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Part II—Agricultural Growth in India

GROWTH AND FLUCTUATIONS IN FOODGRAIN YIELDS PER HECTARE—A STATEWISE ANALYSIS

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This paper presents some further statistical analysis of growth and fluctuations in foodgrain yields per hectare along the lines suggested in the paper entitled "On Analysing Agricultural Growth".[1] The latter paper outlined two alternative models seeking in one case to capture the effect of rainfall on yield variations along with the sustained trend with reference to time; and in another to capture the effect of rainfall, inputs, the interaction between their effects, as well as sustained changes in yields attributable among other things to productivity of inputs. It also presented the results of statistical analysis of cereal yields for two States and three regions of a third State based on the above models.

We have now extended the analysis to data for ten States covering the periods ranging from 15 to 23 years. It provides a better basis for evaluating the explanatory power of the hypotheses underlying the postulated relation, and the extent to which they are able to discriminate between the relative importance of the various explanatory factors in explaining the observed changes in yields.

In the first section, we clarify certain methodological points and outline the procedure adopted for the empirical exercises. In the second section, we present the results and the interpretations.

I

METHODOLOGY AND PROCEDURE FOR THE EMPIRICAL EXERCISES[2]

The Least Square method of estimation of parameters of a specified linear relationship between a set of variables, called the explanatory variables,

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1. A. Vaidyanathan, "On Analysing Agricultural Growth", Dr. Rajendra Prasad Memorial Lecture delivered at the 33rd Annual Conference of the Indian Society of Agricultural Statistics, December 21, 1979.

2. The arguments seeking to show the severe limitations of the usual growth rate computations on the basis of 'trend-fits' were questioned both in the Lonavla Seminar and by T. N. Srinivasan in a private communication. The main point of the criticism is that so long as the effect of weather and of inputs are uncorrelated, the trend-fitting of the usual type is quite valid as a way of approximating the impact of changes in input use. This point is well taken provided (*a*) we are explicitly relating changes in output (or yield) to changes in input variables and (*b*) weather has no effect on either the level of input use or the productivity of inputs. That there are several *a priori* reasons to doubt the latter has been pointed out in the earlier paper (Vaidyanathan, *op. cit.*). As regards (*a*), once we take time (T) as the proxy for sustained changes in inputs, the question whether rainfall is uncorrelated with time becomes relevant to the interpretation of the coefficients of the fitted trend. If rainfall does exhibit systematic pattern of behaviour over the period of analysis, then the coefficients will necessarily confound the effects of weather with that of inputs. This is quite apart from the possible confounding due to the effects of weather on the level and productivity of inputs.

and a variable called the explained variable, assumes the following set-up:

$$y_i = f(x_{1i}, x_{2i}, \ldots\ldots, x_{ki}) + e_i \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where (*i*) suffix i stands for the observation number,

(*ii*) $x_{1i}, \ldots\ldots, x_{ki}$ are the given values of the k explanatory variables,

(*iii*) y_i is the explained variable observed for the given set $(x_{1i} \ldots\ldots, x_{ki})$,

(*iv*) f is a specified linear function,

(*v*) e_i are random variables, known as the residuals, independently and identically distributed with mean equal to zero.

Usually, for the lack of knowledge of 'f', a few forms of f are specified using different transforms of the original variables or/and different subset of them, and the one with the highest R^2 is fished out as the true functional form. Next, tests of significance are carried out for 'non-zeroness' of each of the coefficients estimated in order to establish the bearing of the corresponding explanatory variable on the variable on the left hand side of the equation. This test of significance requires a further assumption that e_i are normally distributed.

There are two difficulties in the above procedure. First, there is no theoretical justification to choose the functional form corresponding to the highest R^2 as the true one where the assumption of e_i will be valid. This assumption (*v*) is crucial for the method of estimation. For example, if (Y, X) has a Bivariate Normal distribution with a low correlation on between Y and X, the true function in this case will be a linear one with a very low R^2 value. But depending on the sample it can so happen that a polynominal in X produces a more impressive R^2 value although the function specification is totally wrong. Secondly, the additional assumption of normal distribution of the residuals for the purpose of the test of significance is very stringent because of the nature of variables we are using.

We propose to proceed in the following way:

Let T = year,

SR_T = south-west monsoon rainfall, *i.e.*, rainfall during June to September of the agricultural year T,

TR_T = total annual rainfall, *i.e.*, rainfall during June to May of the agricultural year T,

I_T = index of input for the agricultural year T,

Y_T = yield per hectare of foodgrains in agricultural year T.

