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AN ANALYSIS OF GROWTH OF PRODUCTION OF RICE AND WHEAT CROPS IN INDIA

T. P. Abraham and S. K. Raheja

INTRODUCTION

Rice and wheat are the major food crops in India on the production of which depends, to a large extent, the economy of the country. A number of measures have, therefore, been taken by the Government of India to effect rapid increase in the production of these important cereal crops. A study of the trends in production of these crops in recent years has been made by Panse[1] and the Directorate of Economics and Statistics.[2] The overall growth of agricultural production in some of the States was also studied by Parikh.[3] An analysis of the growth of production can be most useful for policy making if it is related to the various measures particularly technical inputs, such as, area under the crop, additional irrigation facilities, use of fertilizers and manures and improved seeds. The object of the present paper is to examine to what extent the production of rice and wheat in the last 14 years is explained by the changes in some of these factors. Change in the quality of seed and its replacement is a continuous process and no reliable data on the extent of its spread from year to year are available. This factor was, therefore, not included as a variable. However, to the extent improved seed has been used in association with the other factors which have been taken into account in the study, the effect of seed is included in the benefit imputed to the other factors. Further, to take account of this and other factors, such as improved technology the analysis was also done with the inclusion of the time variable, otherwise called the catch-all variable, in the production function. Since the growth of output as well as inputs and the agro-climatic conditions vary widely from State to State in a vast country like India, it was felt that the utility of an analysis of production changes will be enhanced if it is done on a regional basis. However, due to the limitations in the availability of reliable estimates of inputs at the district level, such regionalisation had to be limited to the State level. The study was taken up for those States which are important for the particular crop. More than 97 per cent of the area under rice and 94 per cent of the area under wheat have been accounted for by the States under this study.

SOURCE OF DATA

For the output, data on index numbers of production for rice and wheat crops for the years 1951-52 to 1964-65 were available from the Directorate of Economics and Statistics, Ministry of Food and Agriculture, Government of India. From these, using the actual production figures of 1960-61, the production for the different years was obtained. The area under the crops as also the irrigated area were available from the same source. However, the irrigated area for

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1. V. G. Panse, "Yield Trends in Rice and Wheat in First Two Five-Year Plans in India," *Journal of the Indian Society of Agricultural Statistics*, Vol. XVI, No. 1, 1964.

2. Government of India : Growth Rates in Agriculture 1949-50 to 1964-65, Directorate of Economics and Statistics, Ministry of Food and Agriculture, New Delhi, March, 1966.

3. Ashok Parikh, "State-wise Growth Rates in Agricultural Output—An Econometric Analysis," *Artha Vijñāna*, Vol. VIII, No. 1, March, 1966.

the last two years, namely, 1963-64 and 1964-65 was not available and was estimated from the earlier years' figures. The data for fertilizer consumption were taken from the "Fertilizer Statistics" but they pertained to the total for all crops in each State. The total consumption of fertilizers in a State was taken as the sum of nitrogen and phosphate figures (weighted by their respective prices). The total fertilizer consumption in a State was apportioned among the important crops grown in the State (assuming that fertilizers were applied to the important crops only), using compound weights based on area under the crop and the corresponding rate of application of fertilizers. Information on the rates of application of fertilizers was available from the results of surveys carried out by the Institute of Agricultural Research Statistics in selected districts to study the pattern of fertilizer use. For wheat crop, where no reliable estimate of rate of application of fertilizers to unirrigated wheat was available, this was taken as half of that to irrigated wheat. In the States where such surveys had not been conducted, the rates of application were assumed proportional to the departmentally recommended levels. Thus if A_1, A_2 and A_3 are the areas under say, rice, wheat and sugarcane crops respectively and x_1, x_2 and x_3, the rates of application of fertilizers to these crops, the total fertilizer consumption was apportioned in proportion to A_1x_1, A_2x_2 and A_3x_3, where A_2 was obtained as $\left(AI + \frac{Au}{2}\right)$, AI and Au being irrigated and unirrigated areas under wheat crop.

