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IMPROVING GROWTH OF FOODGRAINS PRODUCTIVITY IN THE WESTERN REGION OF INDIA

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The paper is divided into three sections. The first section deals with the study of growth rates of production, area and productivity of major foodgrains (rice, wheat, bajra and jowar) in the four States, *viz.*, Gujarat, Madhya Pradesh, Maharashtra and Rajasthan of the Western region of India. After getting some idea about the state of affairs regarding the growth rates of production of foodgrains, we tried to investigate the probable reasons. Inferring that there are indications for slowing down of productivity, section II deals with a study to relate productivity which is the main force behind the growth of agricultural production with the factors influencing productivity. Section III presents the summary and conclusions and makes recommendations regarding the steps to be taken to improve productivity.

I

GROWTH OF PRODUCTION, AREA AND PRODUCTIVITY OF MAJOR FOODGRAINS IN THE WESTERN REGION

Recently discussions among economists, administrators and knowledgeable persons have focused on the theme that agricultural growth in India is either stagnating or decelerating.[1] In the recent past, particularly in the green revolution period (1967-68 onwards) agriculture has been the mainstay for the overall economic growth in India. If this main force of economic growth peters out and other forces do not substitute this force the future economic growth is going to be jeopardised. It is, therefore, in the fitness of things that the question of agricultural growth is examined not only at the aggregate level of the country as a whole but at the regional levels. In the Western region, we decided to examine the question at the disaggregate level of States and crops. We have included four States: Gujarat, Madhya Pradesh, Maharashtra and Rajasthan and examined the question of growth of four major foodgrains, *viz.*, rice, wheat, bajra and jowar. We studied the problems of growth of production, area and productivity of individual crops for the region as a whole and for individual States.

Data Base

In order to study the growth rates, we have focussed mainly on the green revolution period because the major break-through in foodgrains production came after the introduction of high-yielding varieties (HYVs) of foodgrains in 1966-67. Since then in spite of weather fluctuations, the foodgrains

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1. Centre for Monitoring Indian Economy: Agricultural Production in India: State-wise and Crop-wise Data: 1949-50 to 1981-82, Bombay, May 1983.

production has not gone below the trough points of pre-1966-67 era.[2] We collected data of annual production of four major foodgrains for the four States for the period from 1965-66 to 1981-82. The question about the stagnation or deceleration of growth is examined by studying the growth rates for two periods: 1965-66 to 1976-77 and 1965-66 to 1981-82. These periods will be designated as period I and period II throughout the paper. The objective in differentiating these two periods is to examine the phenomenon whether the production in the last five years (1977-78 to 1981-82) had stagnated or decelerated the growth rates achieved upto 1976-77. We have not taken 1965-66 to 1976-77 and 1976-77 to 1981-82 as two separate periods because the latter was too short a period for using any statistical technique to find out the growth rates. Moreover, to find out the growth trends during the last five years and compare it with the growth trends of the previous period, if the same base year is used, the difficulty of having different base periods in such comparison is obviated.

Statistical Functions for Growth Rates

We decided to fit different statistical functions on the basis of (*a*) *a priori* reasoning and (*b*) visual impression.* The statical functions used are as follows:

I	log	Y	=	$a+bt$
II	log	Y	=	$a+bt^2$
III	log	Y	=	$a+bt+ct^2$
IV		Y	=	$a+bt$
V		Y	=	$a+bt^2$

where Y stands for production, area and yield and t for time. The *a priori* reason for the log-linear functions was the same as given by Dandekar, "the postulate that the change in agricultural output in a year would depend upon the output in the preceding year is reasonable. . . ."[3]

The first three are log-linear functions and the last two are linear functions. All the five functions are fitted for four major foodgrains production, area and yield for the Western region as a whole and for different States. It was observed that for bajra production not a single function was a good fit in the Western region and in all States except Madhya Pradesh. Function III ($\log Y = a+bt+ct^2$) was also not a good fit for any of the four crops in the Western region. Looking to the values of R^2, significance of 'b' values, and 'f' values, functions I, II, IV and V appeared to be good fits for rice, jowar and wheat. These would be designated as functions I, II, III and IV throughout the rest of the paper.

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2. J. S. Sarma and Shyamal Roy and P. S. George: Two Analyses of Indian Foodgrain Production and Consumption Data, Research Report 12, International Food Policy Research Institute, Washington, D.C., November 1979.

3. V. M. Dandekar, "Introduction" to Seminar on Data Base and Methodology for the Study of Growth Rates in Agriculture, *Indian Journal of Agricultural Economics*, Vol. XXXV, No. 2, April-June 1980, p. 3.

* The charts giving visual impression are not presented here.

Growth Rates of Production

The growth rates were worked out from the log-linear functions applying the usual method and from the linear functions using the harmonic means as basis.* As no 'b' values were significant for bajra except in Madhya Pradesh, we have restricted the discussion to only three crops: rice, wheat and jowar.