All the above variables are defined for a given State.

Our *a priori* assertion is that I_T, SR_T, TR_T, T are capable of explaining the variations in Y_T. Our purpose of estimation is to approximate the functional relations between Y_T, on the one hand and some of the other variables, on the other hand. But, since we do not have any idea of the form of the functional relations that actually exist, we shall try out linear and quadratic forms of SR_T, TR_T and T, and only linear form of I_T. In the absence of any knowledge of the functional form we are in search of a satisfactory approximation of the true function so that the residuals left are fairly random in nature and adequately satisfy assumption (*v*). To begin with, we shall try out the following linear functions for a number States:

(1) $Y_T = f(SR_T, SR_T^2, T, T^2)$
(2) $Y_T = f(TR_T, TR_T^2, T, T^2)$
(3) $Y_T = f(I_T, SR_T, T)$
(4) $Y_T = f(I_T, TR_T, T)$
(5) $Y_T = f(I_T, SR_T, I_T \times S_{RT}, T)$
(6) $Y_T = f(I_T, SR_T, I_T \times T_{RT}, T)$

In addition to the above functions, we shall also try out the usual trend-fitting in each State. The following is the trend function fitted:

(7) $\log Y_T = f(T, T^2)$

With the above function, growth rates (constant, accelerating or decelerating) are usually studied. In order to find out a satisfactory approximation of the true function, we begin with the examination of the residuals corresponding to each fitted function. Now, there can be more than one functional form which satisfy the assumptions about the behaviour of the residuals. In such cases we shall choose the one with the highest $\bar{R}^2$ which permits comparison of the explanatory powers of two functions with different number of explanatory variables. Also for each State, the trend-fit is performed by estimating both $f(T)$ and $f(T, T^2)$, and choosing the one with the highest $\bar{R}^2$ value.

Thus from among the first six functions mentioned above, the 'best-fitting' one is selected by proceeding in three stages.

(*i*) In the case of each function, the explanatory variables are introduced one by one (in the same sequence as they are mentioned above), and parameters estimated. After each step of introduction of a variable the corresponding $\bar{R}^2$ value is noted. Finally, the function corresponding to the step which gives the highest $\bar{R}^2$ value is selected. Thus, we will have six functions at the end of this exercise for each State.

(*ii*) The chosen six functions are now ranked in the descending order of their $\bar{R}^2$ values.

(*iii*) The residuals corresponding to the function with the highest (among the six) $\bar{R}^2$ value are now examined. First, we perform two non-parametric tests—the Sign test and the Run test—on the signs of the residuals. The first test is to verify whether the median of the distribution of the residuals is equal to zero, *i.e.*, whether positive and the negative signs are equally likely. The second test is to verify whether the opposite signs fall in a random sequence over time. If both the tests are not significant, we then study the scatter of the residuals over time. If the assumption (*v*) in display is true, the visual impression of the scatter will be that of a random scattering within a horizontal band around the horizontal axis. All these are to check whether the residuals are consistent with the assumption that they are independently and randomly distributed with mean zero. If nothing contradictory to the assumption is found, the function is selected as the 'best-fitting' one. Otherwise, we examine the residuals of the function with the second highest $\bar{R}^2$ value in the same way. And so on till we get a fraction with satisfactory behaviour of the residuals. It can so happen that none of the functions selected passes the examination of the residuals.

In some cases it should be possible to improve the explanatory power by specifying a modified function. Such modification can be made on the basis of the performance of the six functions chosen at the outset.

Because of the lack of proper data to construct the input indices as suggested by Vaidyanathan, we have chosen instead the first principal component of the proportion of gross area (under foodgrains) irrigated and the nutrients per hectare of gross area under foodgrains in each State.

In order to avoid the high correlation between T and T^2 we have transformed T as follows:

$$T' = T - \frac{n+1}{2}$$

where n is the number of years for which we have the time-series data. Hence onward we shall use T to mean T′. Correlation between T′ and T'^2 is zero.

II

RESULTS OF THE EMPIRICAL EXERCISES

For the purpose of the empirical exercises we have used whatever data we could lay our hands on. Ideally, one would like to have as long a time-series as possible. But, unfortunately, except for Punjab-Haryana and Tamil Nadu, we could collect only 14 to 15 years long time-series for different States. Cropwise fertilizer statistics are not available, so we have used the total fertilizer consumption by each State. This, again, is another handicap.