ANALYSIS OF PRODUCTION

In the first instance the output and the various inputs were plotted for each State. Some of the more plausible types of functional relationships relating yield with the inputs are the following :

(i) $y = a + b_1x_1 + b_2x_2 + b_3x_3$ ....(Linear)

(ii) $y = ax_1^{b_1}x_2^{b_2}x_3^{b_3}$ ....(Cobb-Douglas)

(iii) $y = \log a + b_1 \log x_1 + b_2 \log x_2 + b_3 \log x_3$ ....(Semi-log)

(iv) $\log y = a + b_1x_1 + b_2x_2 + b_3x_3$ ....(Exponential)

where y is the output, x's are the inputs and a and b's are constants.

The simplest functional form is no doubt the Linear which, however, assumes that the marginal product is constant with respect to any of the inputs. With this model, the effects of individual factors are assumed to be additive. The Cobb-Douglas function is frequently employed in the production function studies and this function exhibits the characteristic of diminishing returns to factors with a constant elasticity of production. In the Exponential function, it is assumed that the relative rate of growth with respect to any input is constant while in the Semi-log function, the rate of growth in the output is assumed to be at a lower rate than the rate at which the input increases, being proportional to the inverse of the inputs.

All these functions were fitted to the data using standard Least Squares procedure, where necessary, by transformation of data to the logarithmic scale. The correlation between estimated production figures from the fitted functions and observed production can be taken as a measure of the adequacy of the functional form. The squares of these correlation coefficients, also known as coefficient of determination, are given in Table I(a) and I(b), for rice and wheat crops respectively. In the case of rice, it is seen that a high correlation was obtained in the southern States of Andhra Pradesh, Madras, Mysore, and Kerala with all the functions. In Punjab also, the correlation was equally high. The correlation was extremely poor in Assam, where the output itself did not show any appreciable change in the period covered. Similar relatively low correlations were obtained in Gujarat, Orissa, West Bengal and Bihar. In the case of wheat crop also, the coefficient of determination was high in the Punjab, while in the States of Uttar Pradesh and Bihar, it was rather poor. Thus it appears that in the entire eastern and north-eastern region, characterized by mainly rain-fed crop and largely depending on the vagaries of monsoon, the correlation was relatively low as compared to the southern region and Punjab with high percentage of irrigated area under the crop.

TABLE I (a)—VALUES OF R^2 (SQUARE OF MULTIPLE CORRELATION) $\times$ 100

CROP : RICE

State	Linear	Cobb-Douglas	Exponential	Logarithmic
1	2	3	4	5
Andhra Pradesh	92.160	96.300	91.165	91.224
Assam	36.433	35.352	35.231	38.315
Bihar	53.232	59.622	59.149	65.622
Gujarat	49.351	60.747	43.288	62.867
Kerala	88.135	93.736	88.317	93.584
Madhya Pradesh	73.051	70.807	74.044	71.360
Maharashtra	70.947	71.712	70.028	72.487
Madras	92.391	97.797	97.358	96.914
Mysore	88.774	91.370	90.060	89.984
Orissa	37.198	38.345	48.832	—
Punjab	97.042	94.207	96.146	91.681
Uttar Pradesh	72.795	85.550	74.370	84.754
West Bengal	54.067	52.816	54.349	51.854

TABLE I (b)—VALUE OF R^2 (SQUARE OF MULTIPLE CORRELATION) × 100

CROP : WHEAT

State	Linear	Cobb-Douglas	Exponential	Logarithmic
1	2	3	4	5
Bihar	37.761	30.478	31.398	37.799
Gujarat	65.190	56.205	65.015	57.678
Madhya Pradesh	82.428	82.207	83.085	81.447
Maharashtra	76.720	80.710	81.384	77.026
Punjab	92.410	92.488	93.583	91.410
Rajasthan	57.692	55.512	63.187	54.430
Uttar Pradesh	25.746	25.032	26.525	25.132

Since the difference among the various fitted functions accounting for the variation in output was not substantial, the commonly used Cobb-Douglas function has been taken for subsequent analysis.

The values of the regression coefficients with and without time variable showed that in the case of rice, inclusion of this variable, while not improving the fit, gave less plausible coefficients. In the case of wheat, the reverse was the case. The analysis of growth of production of rice was, therefore, made excluding time variable while for wheat it was included.