Rice production: The growth rates of rice production for the Western region were worked out from 'b' values (Table I). The growth rates varied from 3.56 to 6.04 per cent for the period II. These were less than the growth rates for period I (except for function II).**

At the level of States taking into consideration only the significant 'b' values, we had to restrict the observations to Gujarat, Maharashtra and Rajasthan (Table I). The high growth rates (more than 10 per cent) in Rajasthan may be due to the impact of canal irrigation. But the disturbing trend in Rajasthan was that the growth rates as indicated by the four functions had substantially declined between 1976-77 and 1981-82. This indicates the phenomenon of deceleration. The difference in 'b' values for the two periods was significant in function III (Appendix 1). But in Gujarat the growth rates during the last five years seemed to have improved (Table I). However, it cannot be firmly inferred as the differences in 'b' values were not significant in Gujarat. In Maharashtra, the differences in 'b' values were significant for functions III and IV (Appendix 1). This indicated an improvement in the growth rate of production during the last five years. This has balanced somewhat the deceleration effects of Rajasthan and Madhya Pradesh on the overall growth rate of production of the Western region as a whole. Thus it will be seen that the growth rates of rice production have not behaved in the same manner in all the four States. It is difficult to draw a general conclusion of deceleration.

Wheat production: The story of wheat is much different from rice. The 'b' values of all the four functions were significant for both the periods not only for the Western region but for all the four States.† The growth rates derived from these 'b' values for the Western region show that they were higher than 5.5 per cent in both the periods (Table I). However, the growth rates seemed to decline in period II compared to period I but the differences between the growth rates of the two periods were quite small for all the

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* $G_{yt} = \frac{1}{Y_t} \frac{dy_t}{d_t} \times 100$ for log-linear functions.

$G_{yt} = \frac{b}{Y_t\,(HM)} \times 100$ for linear functions.

** The differences between the 'b' values for the two periods were tested for significance using the formula of 't' for the means of two independent samples. The test applied can be considered as first approximation as the two 'b' values are not really from two independent samples. When the test gives non-significant results, it may be erroneous as the covariance in the denominator is not taken into account but when the test gives significant results, it is likely to be true.

† Except functions I and III for period I in Maharashtra.

TABLE I—GROWTH RATES FOR MAJOR FOODGRAINS PRODUCTION IN WESTERN REGION

(per cent)

Crop		Equation	Gujarat		Madhya Pradesh		Maharashtra		Rajasthan		Total (Zone)	
			1965-66 to 1976-77	1965-66 to 1981-82	1965-66 to 1976-77	1965-66 to 1981-82	1965-66 to 1976-77	1965-66 to 1981-82	1965-66 to 1976-77	1965-66 to 1981-82	1965-66 to 1976-77	1965-66 to 1981-82
Rice	I	Log Y = a+bt ..	3·39‡	4·33*	3·66†	2·23†	4·88*	5·27@	18·53@	10·31*	4·45@	3·56@
	II	Log Y = a+bt² ..	5·28‡	7·82*	4·56†	3·09‡	8·88*	9·52@	30·89@	15·30*	5·47†	5·78@
	III	Y = a+bt ..	4·47†	4·80*	3·23†	2·27†	5·64@	5·73@	19·10@	12·10*	4·26*	3·58*
	IV	Y = a+bt² ..	7·26†	8·67*	3·92†	3·35†	10·46@	10·49@	35·42@	18·39*	6·58†	6·04*
Wheat	I	Log Y = a+bt ..	6·13@	6·28@	6·26@	4·77@	5·86†	6·45@	9·04@	7·41@	6·92@	5·90@
	II	Log Y = a+bt² ..	10·80@	10·20@	9·12*	7·48@	13·92*	12·58@	14·88@	12·24@	11·52@	10·03@
	III	Y = a+bt ..	6·68@	6·80@	5·73@	4·60@	3·38†	7·39@	9·18@	7·69@	6·99@	6·04@
	IV	Y = a+bt² ..	12·09@	12·46@	8·36*	7·60@	19·50*	14·15@	15·59@	13·41@	11·77@	10·59@
Jowar	I	Log Y = a+bt ..	2·59†	3·46*	—0·79†	—0·29†	1·83*	4·91*	—1·15†	—1·05†	1·20†	3·16@
	II	Log Y = a+bt² ..	4·80†	6·46*	—1·68†	—0·24†	5·52†	9·86†	—2·40†	—1·70†	3·12*	6·46@
	III	Y = a+bt ..	3·24†	3·65@	—0·81†	—0·16	2·89†	5·82@	—1·11	—1·05†	1·43†	3·38@
	IV	Y = a+bt² ..	6·28†	6·75@	—1·84	0·06†	7·51*	11·56@	—2·96†	—2·03†	3·46†	6·75@

@ Good fit and b-value significant.
* Not good fit but b-value significant.
† Not good fit and b-value not significant.
‡ Good fit but b-value not significant.

functions. The differences in 'b' values for the two periods for all the four functions in all the four States and the Western region as a whole were not found to be significant except function IV for the region as a whole, where the difference was significant and indicated deceleration (Appendix 1).

The growth rate of more than 6 per cent in wheat production seemed to have taken place in Gujarat and Rajasthan (Table I). The differences in the growth rates in Gujarat between the two periods were quite small and the tendency showed that there was no decline. In Rajasthan, on the contrary, there was a tendency of decline in the growth rate but the differences in the 'b' values were not significant. The differences in the 'b' values of Gujarat, Madhya Pradesh and Maharashtra were also not significant. Hence, we cannot definitely conclude that there was a deceleration effect in wheat production in all the four States.

