Weather Yield Model for the Semi Tropical Region (Pakistan)

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ABSTRACT

Weather models are essential tools for checking of the effect of the weather elements in terms of their effect on the production of the crop. This research is an attempt to see the effect of only two variables i.e., temperature and rainfall for the division Faisalabad (semitropical region of Pakistan).

The model fitted is of the linear form:

$$Y = a + bX_1 + cX_2 ,$$

the values of a,b,c have been found. The expected yield has been calculated by using the aridity indices (X_1 and X_2) and the result in the form of coefficient of determination R^2 has been found equal to 0.166. The significance of the regression coefficient has been tested, which shows that the contribution to the yield from aridity index at germination and that at ripening is significant.

The wheat yields are the results of a wide variety of variables, most of which show varying degree of relationship with one another, some positive and some negative in terms of output. These variables may be technology, fertilizers, pesticides, epidemics, kinds of seeds used, market price of crop and the area under cultivation etc, which can be the source of variation in the wheat yield. Since rainfall during germination and temperature at the ripening periods are the necessary factors for the yield of wheat, for this purpose these parameters have been studied in order to their contribution.

I. INTRODUCTION

The realization of the impact of weather and climate on crop production, and hence on world food supply, has led to renewed interest in a continuous world wide watch of crop prospects. Statistical crop weather models have been widely used for identifying, zoning and mapping areas in terms of their suitability for growing crops at their yield potential.

In case of wheat, which is the world's leading agricultural crop in terms of production and trade, there is a need to have an up to date knowledge of prevailing weather pattern and interpretation of current and immediate past weather in terms of expected crop conditions and yields. A critical evaluation of the current status of research into crop weather relationships and models for the assessment of crop yields is, therefore, most timely.

The research by Thompson (1962) on weather and technology in the production of wheat is typical in which he has used multiple regression analysis in relating crop yields to weather variables, whereas Gangopadhyaya and Sarkar (1965) studied the influence of rainfall (amount and distribution on wheat yields in India) using equation of fifth degree.

Coffing (1973) in a report on forecasting wheat production in Turkey developed a mathematical model which provides a comparatively reliable pre–harvest forecast of wheat production from weather data.

II. METHODOLOGY

The data for temperature and rainfall for the period 1947 to 1981 were collected from the department of meteorology of this University, whereas the wheat production data were collected from the statistical Bureau of Faisalabad. From weather data by using Coffing's (1973)

$$L_i = 12P_i / T_i + 10$$

formula, aridity index for each month was calculated and after that the statistical variance V_i for each year was calculated using the above mentioned aridity indices. The summation of all the $V'_i s$ has been given the name as "U". These variances have been used to incorporate the whole effect of the yearly rainfall and temperature. By using the effect formula $L_i(V_i / U)$ the value for each individual month has been found. The cumulative of January & February and May & June was found as X_1 and X_2, which were later used as variables in the model of the form:

$$Y = a + bX_1 + cX_2 \ .$$

Standard statistical techniques were employed to find values of a,b,c the coefficient of determination R^2 and to check the significance of $a,b,c,$ as done by Lomas (1972).

III. RESULTS AND DISCUSSION

In this research an attempt has been made to see the effect of two weather elements such as temperature and precipitation on the total yield of wheat in the Faisalabad district, keeping in mind the research work by Thompson (1962, 1969a, 1969b, 1970) on weather and technology in the production of wheat corn and soybeans in which he used multiple regression analysis in relating crop yields to weather variables. The results in the form of coefficient of regression have been shown in Table 1, which shows the value of R^2 equal to 0.2007. This means that the contribution of rainfall and temperature is twenty percent.