THE FITTED FUNCTION

The coefficients of the Cobb-Douglas production function for rice crop are given in Table II(a). The function showed good fit in all the States except Assam and Orissa, while in Bihar, Gujarat and West Bengal, even though significant, the fit was not so good. The coefficient for unirrigated area showed wide variations from State to State being significant only in Bihar. The coefficient for irrigated area was significant and positive in Andhra Pradesh, Kerala, Madras and Punjab. The coefficient for irrigated area was negative in some of the States and was even statistically significant in Madhya Pradesh. The fact that some of the coefficients for irrigated area were negative is rather in conflict with the general experience that irrigation gives a positive increase in output. An examination of the yearwise data of the irrigated area in the States, where negative coefficient was obtained, showed that in all these cases, there was a large variation in irrigated area, the changes from year to year being somewhat opposite to the corresponding changes in production. One reason might be that in these States, rice is generally grown under rain-fed conditions and only when the normal rainfall is not received and under conditions somewhat unfavourable for the normal crop, whatever little

TABLE II(a)—ELASTICITY COEFFICIENTS OF COBB-DOUGLAS† PRODUCTION FUNCTION

CROP : RICE

State	Unirrigated area (b_1)	S. E.	Irrigated area (b_2)	S. E.	Fertilizer consumption (b_3)	S. E.	$R^2 \times 100$
1	2	3	4	5	6	7	8
1. Andhra Pradesh	0.0210	0.0468	0.5979**	0.1532	0.1475**	0.0352	96.3*
2. Assam	0.3442	0.3914	−0.1741	0.7145	0.0191	0.0188	35.4
3. Bihar	2.6909*	1.1241	1.2061	0.6461	0.0253	0.0782	59.7*
4. Gujarat	−1.5231	1.5415	0.2887	0.2667	0.3388*	0.1132	60.7*
5. Kerala	0.2089	0.2084	0.4027*	0.1401	0.0950**	0.0232	93.8*
6. Madhya Pradesh	2.3609	0.9731	−0.9289*	0.3256	0.0454	0.0555	70.8*
7. Maharashtra	1.0220	0.7594	−0.6086	0.8155	0.0484	0.0650	71.7**
8. Madras	0.0238	0.0823	1.4940**	0.1252	0.0946	0.0597	97.8**
9. Mysore	−0.1279	0.1097	−0.3754	0.6412	0.2116*	0.0905	91.4**
10. Orissa	0.0953	0.6565	−0.3387	0.4411	0.1153	0.0752	38.3
11. Punjab	0.3535	0.2458	0.8994*	0.3092	−0.0060	0.0523	94.2**
12. Uttar Pradesh	0.1946	0.7359	−0.2753	0.2459	0.2516**	0.0733	85.0**
13. West Bengal	1.1874	0.5053	0.1050	0.5679	0.0771	0.0425	53.0*

† This function is of the form $Y = a\, x_1^{b_1}\, x_2^{b_2}\, x_3^{b_3}$.

* Significant at 5 per cent level.

** Significant at 1 per cent level.

TABLE II(b)—ELASTICITY COEFFICIENTS OF COBB-DOUGLAS† PRODUCTION FUNCTION

CROP : WHEAT

State	Unirri-gated area (b_1)	S. E.	Irrigated area (b_2)	S. E.	Fertilizer consump-tion (b_3)	S. E.	Time (b_4)	S. E.	$R^2 \times 100$
1	2	3	4	5	6	7	8	9	10
1. Bihar	0.2573	0.6932	1.0713	0.6683	−0.1899	0.2760	0.0438	0.2346	30.7
2. Gujarat	0.4081	0.2141	0.7222	0.6257	0.2638*	0.1169	−0.3218	0.1935	66.5*
3. Madhya Pradesh ..	1.0301**	0.3107	1.0480*	0.5224	0.0952	0.0823	−0.3631	0.2054	86.7**
4. Maharashtra	0.8445	0.6110	0.9080	0.4930	−0.0910	0.0785	0.0255	0.1655	80.8**
5. Punjab	0.3018	0.2004	1.3998**	0.3814	0.0252	0.0484	−0.0306	0.0851	92.6**
6. Rajasthan	0.3650	0.2381	0.5071	0.7134	0.0229	0.1041	−0.2075	0.3826	56.9
7. Uttar Pradesh	0.2150	0.7591	0.4686	1.0025	−0.0228	0.1430	0.0789	0.1979	27.4

† This function is of the form $Y = a\, x_1^{b_1}\, x_2^{b_2}\, x_3^{b_3}\, t^{b_4}$.

