूमिका का विवेचन किया गया है । निदर्शों की उपयुक्तता की जांच के लिए चार स्वतंत्र वर्षों में उनकी उपज संबंधी सापेक्ष आकलन क्षमता को परखा गया है । अंत में जिला स्तर की उपज के आकलन के लिए भी राज्य निदर्श का सुझाव दिया गया है ।

ABSTRACT. The influence of climate and technology on wheat yield over Punjab State and four of its districts is studied based on climatic models. The important climatic factors are identified and their role is discussed. The validity of the models is judged by their relative performance in estimating the yields over a four year independent data set. The use of State model to estimate the district yields is suggested.

1. Introduction

Estimation of wheat yields before harvest is of immense help in planning strategy of food imports and distribution, internal procurements, storage and export. Models are developed by Lomas (1974), Thompson (1962, 1969) and Williams (1972), 1973) to predict the wheat yields for areas equal or larger than a State and by Katz (1977) and Pitter (1977) for smaller areas like crop report districts. In India, studies have been reported by Das *et al.* (1971) and Appa Rao *et al.* 1977, 1978, 1981) to predict yields mainly on meteorological sub-division scale, bigger than a district. In this paper, an attempt has been made to develop models to estimate the wheat yields over Punjab State and some individual districts based on climate and technology. From this, a method has been suggested to estimate the district yields based on the State model.

2. Data used

Punjab stands third in the acreage for the wheat crop and produces maximum wheat, with an average yied of 25.4 quintals/ha (statistical abstracts, 1978). Out of 10 district (Fig. 1). 4 districts namely Ludhiana, Amritsar, Patiala and Ferozepur produce more than 50% of the State yield. Punjab State, as a whole and the above four individual districts have been selected for the study, covering a period from 1950 to 1978. 25 years data have been used in the development of the models and 4 years for testing their performance. Monthly climatic data like rainfall, temperature, humidity, winds and cloudiness reported from Amritsar, Ludhiana, Patiala and Ferozepur observatories and wheat yields obtained from Punjab Government and ECOSTAT (Department of Economics and Statistics) are used in the study.

The State average yield (Fig. 2) remained more or less constant from 1911 to 1960. Subsequently it rose almost in a linear way with time from 1000 kg/ha to 3000 kg/ha. The average district yield (Fig. 4) increased from about 700 kg/ha to 2700 kg/ha during the period 1950-1978. This phenomenal rise is due to the impact of technology like irrigation, fertilizers, ,hybrid seeds, control of pests and diseases etc. Due to non-availability of these individual factors a combined parameter reflecting them (termed as 'Technological Trend') is used in the analysis.

Generally wheat is sown in the State during first week of November. Germination completes by fifth, tillering by nineth and elongation by

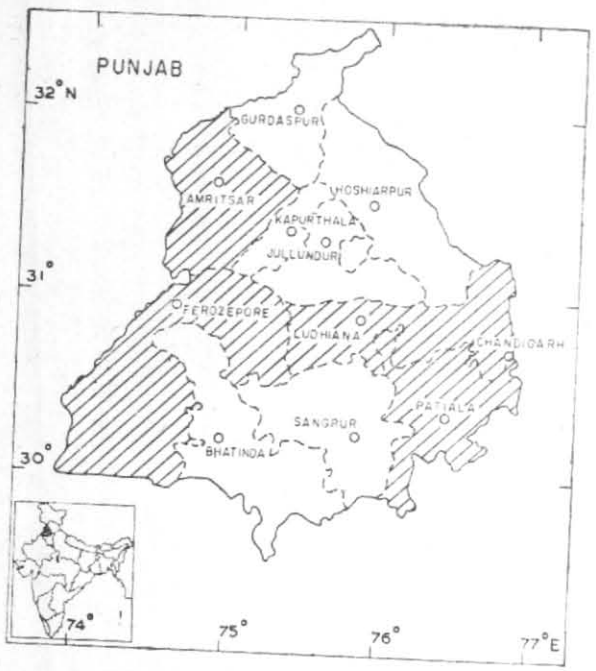

Fig. 1 Punjab State and wheat crop reporting districts, India

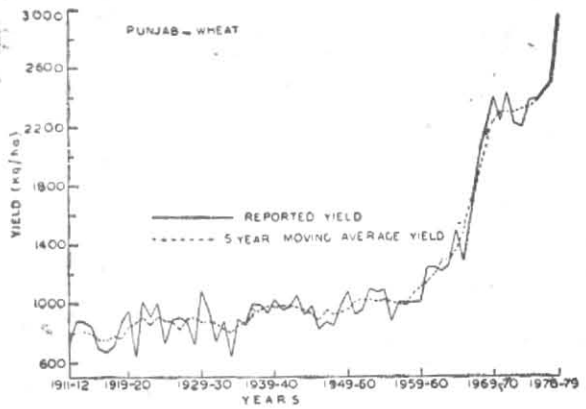

Fig. 2. Reported and 5-year moving average yields over Punjab State

fifteenth week, followed by flowering for about two weeks. Grain formation occurs for four weeks and the crop is ready for harvest by twenty first week after sowing.