Jowar production: Jowar is an important crop of Maharashtra and Madhya Pradesh and not so important in Rajasthan and Gujarat in the Western region. The 'b' values were not significant except for the Western region, Maharashtra and Gujarat for period II. The significant 'b' values for the Western region for period II indicate that the growth rates were more than 3 per cent. The values of growth rates of period I though not significant (except function II) indicate a rising trend during the last five years. This means that there was no deceleration in the production of jowar (Table I). In the State of Maharashtra where 'b' values were significant for function I, the growth trends were of the similar nature. The growth rate was higher for period II than for period I. For Gujarat no definite conclusion can be drawn as the 'b' values for period I were not significant (functions I to IV). As the differences in 'b' values for the two periods were not significant, it is not possible to arrive at a definite conclusion that deceleration had taken place in jowar production during the last five years. In Maharashtra, there was a tendency for acceleration of growth rate in jowar production.

Growth Rates of Area

Generally, the growth rates of production are decomposed into contributions of area and productivity.[4] Instead of going into the statistical problems of the contributions of these two factors to the total production, we have studied the growth rates of the two factors independently for all the four crops for the Western region and the four States. Because none of the statistical functions used by us was a good fit for bajra, we dropped it from the study.

Rice area: The growth rate for rice area in the region was less than 1.55 per cent (Table II). The growth rates of period II were slightly higher than those of period I.* The significant value of 't' for differences of 'b' values in function III in the Western region indicates that during the period 1977-78 to 1981-82, the rice area had expanded.

4. Centre for Monitoring Indian Economy: *op. cit.*

* The differences between the two growth rates in the region are tested (Appendix 2).

In Gujarat, there has been a continuous decline in rice area. However, since 1976-77, the rate of decline in rice area has slightly decreased (Table II). In Maharashtra, the growth rate in period II showed a slight improvement over period I. In Madhya Pradesh, the area expansion of rice has taken place with a smaller growth rate in period II than in period I. But in Rajasthan where the area expansion took place nearly at the rate of 5 per cent in period I, it had declined in period II. The 'b' values for the two periods were not significant consistently for Gujarat and Maharashtra, but they were significant for Rajasthan and Madhya Pradesh. The differences in 'b' values for Rajasthan were not significant (Appendix 2). Hence, we cannot draw a definite inference that there has been expansion or deceleration in the growth rate of rice area in the four States except that an expansion effect was noticed in the Western region as a whole (function III).

Wheat area: The growth rate in area in the region as a whole was approximately 3 per cent. The area expansion was much faster in Maharashtra and Rajasthan (more than 4 per cent) and somewhat slower in Gujarat and Madhya Pradesh (less than 4 per cent)* (Table II).

The comparison of the growth rates of the two periods shows that the area expansion had slowed down during the last five years for the region as a whole. The differences in 'b' values of the two periods for functions III and IV were significant for the region as a whole (Appendix 2). Except in Gujarat where the growth rate of wheat area slightly improved,** the area expansion in all other States had slowed down. In Rajasthan and Maharashtra, the area expansion in the last five years took place at a much slower pace than during period I. The difference in 'b' values for the two periods was significant for function III in Madhya Pradesh and Rajasthan but not significant for any function in Maharashtra (Appendix 2). The overall indication is that the growth rate slowed down during the last five years in the Western region, Madhya Pradesh and Rajasthan.

Jowar area: The growth rates of jowar area showed that the area has declined not only in the region as a whole but in all the four States. The decline was at the rate of about one per cent or more in period I (except Maharashtra) (Table II). The rate of decline had slowed down during the last five years. The rates of decline in Gujarat and Rajasthan were much higher than those in Madhya Pradesh and Maharashtra. The 'b' values were significant in Gujarat and Rajasthan for all the four functions. The tests of significance for the differences in 'b' values for the two periods showed that they were significant in Gujarat and Rajasthan for function III (Appendix 2). Hence, we are more confident about the observation that the rate of decline in area in Gujarat and Rajasthan had slowed down (Appendix 2). Between the two periods the general tendency was either lesser decline or positive growth rate in the last five years in all the States and the Western region as a whole (Table II).

* Except by functions II and IV in Gujarat.

** As the 't' values for period I were not significant, no definite conclusion can be drawn regarding the improvement in area expansion in Gujarat. Similarly, no definite conclusion can be drawn regarding decline in area expansion in Madhya Pradesh (functions II and IV).

TABLE II—GROWTH RATES FOR MAJOR FOODGRAINS AREA IN WESTERN REGION

(per cent)

Crop		Equation	Gujarat		Madhya Pradesh		Maharashtra		Rajasthan		Total (Zone)	
			1965-66 to 1976-77	1965-66 to 1981-82	1965-66 to 1976-77	1965-66 to 1981-82	1965-66 to 1976-77	1965-66 to 1981-82	1965-66 to 1976-77	1965-66 to 1981-82	1965-66 to 1976-77	1965-66 to 1981-82
Rice	I	Log Y = a+bt ..	—1·82*	—0·69†	0·93@	0·89@	0·36†	0·84@	5·17@	4·42@	0·68@	0·83@
	II	Log Y = a+bt² ..	—3·12*	—1·02‡	1·61@	1·56@	0·84†	1·66@	8·64@	7·48@	1·22@	1·53@
	III	Y = a+bt ..	—1·78@	—0·70†	0·92@	0·89@	0·38†	0·86@	5·13@	4·48@	0·68@	0·83@
	IV	Y = a+bt² ..	—3·11@	—0·94†	1·59@	1·56@	0·87†	1·70@	8·82@	7·58@	1·21@	1·53@
Wheat	I	Log Y = a+bt ..	1·90†	2·59*	2·74*	1·79*	5·85*	4·33*	5·38@	4·09@	3·75@	2·80@
	II	Log Y = a+bt² ..	4·08†	5·10@	3·84†	2·62*	10·08*	7·14*	9·12@	6·80@	6·00@	4·49@
	III	Y = a+bt ..	2·36†	3·31@	2·54*	1·66*	5·43@	3·98@	5·40@	4·06@	3·61@	2·68@
	IV	Y = a+bt² ..	5·08†	5·20@	3·48†	2·47†	9·83@	6·76@	9·28@	6·77@	5·85@	4·40@
Jowar	I	Log Y = a+bt ..	—3·25@	—2·61@	—1·61*	—0·84†	—0·08†	0·61†	—3·05*	—1·82*	—1·01@	—0·25†
	II	Log Y = a+bt² ..	—5·71@	—4·52@	—3·29*	—1·26†	—0·17†	1·33*	—6·07@	—2·89*	—1·88@	—0·20†
	III	Y = a+bt ..	—3·25@	—2·70@	—1·62@	—0·86†	—0·06†	0·62*	—2·90@	—1·86*	—1·01@	—0.26†
	IV	Y = a+bt² ..	—5·71@	—4·63@	—3·31@	—1·28†	0·19†	1·35†	—5·76@	—2·98*	—1·73@	—0·23†