* Significant at 5 per cent level.

** Significant at 1 per cent level.

irrigation was available was used to supplement the rainfall. This small addition of irrigation might not be adequate to compensate for the unfavourable rainfall situation so that the overall yield during the season was lower while the area under irrigation would be recorded as high. The fact that such abnormal results were not obtained in States like Andhra Pradesh and Madras, where irrigation is used not merely as protective irrigation, lends support to this presumption.

The relative contribution to the growth of output from use of fertilizer varied widely from State to State, but unlike irrigation, the contribution was positive in all cases except Punjab where it was negligible. The coefficient for fertilizer application was, however, statistically significant only in Andhra Pradesh, Gujarat, Kerala, Mysore and Uttar Pradesh.

For wheat crop, the values of regression coefficients including time variable are given in Table II(b). The coefficients for unirrigated area was significant only in Madhya Pradesh. For irrigated area, the coefficient was significant in Madhya Pradesh and Punjab. An increase of 1 per cent in irrigated area resulted in an increase of a little over 1 per cent in wheat production in Madhya Pradesh while in the Punjab, the corresponding increase was 1.4 per cent. An important observation is that in the case of wheat, the marginal product was positive in all the States both for increase in unirrigated area and irrigated area, which was not the case with rice. Apparently, in the case of rice crop, an increase in area resulted in bringing under cultivation sub-marginal type of land while in the case of wheat better quality of land would have been brought under cultivation. The effect of irrigation also appears to be more pronounced in the case of wheat as could be expected since rice is generally grown under assured moisture conditions.

As in the case of rice, the contribution to the growth of production of wheat crop from fertilizer use showed wide variation from State to State. On the whole, it appears that the fertilizer contribution in the case of wheat was not so marked as in the case of rice.

PRODUCTION CHANGES IMPUTED TO INPUT FACTORS

A knowledge of the contribution of individual input factors to the growth of production is essential for proper planning and target setting. This component-wise contribution to the total change in the output for the period 1951-52 to 1964-65 was calculated on an all-India basis as described below :

If $F(x_1, x_2 \ldots\ldots\ldots\ldots)$ is the production function, then to a first degree of approximation,

$$\triangle F = \sum_i \frac{\partial F}{\partial x_i} \triangle x_i$$

using the Taylor Expansion formula. In the case of Cobb-Douglas function, this reduces to

$$\triangle y = b_1 \frac{y}{x_1} \triangle x_1 + b_2 \frac{y}{x_2} \triangle x_2 + b_3 \frac{y}{x_3} \triangle x_3.$$

Utilizing this formula, we can work out the contribution to the annual changes in production by the annual changes in the individual components of the production function. These were worked out for each year aggregated over all the States both for rice and wheat. The results for rice and wheat are given in Table III. The estimated change in production from 1951-52 to 1964-65 was nearly 12.6 million tonnes. The aggregate of the contribution from individual components, namely, unirrigated area, irrigated area and fertilizer consumption during the same period amounted to a value of nearly 14 million tonnes. The difference of nearly 1.4 million tonnes should be considered to be due to the error in using a first degree approximation in the calculation and due to the random term in the production function. The contribution from an increase in unirrigated area of 7.27 million acres was an increase of 1.04 million tonnes while an increase of 7.74 million acres in the irrigated area added 2.26 million tonnes of rice. These figures indicate a rate of a little over one-third tonne per hectare as the contribution by unirrigated area while with irrigated area, the contribution was nearly double. Fertilizer consumption was estimated to have increased during the period of study by 0.38 million tonne nitrogen equivalent and this fertilizer consumption on rice crop resulted in an output increase of 10.7 million tonnes which works out to be about 25 tonnes increase for every tonne of fertilizer applied.