3. Method of analysis

The method in mainly based on multiple linear regression technique (Draper and Smith 1966). The average wheat yield is taken as dependent variable with weather parameters and technology as independent variables. Technology is considered as a linearly increasing dummy variable from 1960 to 1970, constant from 1970 to 1973 and then increasing linearly from 1974. Mean monthly climatic data based on the four stations are used as the independent variables. Besides, another climatic variable, synergestic heat moisture stress (Pitter 1977), based on the combined effect of temperature and rainfall on wheat yield, represented by a dummy variable of the form :

$$\psi\ (R/T) = \begin{cases} R^* T, \text{ if } T > T_{gm} \text{ and } R < R_{gm} \\ 0, \text{ otherwise} \end{cases}$$

where, '*gm*' refer to grand mean of the variable, is used.

The final variables are the same both for the State and district models. The basic input data used in the models are given in Table 1. The criteria for the selection of significant variable is based on significant *t*-value (5% level) of the regression coefficient and at the same time the physiological growth of the crop. The final model is selected based on its capacity to estimate the yields as accurately as possible with an independent data. The yield estimated directly from the State model and also based on aggregate of the four individual district models by proper weights is computed.

4. Results and discussion

The final regression models (State and districts) are given in the Table. 2 with the important climatic parameters. It is seen that the mean yields are of the same order, both in districts and the State as a whole. The coefficient of determination of the districts and State models are equally effective in estimating the wheat yields. All the regression coefficients are significant at 5% level for the State model.

The fit between the reported and estimated yields by the models are shown in Figs. 3 and 4 for State and districts respectively. It is seen that there is good agreement between the two and in most of the cases the trend is same.

4.1 *Wheat yield estimates based on the models*

These models are used to estimate the wheat yields in the four year period (Table 4) from 1975-78, which is not included in the analysis. The State and district models estimate the yields

TABLE 1

Basic data used in the development of the Punjab State model

Year	Y	X_2	X_3	X_4	X_5	X_6
1950-51	921	10.30	0.0	0	27.10	5.15
51-52	956	20.25	—7.40	0	28.70	6.05
52-53	1098	23.25	—1.20	0	29.37	5.70
53-54	1070	20.05	—16.10	0	28.43	5.03
54-55	1086	22.47	0.0	0	27.70	5.53
55-56	880	20.43	—3.70	0	27.57	5.93
56-57	1009	19.57	—5.40	0	26.97	6.80
57-58	998	21.50	0.0	0	27.03	6.75
58-59	1002	20.97	0.0	0	27.05	6.63
59-60	1046	19.44	—0.50	0	26.46	4.20
60-61	1243	20.84	0.0	1	27.82	6.24
61-62	1235	20.00	0.0	2	25.22	3.72
62-63	1211	20.08	0.0	3	26.56	2.66
63-64	1254	21.54	0.0	4	27.66	3.66
64 65	1495	20.16	0.0	5	27.48	6.80
65-66	1274	20.60	0.0	6	29.74	3.62
66-67	1545	19.26	0.0	7	27.58	3.90
67-68	1902	20.04	0.0	8	26.36	5.32
68-69	2202	22.80	—2.90	9	28.46	4.82
69-70	2394	20.06	—4.60	10	28.62	5.88
70-71	2239	20.78	0.0	11	27.27	3.54
71-72	2425	21 47	—13.52	11	27.49	6.04
72-73	2225	19.86	—0.95	11	27.33	5.60
73-74	2200	21.31	0.0	11	27.12	3.99
74-75	2376	19.41	0.0	12	27.76	5.39

Where, Y =State average wheat yield in kg/ha.
X_2 =Mean temperature in °C for the month March.
X_3 =Heat moisture stress for the month December.
X_4 =Technological trend (trend from 1960-61).
X_5 =Maximum temperature in °C for the month November.
X_6 =Minimum temperature in °C for the month January.