In Table I we present the 'Best'-fitting curves selected from among the various functions we tried. The selection is made in the manner already explained in the earlier section. Table I also presents the 'Trend' fitted in each case for comparison with the other curves. The functions in each State are presented in the descending order of their $\bar{R}^2$ values. Table II presents the analysis of the residuals corresponding to the functions presented in Table I.

In the case of Bihar, Maharashtra and West Bengal we could not find any of the selected functions satisfactory in terms of the behaviour of their residuals although they pass the Sign test and the Run test. See Table II for detailed findings of the analysis of residuals. We shall thus leave these States out for further analysis. In all other cases, the selected best-fitting function is consistent with the usual assumptions on the residuals.

In the case of Kerala, we present two functions [Sr. Nos. (*ii*) and (*iii*) in Table I] with almost the same explanatory power but with different implications about the factors contributing to the variations in the yield. The first one implies that rainfall alone contributes to the observed yield variation whereas in the second one both rainfall and inputs are the contributing factors.

TABLE I—RESULTS OF TREND-FITTING AND THE BEST-FITTING CURVES SELECTED

State	Function	R^2	$\bar{R}^2$	β_1	β_2	β_3	β_4	β_5
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1. Andhra Pradesh ..	(*i*) $Y'_T = f(T, T^2)$	0·7536	9·7125	0·015909 (5·069)	0·002714 (3·319)	—	—	—
	(*ii*) $Y_T = f(I_T, T, T^2)$	0·8171	0·7672	1·127028 (1·631)	0·008763 (2·377)	0·002175 (3·495)	—	—
2. Bihar	(*i*) $Y'_T = f(T)$	0·2109	0·1545	0·017227 (1·935)	—	—	—	—
	(*ii*) $Y_T = f(I_T, SR_T, I_T. SR_T)$	0·6415	0·5518	11·292334) (2·366)	0·002648 (2·244)	—0·009513 (2·002)	—	—
	(*iii*) $Y_T = f(I_T, TR_T, I_T.TR_T)$	0·6357	0·5446	8·153186 (3·410)	0·001572 (2·777)	—0·005145 (2·718)	—	—
	(*iv*) $Y_T = f(SR_T, SR_T^2, T)$	0·5759	0·4699	0·002864 (1·898)	—0·000001 (1·650)	0·013877 (2·631)	—	—
	(*v*) $Y_T = f(I_T, SR_T)$	0·5219	0·4483	1·829963 (2·513)	0·000305 (1·818)	—	—	—
	(*vi*) $Y_T = f(TR_T, TR_T^2, T)$	0·5526	0·4408	0·001089 (2·654)	—0·000001 (2·444)	0·012904 (2·200)	—	—
3. Kerala	(*i*) $Y'_T = f(T)$	0·5409	0·5056	0·010734 (3·913)	—	—	—	—
	(*ii*) $Y_T = f(SR_T, SR_T^2, T)$	0·6568	0·5632	0·000153 (1·824)	—0·000001 (1·774)	0·016201 (4·239)	—	—
	(*iii*) $Y_T = f(I_T, SR_T, T)$	0·6468	0·5505	0·001403 (1·657)	0·000070 (1·705)	0·016495 (4·178)	—	—

(*Contd.*)

TABLE I (*Contd.*)