TABLE III—CHANGES IN PRODUCTION IMPUTED TO INPUT FACTORS

(*in thousand tonnes*)

	Change in production from 1951-52 to 1964-65	Contribution of input factors			
		Unirrigated area	Irrigated area	Fertilizer consumption	Time
Crop: Rice					
All-India	12559.13	1038.96	2255.40	10701.04	
Southern Region	5069.95	73.11	2004.21	3750.63	
Northern Region	2093.66	253.35	6.20	2075.91	
Crop: Wheat					
All-India	3465.02	2018.92	2765.12	1365.36	−2033.01
Western Region	1050.10	1115.41	1040.39	1359.47	−2071.53
Northern Region..	1386.33	351.27	956.19	378.34	− 191.20

During the period 1951-52 to 1964-65, the estimated increase in wheat production was 3.46 million tonnes. The sum total of the addition due to individual components was estimated as 4.1 million tonnes. As in the case of rice crop, the difference of 0.7 million tonne in the two figures should be attributed to the error of approximation. The increase in the unirrigated area during the period by 6.64 million acres resulted in an additional production of 2 million tonnes of wheat. This works out to about one-third of a tonne for every additional acre of area added to wheat crop. During the period, the irrigated area under wheat increased by 2.78 million acres and the additional production from this factor was estimated as 2.76 million tonnes of wheat. Thus the ratio is about 1 tonne per every additional acre of irrigated area. In the case of fertilizers the production increased from its use by 1.36 million tonnes for an input of 0.08 million tonne nitrogen equivalent. The rate of production from unit input of nitrogen equivalent of fertilizer was, therefore, about 17 units of wheat production.

REGIONAL ANALYSIS OF PRODUCTION CHANGES

An examination of the production function showed that in some of the States the fit was rather poor, particularly in the States of Orissa, Gujarat, etc., while in the southern States, a good fit was obtained. Further, in the southern States, rice production pattern is believed to be relatively more advanced as compared to some of the northern States. Therefore, the production changes were analysed separately for the southern States and northern States. In the southern States region, Kerala, Madras, Mysore and Andhra Pradesh were included while under the northern States only Punjab and Uttar Pradesh were considered, since Rajasthan and other northern States are not important for rice crop. The changes in production are given in Table III. In the southern States, the main contribution was again indicated as from fertilizer consumption and increase in irrigated area. In the northern States also, fertilizer accounted for the bulk of the additional production. The contribution from extension of unirrigated area was relatively more in the northern States as compared to the southern States while the reverse was the case with irrigated area.

In the case of wheat crop, there are two distinct regions, one the Punjab where wheat is grown under good moisture conditions and the other the western region consisting of the States of Maharashtra, Gujarat and Madhya Pradesh where it is generally grown under rain-fed conditions. The total change in production in these two regions during the period and the contribution from individual factors are given in Table III. In the Punjab region, the contribution from unirrigated area was much smaller than in the western region while for irrigated area, they were of the same order in both the regions. The contribution from fertilizer consumption was much more in the western zone.

PRODUCTIVITY PER UNIT AREA

Of the major factors of production, land is one of the relatively scarce resources in India and, therefore a study of changes in productivity of land is of considerable interest. For this study, production functions for each State were worked out relating yield per unit area with the proportion of irrigated area to the total area and the consumption of fertilizers per unit area. The imputation of change in productivity to the changes in the inputs was done in the same manner as explained earlier in the case of total production. For each State, the change in the yield per unit area contributed by the two factors was calculated for each year.

In order to get the aggregate average for the country, the estimates for individual States were weighted by the proportion of area under the crop in the

States for each year. The results thus obtained are given in Table IV for rice and wheat. In the case of rice, the productivity change was mainly accounted for by the increased use of fertilizers. In fact, the contribution to the unit area yield from increase in the proportion of irrigated area was even negative. The precise reasons for this rather anomalous situation are not clear, but partly it may be due to multiple cropping without additional irrigation facilities and partly due to less productive area being brought under irrigation gradually. As mentioned earlier, while discussing the total production Statewise, in the case of rice, very often the changes in irrigated area could be due to merely one or two protective irrigations

TABLE IV—PRODUCTIVITY CHANGES IMPUTED TO INPUT FACTORS

(*in thousand tonnes*)