@ Good fit and b-value significant.
* Not good fit but b-value significant.
† Not good fit and b-value not significant.
‡ Good fit but b-value not significant.

Growth Rates in Productivity

It is observed that area expansion has slowed down during the last five years in wheat in the region as a whole and all the four States,* and although no definite conclusion can be drawn regarding area expansion of rice and some improvement in the decline of jowar area, there is no firm evidence about the deceleration in wheat, rice and jowar production. Table III gives the details of growth rates of productivity of different crops in different States and the region as a whole.

Rice yield: The rice area showed an expansion trend around one per cent and the productivity trend was more than 2 per cent resulting in an overall production trend of more than 3 per cent in the region as a whole in period II. The 'b' values for productivity trends for period II were significant in all the four functions but they were not significant in functions II and IV for period I. Taking only the significant values of 'b' into account, the differences in the growth rates of productivity for the two periods were tested for significance (Appendix 3). They were not found significant. Hence, one cannot say with certainty that the growth in productivity declined during the last five years (Table III). But the tendency of a decline should cause concern because the main force in maintaining or not allowing the production trend during the last five years to decline much is the productivity trend. If this force becomes weak the production trend will fall.

In Gujarat, the significant 'b' values for period II show that the growth rate of productivity was more than 4.95 per cent (Table III). In Madhya Pradesh, the 'b' values were not significant. In Maharashtra, the 'b' values for both the periods were significant and the growth rate of productivity was more than 4.4 per cent. The differences in the 'b' values for the two periods were tested for significance (Appendix 3) but they were not found to be significant. However, the tendency for the decline in growth rates for period II compared to period I in Maharashtra should cause worry. In Rajasthan, the 'b' values were significant for period I for all the four functions but only for functions I and III for period II. Comparing the growth rates of productivity of the two periods derived from significant 'b' values, it is observed that there was a tendency for the decline. However, the differences in 'b' values for the two periods were not found to be significant (Appendix 3). Although there is no hard evidence that there was a decline in rice yield, the overall tendency of decline gives us a cause for concern.

Wheat yield: Wheat production had a definite trend of about 6 per cent per annum for the region as a whole in periods I and II. In these trends both area and yield had contributed positively. But the growth rates of wheat yield were higher than those of the area. A comparison of the growth rates of the two periods indicates that there was a decline in the region as a whole and in all the States (Table III) during the last five years. The test of significance for differences in the 'b' values for the two periods showed that they were not significant. However, the tendency for decline in productivity

* Except Gujarat.

TABLE III—GROWTH RATES FOR MAJOR FOODGRAINS YIELD/HECTARE IN WESTERN REGION

(*per cent*)

Crop		Equation	Gujarat		Madhya Pradesh		Maharashtra		Rajasthan		Total (Zone)	
			1965-66 to 1976-77	1965-66 to 1981-82	1965-66 to 1976-77	1965-66 to 1981-82	1965-66 to 1976-77	1965-66 to 1981-82	1965-66 to 1976-77	1965-66 to 1981-82	1965-66 to 1976-77	1965-66 to 1981-82
Rice	I	$\log Y = a+bt$ ..	5·15†	4·97*	2·76†	1·37‡	4·55*	4·45*	12·74@	5·43*	3·76@	2·76*
	II	$\log Y = a+bt^2$ ..	8·40†	8·50*	2·88†	1·56†	8·16*	7·82@	21·26@	9·18†	5·52†	4·25*
	III	$Y = a+bt$ ..	5·97†	5·25@	2·38†	1·38*	5·06@	4·66@	12·30@	6·04*	3·55*	2·68*
	IV	$Y = a+bt^2$ ..	10·12†	9·53*	2·25†	1·57†	9·15@	8·50@	21·70@	8·50†	5·21†	4·33*
Wheat	I	$\log Y = a+bt$ ..	4·22@	3·68@	3·51@	2·06@	7·92@	6·28@	3·66@	3·31@	3·17@	3·11@
	II	$\log Y = a+bt^2$ ..	6·72@	6·12@	5·28*	4·76@	14·88@	10·20@	5·76@	5·78@	5·52@	5·51@
	III	$Y = a+bt$ ..	4·17@	3·67@	3·32@	2·90@	9·64@	6·72@	3·55@	3·31@	3·22@	3·16@
	IV	$Y = a+bt^2$ ..	6·70@	6·29@	5·13*	5·00@	19·25@	11·99@	5·66@	5·73@	5·56@	5·72@
Jowar	I	$\log Y = a+bt$ ..	5·93@	6·12@	0·80†	0·46†	1·94†	4·31*	1·91†	0·76†	2·21†	3·40@
	II	$\log Y = a+bt^2$ ..	10·97@	11·05@	1·49†	0·85†	5·42†	8·67*	3·29†	1·09†	5·04†	6·56@
	III	$Y = a+bt$ ..	6·82@	6·68@	0·84†	0·53†	2·73†	4·85@	1·99†	0·95†	2·54†	3·61@
	IV	$Y = a+bt^2$ ..	12·48@	12·66@	1·44†	1·01†	6·68†	9·67@	3·01†	1·08†	5·50*	6·89@