Table 1. Regression Analysis and Anova

Regression

Variable	Req. Coft.	S.E.	Prob.	Partial r^2
X_1	9.37	42.35	.82634	.0016
X_2	174.08	91.17	.06551	.1052
Constant	1269.92			

S. E. E. = 333.60

R^2 = .2007

Multiple R = .4480

Analysis of Variance

Source	S. O. S.	D. F.	M. S.	F. Ratio	Prob.
Reg.	866276.59	2	433138.3	3.892	.0310
Residual	3449929.36	31	111288.04		
Total	4316205.95	33			

It is clear from the two graphs Figs.1 and 2 that there is a fluctuation in both the total rainfall (mm) & yield (Kg / Hec.) till the "Green Revolution" (1965) in Pakistan, this situation was changed later on with the introduction and advancement of technology (mechanised farming, fertilizers, pesticides etc.) and showed a considerable deviation from the weather

Table 2. Observed and Calculated Yield Based on Regression Equation

Year	Yield Kgs per hectare Observed	Yield Kgs per hectare Calculated	Yield Kgs per hectare Residual
1947–1948	1163.34	1334.620	−171.28
1948–1949	1349.54	1510.027	−160.49
1949–1950	1395.98	1426.359	−30.38
1950–1951	1453.56	1505.457	−51.90
1951–1952	1077.37	1351.658	−274.29
1952–1953	1048.49	1411.946	−363.46
1953–1954	729.00	1375.002	−646.00
1954–1955	1160.57	1442.841	−282.27
1955–1956	1108.84	1448.495	−339.66
1956–1957	1174.83	1404.109	−229.28
1957–1958	1171.38	1518.920	−347.54
1958–1959	1158.95	1369.804	−210.85
1959–1960	1181.70	1441.502	−259.80
1960–1961	1230.39	1344.125	−113.74
1961–1962	1199.17	1361.102	−161.93
1962–1963	973.15	1315.845	−341.89
1963–1964	1204.28	1331.257	−126.98
1964–1965	1361.41	1461.033	−99.62
1965–1966	1168.23	1353.075	−184.84
1966–1967	1333.08	1308.406	24.67
1967–1968	1658.31	1394.613	263.70
1968–1969	1706.45	1389.334	317.12
1969–1970	1842.05	1412.788	429.26
1970–1971	1440.57	1296.664	143.91
1971–1972	1785.30	1411.312	373.99
1972–1973	1844.79	1325.705	519.09
1973–1974	1806.21	1903.132	−96.92
1974–1975	1858.22	1410.667	447.55
1975–1976	1894.33	1660.648	233.68
1976–1977	1895.77	1994.086	−98.32
1977–1978	1863.92	1387.205	476.71
1978–1979	2029.57	1606.145	423.43
1979–1980	1946.55	1763.916	182.63
1980–1981	1095.87	1340.172	755.70

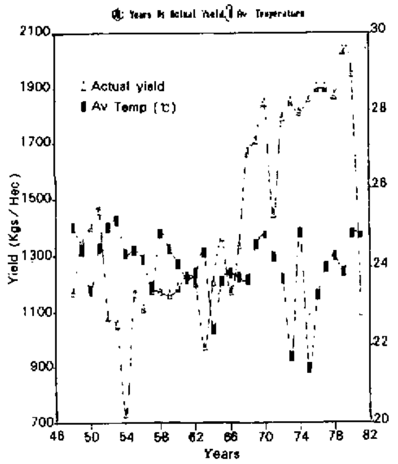

Fig.1. Years Vs actual yield and Av. temperature.

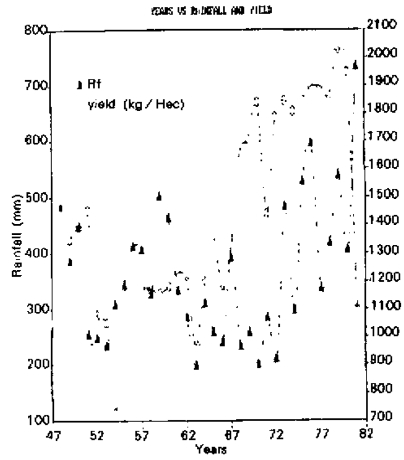

Fig.2. Years Vs rainfall and yield.