	Change in productivity from 1951-52 to 1964-65	Contribution of input factors		
		Proportion of irrigated area	Fertilizer consumption	Time
Crop: Rice	7.8764	--2.3761	11.7518	
Crop: Wheat	0.3916	--0.0740	3.1058	−1.6253

being given in relatively unfavourable seasons. This may be also another reason for the anomalous productivity change explained by irrigation. The large contribution indicated on account of fertilizer consumption naturally must be including the contribution from those other factors which are linked with fertilizer use in production. In the case of wheat also, similar studies showed that per unit area increase in production was mainly accounted by fertilizer consumption. Unlike rice crop, in the case of wheat, the change due to proportion of irrigated area was negligible. Here again, this does not necessarily mean that irrigation itself did not increase production per unit area but may be partly due to the same reasons as already mentioned in the case of paddy.

YARDSTICK APPROACH

The above study shows that the approach of fitting production function to time series data, as has been done in the present case, has a number of limitations, such as the multi-collinearity of the input variables, the specification bias, etc. An alternative approach of determining the contribution of individual factors to the overall production is through the use of yardsticks of production calculated from experimental and survey data. The yardsticks of additional production for different fertilizers have been worked out by the Institute of Agricultural Research Statistics from extensive fertilizer trials in cultivators' fields conducted in the country over a period of years. Similar reliable yardsticks for irrigation are not readily available at present. However, a yardstick of about one-fifth tonne of additional foodgrains has been assumed generally. The limited experimental evidence available also was not at variance with this figure. Using these yardsticks, contributions to the additional production from these factors were worked out for each State annually.

The yield per unit area of unirrigated land was estimated as follows :

$$y = (u_1A_u + u_2A_i + u_3F)/A$$

where y is the average yield per unit area,

A_u is the total area unirrigated,
A_i is the total area irrigated,
A is the total area $(A_u + A_i)$,
F is the total fertilizer consumption,
u_1 is the yield per unit area of unirrigated and unfertilized land,
u_2 is $(u_1 + 0.2)$, and
u_3 is the yardstick of fertilizer consumption (per tonne).

The yardsticks for the three factors, mentioned above, could be utilized to calculate what may be called a composite input index for each year. This input index, I_c, was calculated as follows :

$$I_c = \frac{u_1x_1 + u_2x_2 + u_3x_3}{u_1x_1^0 + u_2x_2^0 + u_3x_3^0} \times 100$$

where x_1, x_2, x_3 are the variables unirrigated area, irrigated area and fertilizer consumption and x_1^0, x_2^0 and x_3^0 are similar quantities for the base year (1960-61).

The values of this index for the various States are presented in Tables V(a) and V(b) for rice and wheat crops respectively. The relationship between the index of production and the composite input index was worked out for each State. Both linear and Cobb-Douglas functions were fitted. The regression coefficient and the square of the correlation between the output index and the composite input index are given in Tables VI(a) and VI(b) for each of the States for the two crops.

Considering the States where the correlation between the output and the input indices were very high, the regression coefficients were not significantly different from unity both for rice and wheat indicating thereby that the output index increases by unity for unit increase in the input index. Even for the States where the correlation was moderate, the regression coefficient was not different from unity except in Bihar and Mysore for rice and Rajasthan for wheat.

The linear function gave generally as good a fit as the Cobb-Douglas function. For rice crop, except for Orissa, Madhya Pradesh, Gujarat, Assam and West Bengal, the relationship between the output and the input indices was quite good, accounting for 60 to 95 per cent of the variation in the various States. In the case of wheat also, the position was somewhat similar with regard to the two types of functions fitted. The correlation between output and input indices was particularly poor in Bihar and Uttar Pradesh, while the best fit was obtained in the Punjab.