State	Function	R^2	$\bar{R}^2$	β_1	β_2	β_3	β_4	β_5
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
4. Madhya Pradesh ..	(*i*) $Y'_T = f(T, T^2)$	0·2454	0·1196	0·011873 (1·658)	0·002002 (1·073)	—	—	—
	(*ii*) $Y_T = f(SR_T, SR_T^2, T)$	0·6264	0·5641	0·001016 (4·014)	—0·000001 (3·605)	—	—	—
5. Maharashtra ..	(*i*) $Y'_T = f(T, T^2)$	0·1490	0·0072	0·000182 (0·016)	0·004330 (1·449)	—	—	—
	(*ii*) $Y_T = f(I_T, TR_T, I_T. TR_T, T)$	0·8006	0·7208	—24·454033 (3·762)	—0·000523 (1·275)	0·007241 (1·846)	0·047593 (1·859)	—
	(*iii*) $Y_T = f(I_T, TR_T, T)$	0·7326	0·6597	—14·931736 (3·418)	0·000231 (5·298)	0·041603 (3·167)	—	—
	(*iv*) $Y_T = f(SR_T, SR_T^2, T, T^2)$	0·6904	0·5666	0·003305 (3·048)	—0·000002 (2·776)	0·008584 (2·102)	0·001984 (2·067)	—
6. Punjab and Haryana	(*i*) $Y'_T = f(T, T^2)$	0·8708	0·8579	0·038829 (11·382)	0·001317 (2·284)	—	—	—
	(*ii*) $Y_T = f(I_T, TR_T, TR_T^2, T, T^2)$	0·9467	0·9310	2·771382 (3·626)	0·001220 (3·038)	—0·000001 (2·293)	—0·006144 (0·402)	—0·000325 (0·362)
7. Rajasthan	(*i*) $Y'_T = f(T)$	0·1580	0·0932	0·017485 (1·562)	—	—	—	—
	(*ii*) $Y_T = f(SR_T, SR_T^2, T)$	0·6871	0·6018	0·003185 (2·471)	—0·000003 (2·094)	0·011802 (2·532)	—	—

(*Contd.*)

TABLE I (*Concld.*)

State	Function	R^2	$\bar{R}^2$	β_1	β_2	β_3	β_4	β_5
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
8. Tamil Nadu ..	(*i*) $Y'_T = f(T)$	0·7164	0·7046	0·015251 (7·787)	—	—	—	—
	(*ii*) $Y_T = f(TR_T, TR_T^2, T, T^2)$	0·7999	0·7618	0·001894 (2·260)	—0·000001 (2·039)	0·015122 (6·599)	0·000828 (2·515)	—
	(*iii*) $Y_T = f(I_T, TR_T, T, T^2)$	0·7612	0·7157	—0·285539 (0·294)	0·000204 (1·926)	0·016227 (3·309)	0·000542 (1·431)	—
9. Uttar Pradesh ..	(*i*) $Y'_T = f(T)$	0·5187	0·4817	0·021983 (3·743)	—	—	—	—
	(*ii*) $Y_T = f(TR_T, TR_T^2, T)$	0·6989	0·6168	0·000359 (1·802)	—0·000001 (1·370)	0·017272 (3·721)	—	—
10. West Bengal	(*i*) $Y'_T = f(T, T^2)$	0·5736	0·4960	0·016237 (3·616)	—0·001435 (1·202)	—	—	—
	(*ii*) $Y_T = f(I_T, TR_T, I_T . TR_T)$	0·6874	0·5936	—13·364106 (2·452)	—0·001215 (1·731)	0·006054 (1·833)	—	—
	(*iii*) $Y_T = f(I_T, SR_T)$	0·6484	0·5845	—4·196392 (2·957)	0·000224 (1·688)	—	—	—
	(*iv*) $Y_T = f(TR_T, TR_T^2, T)$	0·6337	0·5238	0·000659 (1·400)	—0·000001 (1·217)	0·010018 (1·526)	—	—

Note:— Y_T = Foodgrain yield. I_T = Input index. SR_T = South-west monsoon rainfall. TR_T = Total annual rainfall.

T = Year. $Y'_T = \log_e Y_T$.

Figures in brackets are the well-known absolute T-values.

TABLE II—ANALYSIS OF THE RESIDUALS OF THE CURVES PRESENTED IN TABLE I

State	Sr. No. of the function in Table I	Sign test	Run test	Visual impression of the pattern of scattering
1. Andhra Pradesh ..	(ii)	IS	IS	
2. Bihar	(ii)	IS	IS	Variance seems to be increasing over time.
	(iii)	,,	,,	,,
	(iv)	,,	,,	,,
	(v)	,,	,,	,,
	(vi)	,,	,,	,,
3. Kerala	(ii)	IS	IS	*
	(iii)	,,	,,	*
4. Madhya Pradesh ..	(ii)	IS	IS	*
5. Maharashtra	(ii)	IS	IS	Shows cyclical pattern.
	(iii)	,,	,,	,,
	(iv)	,,	,,	Variance does not seem to be constant. It is higher in the middle.
6. Punjab and Haryana ..	(ii)	IS	IS	*
7. Rajasthan	(ii)	IS	IS	*
8. Tamil Nadu	(ii)	IS	IS	Location seems to have shifted in the middle.
	(iii)	IS	IS	*
9. Uttar Pradesh	(ii)	IS	IS	*
10. West Bengal	(ii)	IS	IS	Scattering seems to be spread in an arch-band.
	(iii)	,,	,,	,,
	(iv)	,,	,,	,,

Note:— IS = Insignificant.