@ Good fit and b-value significant.
* Not Good fit but b-value significant.
† Not Good fit and b-value not significant.
‡ Good fit but b-value not significant.

in the region as a whole and in all the four States during the last five years should cause worry (Appendix 3).

Jowar yield: The trend of jowar area showed a decline both at the regional level and at the levels of individual States. However, jowar production trend was positive and more than 3 per cent per annum for the region as a whole. This is mainly because the productivity trend remained at a level of more than 3 per cent for the region as a whole (Table III). Comparing the growth rates of productivity for the two periods, it is observed that the productivity has improved during the last five years for the region as a whole. In Gujarat, the growth rate of productivity was more than 6 per cent during period II. The differences in the growth rates for the two periods derived from significant 'b' values in Gujarat were not significant. This means that the productivity trend was at least maintained during the last five years. In Madhya Pradesh and Rajasthan, the 'b' values were not significant for both the periods. In Maharashtra, the 'b' values were significant for period II but not significant for period I. In this case also we cannot conclude that there was a deceleration in yield per hectare. The general tendency was towards improvement of yield per hectare during last five years.

The study of growth rates of production, area and yield of the three major foodgrains (rice, wheat and jowar) in the Western region and individual States indicates that although the growth rates of production had declined (though not significantly) for rice and wheat and slightly improved for jowar, the growth rates of yield particularly of rice and wheat had showed declining tendencies during the last five years. This calls for an investigation as to the probable reasons for such a phenomenon. Section II deals with this aspect.

II

RELATIONSHIP OF YIELD AND INPUT USE

What are the causes of the tendencies of yields of rice and wheat to decline? Does the theory of diminishing returns explain this phenomenon? Is the price squeeze operating at the farm level? Is the force of technology improvement exhausted? All these questions begin to crop up. We have examined these questions in this section restricting the scope of our investigation to rice and wheat only.

It would have been ideal if we had data of input use at the farm level for different periods. We would have attempted a simplified version of the growth model prescribed by Ray.[5] But such data were not easily available. What we had was the data of fertilizer consumption for the State as a whole (not distributed cropwise), irrigated area under rice and wheat for each State for the period from 1965-66 to 1981-82 and data which would allow to make some judgement about the weather. Unfortunately, the data about irrigated area for rice and wheat were not available beyond 1976-77.* Under these

5. S. K. Ray: Growth and Instability in Indian Agriculture, Institute of Economic Growth, Delhi, 1983 (mimeo.).

* For the rest of the period the data were obtained by fitting trend lines.

circumstances to find out the relationship of the growth of productivity with input use and other factors was very difficult.

Methodology for Obtaining Fertilizer Consumption—Cropwise

In order to solve this problem, we tried to find out fertilizer consumption for rice and wheat on the following basis. The total consumption of fertilizer for the State was distributed to different crops (treating irrigated and unirrigated crops as separate crops). The average area under crops for the last three years was taken as the basis for allocation. The normative consumption of fertilizer for each crop was worked out on the basis of the recommended dose and the average area under the crop. From this the normative total fertilizer consumption was estimated. The proportions of the normative fertilizer consumption for rice and wheat to total consumption were obtained. These proportions were then applied to the 'actual' consumption of fertilizer for each year. Thus we obtained the figures of 'actual' consumption of fertilizers for rice and wheat for different years. We worked out fertilizer input per hectare for each year. This would give somewhat upward bias to 'actual' fertilizer consumption in the initial years when the rate of adoption was low.

Production Functions

To determine whether fertilizer consumption and irrigation have any significant impact on yield for rice and wheat, we used multiple regression analysis:

$$Y_i = f(X_{1ti}, X_{2ti}, X_{3t})$$

where Y_{ti} = yield per hectare for the year, t in quintals, i varies from 1 to 2. 1 = rice, 2 = wheat.

X_{1ti} = fertilizer (NPK) use per hectare for year t for crop i in kilograms,

X_{2ti} = percentage of irrigated area to total area under the crop i for year t,

X_{3t} = dummy variable for the season for year t.

A Cobb-Douglas function was fitted to the data. The results of the function are given in Table IV. The limitations of Cobb-Douglas functions are well known.* The use of Cobb-Douglas function for finding out the phenomenon of diminishing returns to inputs is logically justifiable for agriculture in developing countries.[6] The elasticity of substitution between inputs in

* There are a large number of studies with Cobb-Douglas production function.

6 U. K. Srivastava and E. O. Heady, "Technological Change and Relative Factor Shares in Indian Agriculture: An Empirical Analysis", *American Journal of Agricultural Economics*, Vol 55, No. 3, August 1973.