In conclusion it may be stated that the utility of a production function approach to the analysis of growth can be greatly enhanced if suitable adjustment is made in the output for weather fluctuations. The importance of weather variable is apparent from the contrasting values of the multiple correlation coefficient obtained, on the one hand, for the States like Punjab, Madras, Andhra Pradesh, etc., where the crops are less affected by weather, being generally raised under assured mois-

TABLE V(a)—COMPOSITE INPUT INDEX

CROP : RICE

State	1951-52	1952-53	1953-54	1954-55	1955-56	1956-57	1957-58	1958-59	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Andhra Pradesh ..	76.92	71.74	88.35	89.72	94.49	101.96	98.83	105.58	109.09	100.00	109.65	121.88	129.92	135.89
Assam	96.82	98.87	99.40	98.45	101.48	101.80	98.94	102.97	99.65	100.00	101.04	102.81	105.47	108.99
Bihar	88.70	91.78	89.85	84.61	91.99	92.98	92.30	98.98	93.26	100.00	99.72	105.40	106.48	110.96
Gujarat	81.39	93.82	98.17	96.33	88.84	95.09	96.16	95.70	95.51	100.00	114.08	105.79	107.80	112.56
Kerala	78.42	75.44	88.28	89.58	91.50	90.16	92.74	92.77	95.58	100.00	97.34	102.65	116.53	111.13
Madhya Pradesh ..	90.30	89.37	93.11	91.24	91.38	93.38	98.01	96.02	99.10	100.00	102.39	106.57	108.33	114.43
Maharashtra	83.63	83.18	86.52	89.23	88.21	90.23	95.80	95.94	95.90	100.00	100.37	103.31	113.52	111.52
Madras	74.29	70.30	84.20	87.94	91.23	94.65	94.74	95.71	97.56	100.00	102.36	109.88	116.69	118.79
Mysore	70.11	69.68	78.78	96.58	75.07	85.77	93.15	99.28	98.52	100.00	103.01	107.42	139.56	151.90
Orissa	97.27	96.14	97.22	96.68	100.81	101.54	101.98	102.38	112.33	100.00	105.94	114.51	112.24	113.35
Punjab	51.36	55.91	59.61	60.12	61.48	67.99	75.40	83.48	89.66	100.00	104.45	110.92	113.74	128.52
Uttar Pradesh ..	76.13	77.87	78.08	78.07	79.17	84.90	87.13	96.28	105.28	100.00	100.15	107.52	118.57	125.49
West Bengal	89.31	101.66	96.49	89.80	93.22	94.14	95.37	93.08	96.17	100.00	90.71	97.02	100.15	103.31

TABLE V(b)—COMPOSITE INPUT INDEX

CROP : WHEAT

State	1951-52	1952-53	1953-54	1954-55	1955-56	1956-57	1957-58	1958-59	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Bihar	82.44	88.79	91.17	93.72	88.24	110.37	76.03	93.69	96.73	100.00	110.54	120.12	121.63	115.02
Gujarat	59.64	76.36	93.39	87.59	105.21	110.65	89.78	97.76	114.50	100.00	99.41	103.82	109.79	117.79
Madhya Pradesh ..	63.20	66.31	68.61	76.98	90.86	103.75	82.65	91.01	102.48	100.00	103.18	105.28	108.29	105.74
Maharashtra ..	65.69	63.58	73.80	80.46	89.91	93.11	90.68	90.18	95.44	100.00	103.21	106.88	111.70	106.86
Punjab	77.68	74.44	78.02	83.73	89.52	91.10	90.28	96.47	97.45	100.00	103.62	110.78	114.08	122.77
Rajasthan	42.60	64.43	72.02	81.02	86.57	117.79	96.75	106.31	108.76	100.00	116.88	117.81	109.20	119.58
Uttar Pradesh ..	85.30	85.68	95.29	95.65	100.86	89.00	93.37	97.36	98.35	100.00	101.45	104.29	104.57	105.20