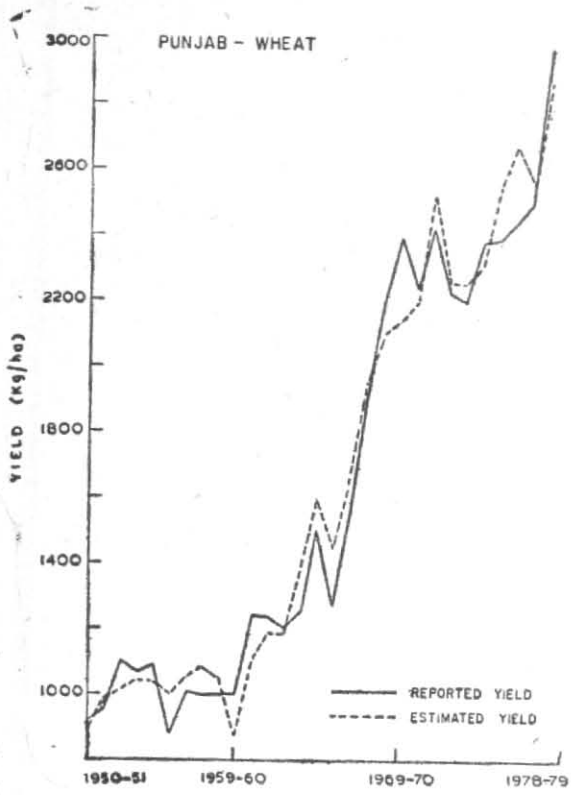

Fig. 3. Estimated (based on regression models) and reported wheat yields over Punjab State

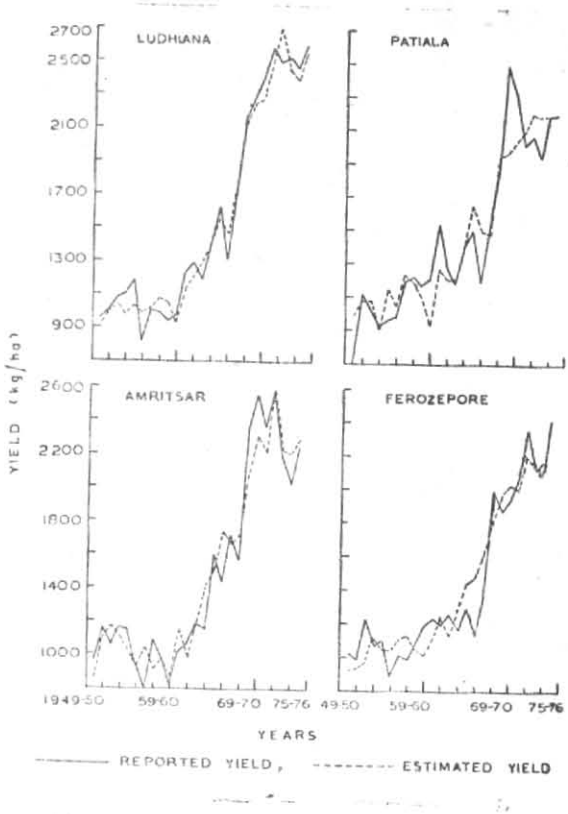

Fig. 4. Estimated (based on regression models) and reported, wheat yields over four districts of Punjab State

TABLE 2

Regression models to forecast wheat yield in India (Period : 1950-1974)

	Mean yield kg/ha	Standard deviation kg/ha	Coefficient of variation	Regression equation	M.C.C.	Total percentage of variation accounted for
Punjab State	1491.0	546.0	37.0	$Y = 1043.3 + 54.5X_2 - 12.2X_3 + 120.7X_4 - 54.6X_5 + 51.2X_6$ (2.3) (2.1) (23.1) (2.0) (2.4)*	0.98	97
Patiala district	1489.0	492.0	33.0	$Y = 1144.3 + 41.0X_2 - 142.8X_3 + 105.6X_4 - 56.9X_5 + 88.4X_6$	0.93	86
Amritsar district	1488.0	569.0	38.0	$Y = -2350.0 + 52.6X_2 - 12.4X_3 + 104.4X_4 + 83.4X_5 + 17.5X_6$	0.97	94
Ludhiana district	1569.0	623.0	40.0	$Y = 1553.9 + 45.6X_2 - 4.6X_3 + 133.5X_4 - 59.5X_5 + 21.5X_6$	0.99	98
Ferozepur district	1445.0	479.0	33.0	$Y = 1638.1 + 28.3X_2 - 7.4X_3 + 101.4X_4 - 55.1X_5 + 57.6X_6$	0.95	90

Where, X_3 = Mean temperature in °C for the month March
X_2 = Heat moisture stress for the month December
X_4 = Technological trend (Trend from 1960-1961)
X_5 = Maximum temperature in °C for the month November.
X_6 = Minimum temperature in °C for the month January.
* = t—test values given in brackets
($t_{0.5}$=2.06 for 25 data set)

TABLE 3

Comparison between reported and estimated wheat yields (kg/ha) over Punjab

Year	Reported	Estimated from		Percentage error between reported and estimated yields from	
		State model	district model	State model	district model
1975-1976	2385	2552	2492	7	5
1976-1977	2441	2669	2626	9	8
1977-1978	2503	2562	2577	2	3
1978-1979	2976	2869	2849	—3	—4

well within the tolerable limits (equal or less than 10%) in all the years except in one year for Ludhiana district.