TABLE IV—RESULTS OF PRODUCTION FUNCTION FOR RICE AND WHEAT

Zone/State	Crop	Log a	b_1	t-value	b_2	t-value	b_3	t-value	R^2	F	D.W
Western zone	Rice	1·156 (1·4)	0·105	2·41**	0·141	0·45	0·486	9·64*	0·92	52·2*	1·21
	Wheat	1·449 (2·0)	0·347	3·5*	—0·05	—0·21	0·146	2·43**	0·72	11·5*	1·47†
Gujarat	Rice	1·039 (7·7*)	0·018	0·37	—0·013	—0·23	0·82	11·74*	0·95	83·1*	2·67†
	Wheat	0·787 (1·00)	0·290	7·40*	0·200	1·09	0·150	2·68*	0·87	29·9*	1·35†
Madhya Pradesh	Rice	2·068 (2·3*)	—0·024	—0·60	—0·207	—0·6	0·624	8·94*	0·89	44·0*	2·30†
	Wheat	1·459 (8·1*)	0·135	1·52	0·65	0·63	0·161	2·61**	0·73	16·9*	2·32†
Maharashtra	Rice	2·911 (4·4*)	0·219	2·86**	—0·453	—2·07	0·475	5·7*	0·89	37·4*	2·51†
	Wheat	0·192 (0·40)	0·110	0·44	0·241	0·85	0·57	4·22*	0·77	14·2*	1·69†
Rajasthan	Rice	0·737 (1·1)	0·364	1·57	—0·045	—0·14	0·874	7·04*	0·92	49·6*	1·97†
	Wheat	0·187 (0·31)	0·200	4·05*	0·424	2·68**	0·123	3·20	0·92	52·4	2·96

* Significant at 1 per cent level.
** Significant at 5 per cent level
† No autocorrelation at 5 per cent level of significance. (Figures in brackets show t-values of a.)

the Cobb-Douglas function is forced to unity. It is assumed that the limitations of the Cobb-Douglas functions would not affect the inference regarding diminishing returns.

Analysis of Results

The zero-order correlation matrice showed that the independent variables of fertilizer (X_{1t}) and irrigation (X_{2t}) were more correlated in rice than in wheat functions. The fertilizer variable (X_{1t}) was more correlated with the dummy variable of weather (X_{3t}) than the irrigation variable (X_{2t}). The dependent variable of yield per hectare (Y_{ti}) was highly correlated with the dummy variable of weather. Hence in the functions, there would be a problem of multicollinearity. In spite of these limitations, we shall attempt to interpret the results to arrive at some judgements.

In the case of rice, the 'b' values for fertilizer (X_{1t}) were not significant in the Cobb-Douglas function in Gujarat, Madhya Pradesh and Rajasthan whereas they were significant in the Western zone and Maharashtra. The 'b_2' values for irrigation (X_{2t}) were not significant in any State except Maharashtra. The b_2 value was also not significant in the zone as a whole. The 'b_3' values for the dummy variable for weather were significant in all the States and the zone. The explained variation (R^2) was quite high in the Western region and the individual States.

In the case of wheat, the 'b_1' values for fertilizer (X_{1t}) were significant for Gujarat, Rajasthan and the Western zone. The 'b_2' values for irrigation (X_2) were not significant in any State and the 'b_3' values for dummy variable of weather (X_{3t}) were significant in all the States. The explained variation R^2 was quite high in all the States (Table IV).

It will be seen that weather had an important effect on the productivity of rice and wheat. With the improvement of weather from bad to good the productivity improved substantially. In the study of growth rates of food production, one has to take into account this factor. According to our classification of weather into bad, normal and good years, one year was bad, one was normal and three were good for the Western zone as a whole during the last five years (1977-78 to 1981-82). However, the conditions varied from State to State. A substantial part of the total variation in the yield per hectare both in rice and wheat in different States and the Western zone could be explained by weather (Table IV). The contribution of the farmer-controlled factor of production, such as fertilizer use and the government-controlled factor, such as irrigation appears to be small compared to the weather factor. So long as crop production remains largely nature-controlled, the manoeuvring of the growth rate of production becomes very difficult. It is surprising to note that the contribution of irrigation factor was not significant. This may be due to the fact that manoeuvrability of farmers on government-controlled canal irrigation and individually-controlled "lift irrigation" because of erratic supply of electric power was much less.

Diminishing Returns

What we are interested in is to find out the effect of farmer-controlled input use, particularly fertilizers over the period on the yield per hectare. We have therefore concentrated on the analysis of the effects of fertilizer use on productivity. Using *ceteris paribus* conditions for other factors in the production function, we have derived the marginal physical product (MPP) for various levels of fertilizer use in rice and wheat in different States and the zone. Table V gives the details.

It will be clear from the table that the law of diminishing returns prevailed with respect to the response of rice and wheat yield to fertilizer use in the Western zone, Gujarat and Maharashtra for the former and in the Western zone, Gujarat and Rajasthan for the latter. We had used the statistics of only significant 'b_1' values of fertilizers (except rice in Gujarat) to find out the phenomenon of diminishing returns. The levels of fertilizer use in 1981-82 both in rice and wheat were much higher than those in 1976-77. But the MPPs were much lower in 1981-82 than in 1976-77. This explains the tendencies of declining growth rates of productivity of rice and wheat during the last five years.

