

NON-REVERSIBILITY APPROACH : AN APPLICATION TO ESTIMATING SORGHUM YIELD RAINFALL RELATIONSHIP

1. In crop weather modelling with the multiple regression approach, the variable whose effect generally not taken into account is the total annual rainfall. It may be due to that it, being a linear combination of all the constituent period rainfalls. Contrary to this, we feel that the total rainfall may leave 'residual' effect or 'carry-over' effect sufficient to affect the crop yields in the subsequent years. For instance, the response of crop to rainfall in a particular year could be different in cases where the preceding year was a drought year than when the preceding year was an excessive rainfall year. Such 'differential' responses can be studied using the non-reversibility approach. The approach has been employed to estimate the supply relations in economics (Tweeten

and Quance 1969, Wolfram 1971, Houck 1971 and Trail *et al.* 1978). Here, we demonstrate the plausibility of this approach in estimating sorghum yield rainfall relationship for Parbhani district based on 24 years data from 1957-58 to 1980-81. The relationship was estimated with time trend (t), monthly rainfalls of monsoon season and the total annual rainfall (W) as the explanatory variables. The choice of monthly rainfall is justified since the objective is to obtain an aggregative relationship for the district.

2. *Present approach*— Considering the probable non-reversible behaviour of the annual rainfall, the variable W was split into the Positive (P) and Negative (N) components (Houck 1977), as follows :

$$P = \sum \Delta W_{i 1}, \Delta W_{i 1} = (W_i - W_{i-1}), \text{ if } W_i > W_{i-1} \\ = 0, \text{ otherwise}$$

$$N = \sum \Delta W_{i 2}, \Delta W_{i 2} = (W_i - W_{i-1}), \text{ if } W_i \leq W_{i-1}, \\ = 0, \text{ otherwise.}$$

$$i = 1, \dots, n \text{ years.}$$

TABLE 1
Sorghum yield rainfall models

Equation	Eqn. No.	R ²
$Y = 53.17 + 20.48t + 1.26U -$ (5.06)** (0.39)** $0.0028V^2$ (0.0012)	1	0.6285
$Y = 204.92 + 72.89t + 1.08U +$ (26.87)* (0.28)* $0.577P + 0.056N$ (0.126)* (0.136)	2	0.7723
$Y = 321.58 + 20.18t + e$	3(a)	0.3500
$e = -270.93 + 1.26U - 0.0025V^2 +$ (0.39)** (0.001)* $0.2233P - 0.2230N$ (0.105)* (0.112)	3(b)	0.6841
$Y = 50.65 + 20.18t + 1.26U -$ $0.0025V^2 + 0.2233P - 0.2230N$	3(c)	0.7944
$Y = -3.37 + 20.14t + 1.39U -$ (4.63)** (0.37)** $0.0029V^2 + 0.21p + 0.18n$ (0.0019) (0.14) (0.16)	4	0.6892

(Figures in paranthesis are SE of the estimates)

*Significant at 0.05 level of probability

**Significant at 0.01 level of probability.

Thus the two components P and N represent the cumulative (persistent) changes in the annual rainfall. Another splitting of W , which considers year to year changes only was also considered as follows :

$$p_i = W_i - W_{i-1}, \text{ if } W_i - W_{i-1} > 0, \\ = 0, \text{ otherwise} \\ n_i = W_i - W_{i-1}, \text{ if } W_i - W_{i-1} \leq 0, \\ = 0, \text{ otherwise.} \\ i = 1, \dots, n \text{ years.}$$

These components, along with the monthly rainfall variables were then screened for their entry into the regression equation by the stepwise regression procedure.

3. *Results and discussion* — It was found that difference of the coefficients of P and N in the relationship (with July rainfall and trend t as the other variables, Eqn. 2, Table 1) was statistically significant, indicating the strong non-reversible effect of the annual rainfall on the crop yield. However, due to the strong collinearity between the variables (t, P) and (t, N), there was a distortion even in the sign of the trend coefficient, as can be seen from the relationship estimated without the components (Eqn. 1, Table 1). Hence the equation (with P and N) was estimated by applying the Restricted Least Squares approach (RLS) which is generally recommended under the multicollinearity situation (Koutsoyiannis 1978) and the results are presented in Table 1 (Eqns. 3a, 3b, 3c). It may be observed that the application of RLS approach has resulted in the inclusion of the October rainfall (V^2) also along with the July rainfall (U) in the relationship.

The significance of P in Eqn. 3 (which can now be considered for interpretation) indicates the existence of persistent effect of annual rainfall over years, thereby confirming the non-reversibility in W . This shows that year to year changes in the annual rainfall, taken

TABLE 2
Observed and estimated sorghum yield (kg/ha)
(Estimated from Eqn. 3c, Table 1)

Year	Observed	Estimated	Error (\pm)%
1957-58	422	348	17.54(+)
1958-59	422	610	44.55(-)
1959-60	422	327	22.51(-)
1960-61	376	372	1.06(+)
1961-62	281	272	3.20(+)
1962-63	365	512	40.27(-)
1963-64	664	465	29.97(+)
1964-65	633	649	2.53(-)
1965-66	574	528	8.01(+)
1966-67	598	512	14.38(+)
1967-68	624	505	19.07(+)
1968-69	563	588	4.44(-)
1969-70	534	611	14.42(-)
1970-71	534	486	8.99(+)
1971-72	289	319	10.38(-)
1972-73	308	445	44.48(-)
1973-74	284	453	59.51(-)
1974-75	662	577	12.84(+)
1975-76	557	735	31.96(-)
1976-77	1028	998	2.92(+)
1977-78	935	691	26.09(+)
1978-79	721	841	16.64(-)
1979-80	1249	1038	16.89(-)
1980-81	730	906	24.11(-)
1981-82*	1198	854	28.71(+)
1982-83*	1212	764	36.96(+)

(Error percent = (Observed — Estimated) \times 100 / Observed)

*Estimates on the basis of independent data.

cumulatively, do affect the crop yield individually according to increases and decreases. This is obvious from the fact that increasing rainfalls add to the residual soil moisture and the rate at which it recoups (compensated) is different than the rate at which it is lost during the year of decreasing rainfall. In comparison, there seems to be no significant impact of year to year changes alone (unless taken cumulatively) in the annual rainfall, as seen from the non-significance of p and n coefficients of the relationship (Eqn. 4, Table 1). It can be also observed that introduction of the components p and n in the relationship has increased the explanatory power from 62.8 per cent to 79.4 per cent, as can be also seen from the 'closeness' of the estimates (Table 2) obtained from Eqn. 3(c).

Thus, it can be concluded that there is ground to presume non-reversibility in respect of annual rainfall affecting the sorghum yields.

References

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