* Fairly random scattering within a horizontal band.

In the case of Tamil Nadu again, we present two functions. The first one (*i.e.*, one with the highest $\bar{R}^2$) does not seem to be properly specified (see Table II). The second function is chosen as the best-fitting one as the corresponding residuals look fairly satisfactory. Notice that the estimated coefficient for the input index is negative and the corresponding T-value is very low. The T-value can be taken as a measure of the precision in the estimate. Thus, the said coefficient estimate is not reliable enough and the possibility of the actual parameter being positive cannot be ruled out.

From Table I it can be seen that the explanatory power (EP) of the best-fitting functions are uniformly better than their corresponding trend-fits. But the extent of improvement in EP differs from State to State, so also the EP itself. The variables which figure in the best-fitting functions also differ from State to State. Barring the cases of Bihar, Maharashtra and West Bengal (for which we could not find a proper function and hence left out of further analysis), the rainfall variable appears in 6 out of 7 cases (with a weakly negative coefficient in Tamil Nadu). Time variable also appears in 6 out of the 7 cases (with Madhya Pradesh as the exception). The coefficient for T cannot be always interpreted as a measure of 'technological progress' —for in several States (Rajasthan, Uttar Pradesh) where the input index has risen, I_T does not appear in the best-fitting functions. Only in the cases where T appears along with I_T or where the level of inputs is low or falling, the coefficient of T can be interpreted as an indicator of 'technological progress'.

It is to be noted that the product term of I_T and rainfall does not appear in any of the best-fitting functions. The reason may be that the interaction between weather and inputs is not properly specified. For example, in West Bengal, the function with the interaction term produces unsatisfactory residuals.

In Table III we have categorised the seven States according to the extent of improvement in the EP of the best-fit over the trend-fit along with the level of the inputs in order to study the relation among them.

TABLE III—ANALYSIS OF THE RELATION BETWEEN THE DIFFERENCE IN EP BETWEEN THE BEST-FIT AND THE TREND-FIT, AND THE LEVEL OF THE INPUTS

State	Level of rainfall	Level of irrigation	Growth of inputs[1]	Variables in the best-fit	Best-fit R^2	Difference of R^2 between best-fit and trend-fit
Rajasthan	Low	Low	Moderate	R,T	·69	·53
Madhya Pradesh ..	Moderate	Low	High	R	·63	·38
Kerala	High	Moderate	Fall[2]	R,T	·66	·12
Uttar Pradesh ..	Moderate	Low	High	R	·70	·18
Andhra Pradesh ..	Low	Moderate	High	I,T	·82	·07
Punjab and Haryana	Low	High	Moderate	I,R,T	·95	·08
Tamil Nadu	Moderate	High	Low	I,R,T	·76	·04

Note:— R=Rainfall variable (SR_T or TR_T) in linear or quadratic form.
T=Time variable in linear or quadratic form.
I =Input index.

1. Growth of inputs has been measured by the percentage increase in the input index average of the first and last three years.
2. Kerala input index shows 13 per cent fall over the period considered.

In the case of Rajasthan and Madhya Pradesh, it can be seen from Table III, the best-fit makes a considerable improvement over the trend-fit in terms of their EPs. These States are characterized by low level of irrigation (5 and 18 per cent respectively). In both cases rainfall seems to be the dominant variable.

In the case of Kerala and Uttar Pradesh, the best-fit makes a moderate improvement over the trend-fit in terms of their EPs. But, though they differ in the level of irrigation, level of rainfall and growth of inputs, both rainfall and time seem to be the dominant variables. In the case of Andhra Pradesh, Punjab-Haryana and Tamil Nadu, the best-fit makes only a marginal improvement over the trend-fit. But, clearly the role of inputs was concealed in the case of the trend-fit for Andhra Pradesh and Punjab-Haryana.

It is interesting to note that the explanatory power is very high in the case of Punjab-Haryana and moderately high in the case of Andhra Pradesh and Tamil Nadu—ranging from 0.76 to 0.95. In contrast, for the rest of the States, the explanatory power seems to be on the lower side—falling between 0.63 and 0 70.