TABLE V—MARGINAL PHYSICAL PRODUCT IN WHEAT AND RICE AT DIFFERENT LEVELS OF FERTILIZER USE IN DIFFERENT STATES AND THE WESTERN ZONE

Levels of fertilizer use	Rice		Wheat	
	Fertilizer (kg.)	MPP (kg.)	Fertilizer (kg.)	MPP (kg.)
Western zone				
Mean level	8·26	7·56	13·70	24·11
1976-77 level	12·89	7·17	15·06	23·09
1981-82 level	22·36	5·32	20·12	20·11
Gujarat				
Mean level	28·22	0·60	38·78	11·74
1976-77 level	29·42	0·80	31·74	14·23
1981-82 level	53·96	0·44	64·02	8·62
Maharashtra				
Mean level	17·27	14·90		
1976-77 level	18·06	16·70		
1981-82 level	32·30	10·92		
Rajasthan				
Mean level			9·42	26·04
1976-77 level			11·16	24·32
1981-82 level			15·84	20·00

It will be noticed that in rice crop, there was a large variation in MPP between States. This means that the use of one kilogram of fertilizer gives a very small incremental yield/ha. of less than one kilogram in Gujarat whereas it gives about 15 kg. of incremental yield/ha. in Maharashtra at the mean levels of use of fertilizer in the two States. In the case of wheat, there was a much higher incremental yield per hectare in Rajasthan (26 kg.) than in Gujarat (about 12 kilograms) at the mean levels of use of fertilizers. These observations raise questions about the uniform fertilizer price policy which does not take into account the variation in MPPs between States and crops. Because of the use of time-series data and limitations of Cobb-Douglas function, we cannot be sure about the absolute response figures obtained but they do indicate the tendencies for diminishing returns and comparative positions of rice and wheat responses in different States and the region as a whole.

III

SUMMARY AND CONCLUSIONS

The study of growth rates of production of major foodgrains, rice, wheat, bajra and jowar in the four States of the Western zone does not give a gloomy picture of a sure deceleration of production during the last five years as is made out by some studies at the all-India level. It is important therefore that before any final conclusions were drawn from the aggregate study at the all-India level, the phenomenon is studied at a disaggregate level of regions and crops. Not only that there are variations in the growth rates of production between crops in the region but also between States within a crop. A generalisation from the aggregation of 'fast' moving and 'slow' moving States for a particular crop and 'fast' developing and 'slow' developing crops in a particular State would lead us to perhaps unnecessary pessimism. At the same time, it is necessary to study the problem of agricultural growth and identify the strength and weaknesses so that proper steps are taken to increase the strengths and remove the weaknesses.

It is quite clear that the growth rate of wheat for the period 1965-66 to 1981-82 was much higher than that of rice in all the four States and in the Western zone. The highest growth rate was in Rajasthan followed by Maharashtra and Gujarat. Madhya Pradesh lagged much behind.

There was a tendency for wheat production to decline during the last five years. This tendency was more discernible in Rajasthan and Maharashtra than in Madhya Pradesh. In Gujarat, there was a slight tendency towards increase in the growth rate. However, the differences in the growth rates of the two periods 1965-66 to 1976-77 and 1965-66 to 1981-82 were not of the magnitude to draw a definite conclusion about the deceleration of the growth rate.

In rice, the overall growth rate was much slower than in wheat. The highest growth rate occurred in Rajasthan followed by Maharashtra, Gujarat and Madhya Pradesh. A general tendency of decline in the growth rate was

noticed in the zone. The highest decline occurred in Rajasthan. But in Gujarat and Maharashtra, there was a tendency of improvement in the growth rate. Looking to these variations between States, it is difficult to draw a general conclusion of deceleration in the growth rate of rice production.

The case of jowar production showed that there was a much larger variation in the growth rates between States although the overall growth rate of the Western zone was positive and as high as that of rice. In Rajasthan and Madhya Pradesh, the growth rate was negative whereas the growth rates were substantial in Maharashtra and Gujarat. The comparison of the growth rates of the two periods indicated that the position was improving in all the four States. In this case, at least, there was no tendency towards deceleration.

The study of factors contributing to the growth rate of production, *viz.*, the growth rates of area and productivity showed that these factors varied between crops and between States. The growth rate of area was positive and substantial (around 3 per cent) in wheat whereas it had come to a standstill in the case of rice and had become negative in jowar.

Among the States, the growth rate of wheat area was highest in Rajasthan followed by Maharashtra and Gujarat. There were tendencies of decline in the growth rate of area in Rajasthan, Maharashtra and Madhya Pradesh but in Gujarat there was a tendency for increase.

In rice, the highest area expansion was in Rajasthan whereas there was a decline in Gujarat. The overall tendency for the decline in the growth rate of area was seen in all States except in Gujarat where the rate of decline had slowed down.

The factor which is responsible for maintaining or allowing only a slow decline in production is the growth rate of productivity. Although the growth rate of production was the highest in wheat, the growth rate of productivity was not the highest in wheat. In this case jowar leads. The growth rate of productivity of rice has not remained much behind that of wheat. Surprisingly, Gujarat had the highest growth rate of productivity of jowar. A comparison of growth rates of productivity between the two periods indicated that there had been a slight improvement in the case of jowar in Gujarat and Rajasthan. In the case of wheat and rice, although not substantial, there was a tendency of decline in the growth rates of productivity in all the States of the region. This tendency is a cause for concern as it is the growth of productivity which is the main force in agricultural growth.