TABLE VI(a)—CORRELATION BETWEEN OUTPUT AND COMPOSITE INPUT INDEX

CROP : RICE

State	Linear			Cobb-Douglas		
	Regression coefficient	S. E.	$R^2 \times 100$	Regression coefficient	S. E.	$R^2 \times 100$
1	2	3	4	5	6	7
Andhra Pradesh	0.91	0.0688	93.6	0.97	0.0670	94.6
Assam	1.02	0.4100	34.4	1.02	0.4400	31.0
Bihar	1.68	0.4010	59.6	2.00	0.5499	52.5
Gujarat	2.70	0.9009	42.8	2.18	0.8478	35.4
Kerala	4.09	0.1356	84.3	1.20	0.1486	84.5
Madhya Pradesh ..	0.66NS	0.4716	14.2	0.75NS	0.5848	12.0
Madras	1.13	0.2418	64.6	1.22	0.2613	64.6
Maharashtra	1.25	0.0946	93.6	1.42	0.0956	94.8
Mysore	0.63	0.1162	70.9	0.76	0.1303	74.0
Orissa	0.82NS	0.3759	28.6	0.91NS	0.4628	24.6
Punjab	1.15	0.0677	96.0	1.12	0.0742	95.0
Uttar Pradesh	0.88	0.1669	69.7	1.04	0.1930	70.7
West Bengal	1.77	0.5731	44.4	1.93	0.6168	44.9

NS = Not significant.

TABLE VI(b)—CORRELATION BETWEEN OUTPUT AND COMPOSITE INPUT INDEX

CROP : WHEAT

State	Linear			Cobb-Douglas		
	Regression coefficient	S. E.	$R^2 \times 100$	Regression coefficient	S. E.	$R^2 \times 100$
1	2	3	4	5	6	7
Bihar	0.50NS	0.3791	12.7	0.47NS	0.5162	56.6
Gujarat	1.05	0.2707	55.7	0.82	0.2232	52.9
Madhya Pradesh ..	0.96	0.1436	78.8	0.93	0.1341	79.9
Maharashtra	1.02	0.2258	62.7	1.17	0.2188	70.5
Punjab	1.25	0.1060	92.1	1.32	0.1146	91.7
Rajasthan	0.57	0.1508	54.3	0.44	0.1274	50.3
Uttar Pradesh	0.95NS	0.4759	24.8	1.07NS	0.5231	25.8

NS = Not significant.

ture conditions and, on the other, for the States of Bihar and Orissa where the crop production is highly susceptible to rainfall and other weather factors. The inclusion of suitable weather variables or a weather index in the production function would improve the fit of the function and help in the imputation of output to planned inputs. The development of such indices is, therefore, of utmost importance for production analysis.

In the new strategy of agricultural production, improved seed is intended to play a much more important role than has been in the past. To take account of this factor, it is necessary to develop the collection of objective statistics of the spread of improved seeds. With the inclusion of these variables, it would be possible to estimate production functions which will explain most of the observed variations in the output.

SUMMARY

In this paper, analysis of the growth of production of rice and wheat crops in India during the last 14 years (1951-52 to 1964-65) has been done with a view to assessing the contributions of the major factors of input, *viz.*, land, irrigation and fertilizer consumption. The study was made for the States which are important for these two crops. The analysis was done by fitting Cobb-Douglas type of production function which gave a good fit in the different States except for Assam and Orissa for rice and Bihar and Uttar Pradesh for wheat.

The total increase in the production of rice crop during the period under study was estimated at 12.6 million tonnes. The three input factors, *viz.*, unirrigated area, irrigated area and fertilizer consumption accounted for about 7, 16 and 77 per cent respectively. These figures indicated a rate of a little over one-third of a tonne per acre for unirrigated area and about two-third tonne per acre for irrigated area. For fertilizer consumption, its contribution worked out at about 25 tonnes per tonne of fertilizer applied.

For wheat crop, the total increase in its production during the period was about 3.5 million tonnes and the three factors accounted for about 30, 35 and 35 per cent respectively. The contribution rate from one acre of unirrigated area under wheat was thus about one-third tonne while for irrigated area, it was 1 tonne per acre. The contribution from fertilizer consumption was 17 tonnes per tonne of fertilizers used. Thus increase in the application of fertilizers was the main factor responsible for increase in the production of rice crop while for wheat crop the three factors contributed almost equally.

Imputation of the increase in the productivity per unit area showed that for both rice and wheat crops, the growth of productivity was mainly on account of increase in the application of fertilizers.

In view of the high correlation generally existing between the inputs, a composite index of input was constructed using the yardsticks calculated from the results of large scale field trials. The regression of output on this composite input index was calculated by fitting both the linear and Cobb-Douglas type of production functions. Both the functions showed good fit in most of the States accounting for 60 to 95 per cent of the variation in output.