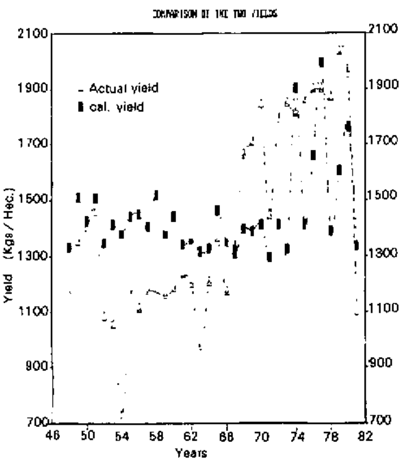

Fig.3. Comparison of the two yields.

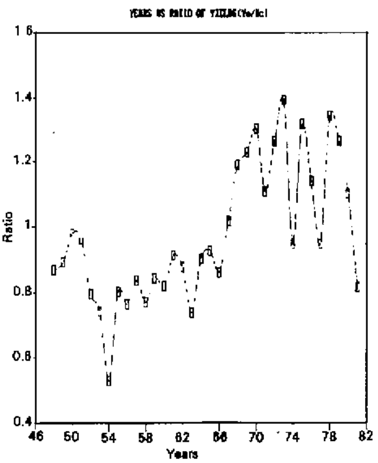

Fig.4. Years Vs ratio of yields (Yo / Yc).

parameters and gave much better results in the form of yield (Fig.2). This result is in consonance with that of Mc Quigg (1975) who in his analysis of crop weather data concluded that the component labelled technology would include about 70–80 percent of the total variance and the "weather" about 12–18 percent of the variation.

The model fitted is of the linear form, by substituting the values of the regression coefficient the regression equation is given by:

$$Ye = 1269.92 + 9.37X_1 + 174.08X_2 \ .$$

This equation gave us the expected yield for the thirty four years shown in the Table 2. A plot of the yearwise yield (Actual & Calculated) is given as Fig.3. Thus a comparison has been made between the actual and calculated yields for different years based on the above mentioned least square equation. The table indicates quite a high amount of errors on both sides of the actual figures, the large error indicates the seasonal variation between the years have not contributed significant increase or decrease in the production figures. Thus other variables like area planted, level of fertilizer application etc. could be studied in more details to find a suitable model for crop production. We can make this support by Mc Quigg (1975) who stated that there are three major sources of variability in yields of grain over a period of years, i. e., (a) Technological Change (b) Meteorological Variability (c) Random Noise.

In meteorological variability both within and between seasons is another source of variability in yields.

i. Use of a "Weather Index" which may be expressed as ratio of actual yields to some trends yield (Fig.4). The value for Weather Index for this region turns out to be 0.9775.

ii. Inclusion of selected meteorological variables such as temperature and precipitation terms in weather yield models. In most of the weather yield models the weather variables are not truly independent; the response to increments of precipitation or temperature is not linear; and there is an increasing tendency towards yield reductions when using meteorological data of sample means differing from those employed in the development of the model. Finally there is often interaction between weather and technology a problem which tends to affect the estimates from such models.

The significance of the regression coefficients has been tested by calculating students "T" values which for "*b*" and "c" are 1.283 and 1.037 respectively, both the values are non significant at 1% and 5% levels, showing that the contribution to the yield from the aridity index at germination and that at ripening is significant. These results are supported by the study of Gangopadhyaya and Sarkar (1965), Salimi (1988) who revealed that addition rainfall during a period of about one month prior to sowing and during the period of germination is in general beneficial to the crop, whereas more rainfall during the tillering phase is detrimental. The study also revealed that if the dry period coincides with a sensitive phenological stage, this could damage the crop development. On the other hand, dry periods at the ripening stage of the crop are sometimes beneficial. Now for the region concerned the average rainfall during the pre–sowing and germination is not sufficient so the farmer can improve the final yield considerably by one or two irrigations during the period.

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