The study of growth rates of production, area and yield of the three major foodgrains (rice, wheat and jowar) in the Western region and individual States indicates that although the growth rates of production had declined (though not significantly) for rice and wheat and slightly improved for jowar, the growth rates of yield particularly of rice and wheat had shown declining tendencies during the last five years. This called for an investigation as to the probable reasons for such a phenomenon. The investigation into the relationship between yield, fertilizer use, irrigation and weather for rice and wheat in different States for the period under study showed that weather played a major role in the variation of yield. The growth rate of productivity remains unstable

because of the weather factor. It is important to bring agricultural production under more and more controlled factors. Farmers in India have undertaken production under nature-controlled factors of weather and government-controlled factors of irrigation, power, credit and prices. The farmer-controlled factors are the adoption of technology in terms of use of seeds, fertilizers, better agronomic practices and use of land, labour and machinery. As the efficacy of these factors increases, there would be greater improvement in agricultural production.

With all the limitations of the use of a particular type of production function, we have tried to study the effect of different factors by using proxy variables of fertilizer use for farmer-controlled variables, irrigation area for government-controlled variables and weather for nature-controlled variables. From the results of the production function, we observed that the declining tendencies of yield per hectare in rice and wheat were due to the phenomenon of diminishing returns.

If the force of productivity, which is going to be the main force for the agricultural growth, has to be accelerated, the government should strengthen all the infrastructure facilities such as agricultural extension, education and credit for higher adoption of the profitable technologies which are developed and develop a continuous process of improving the technology through better agricultural research. The time has now come to give more emphasis to the development of agricultural extension, education and research, and better delivery systems of agricultural inputs and credit to farmers. This will lead to improvement in agricultural productivity and thus to higher agricultural growth.

APPENDIX 1

TEST STATISTICS FOR DIFFERENCES BETWEEN SIGNIFICANT b-VALUES FOR THE WESTERN ZONE (PRODUCTION)

Crop		Formula	t-values				
			Gujarat	Madhya Pradesh	Maharashtra	Rajasthan	Western zone
Rice	I	$\text{Log } Y = a+bt$ ..			0·086	—0·330	—0·052
	II	$\text{Log } Y = a+bt^2$ ..			0·009	—0·119	
	III	$Y = a+bt$ ..			13·09*	—3·22*	—1·62
	IV	$Y = a+bt^2$ ..			2·62**	—1·43	
Wheat	I	$\text{Log } Y = a+bt$ ..	0·010	—0·088		—0·115	—0·073
	II	$\text{Log } Y = a+bt^2$ ..	—0·029	—0·033	—0·036	—0·059	—0·047
	III	$Y = a+bt$ ..	1·83	—1·77		—0·702	—0·807
	IV	$Y = a+bt^2$ ..	—0·510	—0·98	—1·08	—1·76	—2·45**
Jowar	I	$\text{Log } Y = a+bt$ ..			0·136		
	II	$\text{Log } Y = a+bt^2$ ..					0·014
	III	$Y = a+bt$ ..					
	IV	$Y = a+bt^2$ ..			0·737		

* Significant at 1 per cent level.
** Significant at 5 per cent level.

APPENDIX 2

TEST STATISTICS FOR DIFFERENCES BETWEEN SIGNIFICANT b-VALUES FOR THE WESTERN ZONE (AREA)

Crop		Formula	t-values				
			Gujarat	Madhya Pradesh	Maharashtra	Rajasthan	Western zone
Rice	I	Log Y = a+bt ..				—0·061	0·035
	II	Log Y = a+bt² ..				—0·042	—0·005
	III	Y = a+bt ..				—0·151	3·121*
	IV	Y = a+bt² ..				—0·383	—0·304
Wheat	I	Log Y = a+bt ..		—0·074	—0·075	—0·115	—0·076
	II	Log Y = a+bt² ..			—0·039	—0·054	—0·034
	III	Y = a+bt ..		—3·54*	—1·624	—3·206*	—4·93*
	IV	Y = a+bt² ..			—1·134	—1·915	—2·44**
Jowar	I	Log Y = a+bt ..	0·063			0·093	
	II	Log Y = a+bt² ..	0·038			0·050	
	III	Y = a+bt ..	2·44**			2·68**	
	IV	Y = a+bt² ..	1·39			1·47	

* Significant at 1 per cent level
** Significant at 5 per cent level.

APPENDIX 3

TEST STATISTICS FOR DIFFERENCES BETWEEN SIGNIFICANT b-VALUES FOR THE WESTERN ZONE (YIELD)

Crop		Formula	t-values				
			Gujarat	Madhya Pradesh	Maharashtra	Rajasthan	Western zone
Rice	I	Log Y = a+bt ..			—0·006	—0·258	—0·061
	II	Log Y = a+bt² ..			—0·023		
	III	Y = a+bt ..			0·021	—0·684	—0·115
	IV	Y = a+bt² ..			—0·075		
Wheat	I	Log Y = a+bt ..	—0·051	—0·042	—0·100	—0·031	—0·007
	II	Log Y = a+bt² ..	—0·030	—0·021	—0·069	—0·023	—0·027
	III	Y = a+bt ..	—0·034	—0·046	—0·237	—0·002	0·056
	IV	Y = a+bt² ..	—0·089	—0·042	—0·172	—0·056	—0·056
Jowar	I	Log Y = a+bt ..					
	II	Log Y = a+bt² ..					
	III	Y = a+bt ..	0·087				
	IV	Y = a+bt² ..	—0·046				—0·0007