The above observations seem to indicate that—within the limitations (discussed later) of our exercises—the level of uncertainty in yield reduces as the level of inputs rises. At a low level of inputs, the weather variation contributes to most of the variation in yield.

We note that the explanatory power can probably be further improved by considering better and finer measures of weather as well as of inputs. For example, since it is the moisture that is finally available to a plant during its growing stage, which affects the yield, it would be desirable to introduce the estimated contribution of rainfall to soil moisture in the regression rather than the quantum of rainfall by itself. But we do not know enough yet to be able to transform rainfall into the soil moisture supply. Similarly, the percentage of gross cropped area irrigated cannot capture the quantum of water supplied or the dispersion in the quality of irrigation due to varying mixes of different sources of water supply. Again, as the sowing times and growing periods of different foodgrain crops are different, aggregation over different crops and seasons could lead to confounding of relations among them.

In addition to all these, we also have the problem of spatial aggregation. Agro-climatic conditions differ considerably across the regions within a State. The importance of intra-State variation in rainfall and its distribution and the difference it makes to the estimated weather-free trends are illustrated by the regionwise analysis for Andhra Pradesh reported in Vaidyanathan's paper.[3] The best-fitting functions were found to be different for different regions as well as for rice and other foodgrains. In general, the functional forms considered by us may be too simplistic to describe the aggregations of several different relationships among the variables.

3. *op. cit.*

In the case of fertilizers, lack of data on the quantity applied to different crops made it necessary to use the average quantity per gross cropped hectare for measuring the intensity of fertilizer use on foodgrains as a whole. This assumption is obviously open to question; as is our inability to distinguish between different intensities of fertilizer use on different foodgrains under different moisture regimes. While there is no prospect of remedying these defects in the near future, it should be possible to carry out the analysis for more disaggregated agro-climatic regions using districtwise data for irrigation and fertilizer use for all foodgrains. In the case of individual foodgrains, input indices including fertilizer cannot be constructed at present; but it would be worthwhile to try out formulations with more refined specifications of at least rainfall, irrigation and sowing dates.

The results of the analysis presented in this paper seem promising enough to warrant further work along these lines.

APPENDIX A

SOURCES OF DATA

The sources of data used for the purpose of the empirical exercises are as follows:

1. For 1967-68 to 1975-76: Figures of area, production and irrigated area for foodgrains are collected from an article titled "Foodgrains Production and Trends—A Statewise Analysis", V. Mackrandilal, The World Bank, 1979.

2. For 1950-51 to 1966-67: Figures of area and production for foodgrains are collected from Estimates of Area and Production of Principal Crops in India.

3. Irrigated area under foodgrains prior to 1967-68 have been collected from various sources.

(*i*) Andhra Pradesh: Statistical Abstracts of Andhra Pradesh.

(*ii*) Bihar: Season and Crop Reports of Bihar.

(*iii*) Kerala: Statistics for Planning, Kerala, 1972.

(*iv*) Madhya Pradesh: Season and Crop Reports of Madhya Pradesh.

(*v*) Maharashtra: Indian Agricultural Statistics, Vol. II.

(*vi*) Punjab and Haryana: Statistical Abstracts of Punjab and Haryana.

(*vii*) Rajasthan: Indian Agricultural Statistics, Vol. II.

(*viii*) Tamil Nadu: Statistical Abstracts of Tamil Nadu.

(*ix*) Uttar Pradesh: Indian Agricultural Statistics, Vol. II.

(*x*) West Bengal: Indian Agricultural Statistics, Vol. II.

4. For 1962-63 to 1975-76: Figures of total fertilizer consumption (NPK nutrients) have been collected from Fertiliser Statistics, India. For Tamil Nadu, total fertilizer consumption figures for 1950-51 to 1961-62 have been collected from Towards a Greener Revolution, Report of the Task Force on Agriculture, 1972-1984, Perspective Planning Commission, Madras.

   For Punjab and Haryana, total fertilizer consumption figures prior to 1962-63 have been collected from Season and Crop Reports of Punjab and Haryana.

5. For 1950-51 to 1974-75: Rainfall data have been collected from an article titled "Variations in Crop Output", S. K. Ray, Institute of Economic Growth, Delhi, 1977.

   For 1975-76: Rainfall data have been collected from Estimates of Area and Production of Principal Crops in India. Note that all the rainfall figures are weighted average of rainfall data of the different agro-climatic regions within each State. Weights used are reported in the above article.