4.2. *Relationship between State and district models*

The other question is the usefulness of the State model to forecast the district yields and *vice-versa*. The estimate obtained by models of State and by the individual districts of Punjab are shown in Table 3. It is seen that the estimates obtained from the State model are quite comparable to those of districts within 10% error. This shows that the district models can be used to obtain the yield of State. The other aspect is the utility of the State model to estimate the district yields based on the district weather data. Table 4 shows that the estimates

TABLE 4

Comparison between reported and estimated wheat yields (kg/ha) over important districts of Punjab

District	Year	Reported	Estimated from		Percentage error between reported and estimated yields from	
			District model	State model	District model	State model
Amritsar	1975-76	2526	2308	2466	—9	—3
	1976-77	2590	2587	2567	—1	—1
	1977-78	2507	2577	2491	3	—1
	1978-79	2662	2715	2938	2	10
Ludhiana	1975-76	2526	2712	2539	7	1
	1976-77	2590	2890	2732	12	5
	1977-78	3199	2983	2739	—7	14
	1978-79	3454	3252	3050	—6	—12
Ferozepur	1975-76	2321	2483	2678	7	15
	1976-77	2446	2444	2684	0	10
	1977-78	2490	2338	2476	—7	—1
	1978-79	2846	2637	2810	—7	—1
Patiala	1975-76	2339	2434	2581	4	10
	1976-77	2423	2540	2758	5	14
	1977-78	2656	2383	2607	—10	—2
	1978-79	2944	2729	2900	—7	—2

obtained from the district and State models are very close. The error of estimate is 10% or less, in 12 out of 16 cases. It is thus possible to use the State model to estimate district yields also, based on the district weather data.

5. Conclusions

Estimation of wheat yields over Punjab State and some of its important districts based on climatic variables, synergestic heat moisture stress and technology have been obtained by regression models. The yields during the period from 1960 to 1980 increased nearly three times due to technology. November maximum temperature, January minimum temperature, March mean temperature and synergestic heat moisture stress during December are the factors that effect the final crop yield. The State model is used to estimate the district yield and *vice versa* with a fair degree of accuracy. The models are able to estimate the wheat yields within 10% error for 4-year independent data.

Acknowledgement

The author wishes to thank Shri H. M. Chaudhury, D. D. G. M. (C & G) for his kind encouragement during the study.

References

Appa Rao, G., Jaipal, Lawrence Joseph, Deshpande, S. P. and Mahajan, A. V., 1977, Forecasting the yield of principal crops in India from weather parameters—Wheat, Pre-pub. Sci. Rep. No. 77/8; India Met. Dep., New Delhi, India.

Appa Rao, G., Sarwade, G. S., Jaipal, Sarkar, M. B., Lawrence Joseph and Jangle, N. K., 1978, Forcasting rice yield in India from weather parameters, Pre-pub. Sci. Rep. No. 15/78; India Met. Dep., New Delhi, India.

Appa Rao, G., 1981, The role of third generation computers in estimating the principal crops of India, Proceedings of computer society of India, New Delhi, India.

Das, J. C., Mehra, A. K. and Madnani, M. L., 1971, Forecasting yields of principal crops of India, *Indian J. Met. Geophys.*, **22**, 1, p. 47.

Draper, N. Y. and Smith, H., 1966, *Applied Regression Analysis*, John Willey and sons, Inc.

Katz, R.W., 1977, Assessing the Impact of climatic change on Food Production, *Climatic Change*, **1**, p. 85.

Lomas, J. and Shashowa, Y., 1974, the dependence of wheat yields and grain weight in a semi-arid region on rainfall and on the number of hot dry days, *Isreal J. Agril. Res.*, **23**, p. 113

Pitter, R. L., 1977, The effect of weather and Technology on wheat yields in Oregon, *Agric. Met.*, **18**, p. 115-131.

Statistical Abstracts of India, 1978, Central Statistical Organisation, Government of India, New Delhi.

Thompson, L. M., 1962, Evaluation of Weather Factors in the Production of Wheat, *J. Soil and Water Conser.*, **17**, p. 149.

Thompson, L. M., 1969, Weather, Technology in the production of Wheat in the United States, *J. Soil and Water conser.*, **23**, p. 219.

Williams, G. D. V., 1972, Geographical Variations in Yield-Weather Relationships over a Large Wheat Growing Region, *Agric. Met.*, **9**, p. 265.

Williams, G. D. V., 1973, Estimates of Prairie Provincial Wheat yields Based on Precipitation and Potential Evapotranspiration., *Can. J. Plant Sci.*, **53**, p. 17.