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Agricultural Productivity Trends in India: Sustainability Issues

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Abstract

The sustainability issue of the crop productivity is fast emerging. The post-Green Revolution phase is characterized by high input-use and decelerating total factor productivity growth (TFPG). The agricultural productivity attained during the 1980s has not been sustained during the 1990s and has posed a challenge for the researchers to shift the production function upward by improving the technology index. It calls for an examination of issues related to the trends in the agricultural productivity, particularly with reference to individual crops grown in the major states of India. Temporal and spatial variations of TFPG for major crops of India have also been examined.

Introduction

India has made impressive strides on the agricultural front during the past three decades. Much of the credit for this success should go to the several million small farming families that form the backbone of Indian agriculture and Indian economy. Policy support, production strategies, public investment in infrastructure, research and extension for crop, livestock and fisheries have significantly helped in increasing the agricultural productivity, food production and its availability. Notwithstanding these achievements, producing additional food with limited land, and providing economic access to food at the household level for ensuring food security would continue to be a major challenge for the nation. India has experienced considerable changes in the crop mix, yield and production since the inception of the Green Revolution. The Green Revolution phase displayed a high yield growth

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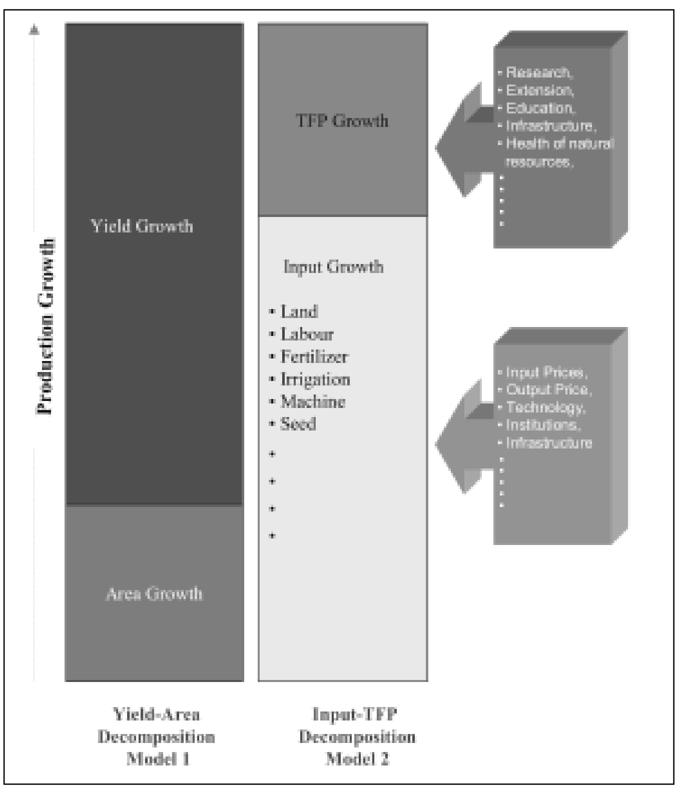
per unit of input. The first post-Green Revolution phase (from late-1960s to mid-1980s) was marked by the continued growth in returns from land through the intensification in use of chemical inputs and machine labour. The second post-Green Revolution phase (beginning the mid-1980s) was characterized by high input-use and decelerating productivity growth. It calls for an examination of the issues related to the trends in agricultural productivity, particularly with reference to individual crops in recent years. In the present paper, the temporal and spatial variations in the productivity status of major crops in India have been analysed using the TFPG estimates. Some policy measures have also been suggested for sustaining TFP of the crops.

The Approach

Decomposition of growth in agricultural output in India has attracted the interest of researchers and policymakers since long. Various attempts have been made to explain the growth in agricultural output in terms of area and yield components, beginning with the first systematic study of Minhas and Vaidyanathan (1965). Later, work on the decomposition of growth in



Box 1. Production growth models; *Source:* Kumar *et al.* (2004b)

agricultural output became more refined and invoked the total productivity concept. Contributions of Evenson and Jha (1973), followed by Dey and Evenson (1991), Sindhu and Byerlee (1992), Kumar and Mruthyunjaya (1992), Rosegrant and Evenson (1992), Dholakia and Dholakia (1993), Kumar and Rosegrant (1994), Evenson *et al*. (1999), Fan *et al*. (1999), Ali and Byerlee (1999), Coelli and Rao (2003), Rozelle *et al*. (2003) and few others have been the important parts of this genre. A comparison of the yield-area decomposition model and productivity growth accounting model has been depicted in Box 1. In Model 1, growth in agricultural output is decomposed simply into area and yield components. This simple scheme is easy to understand the dynamics of agricultural growth, particularly when growth in land is the main source of output growth. In India, this was the situation till 1960s; subsequently, with technological changes and as other (non-land) inputs became more important, an alternative approach became necessary. Model 2 is able to identify the sources of output growth in terms of inputs and (total) productivity. The contribution of improved technology is measured as TFP growth, which can be further decomposed into several factors, viz. research, extension, education, infrastructure, health of natural resources, and so on. The input growth is also influenced by several factors like input-output prices, technological innovations, institutions, infrastructure, policy initiatives, etc. As can be seen, Model 2 is more comprehensive and more appropriate for understanding the dynamics of agricultural growth in India.

Following pioneering works of Schultz (1953), Solow (1957), and Griliches (1964), voluminous literature has appeared dealing with the measurement and analysis of agricultural productivity at different levels of aggregation. Three approaches for the measurement are the most representative:

(i) **The parametric approach:** It models the state of technology by including a time trend in the production or cost functions and the partial differentiation with respect to time to get estimates of technological changes;

(ii) **The accounting approach:** It approximates technological change by the computation of factor productivity indices, mainly the rate of change of total factor productivity indices (Christensen, 1975); and

(iii) **Non-parametric approach:** This recent approach, termed as 'non-parametric' by Chavas and Cox (1988) identifies a group of implied linear inequalities that a profit maximizing (or cost minimizing) firm must satisfy and estimates the rate of TFP using linear programming.

Amongst these, the accounting approach is popular because it is easy to implement, requiring no econometric estimation.

The use of TFP indices gained prominence since Diewert (1976; 1978) proved that the Theil-Tornqvist discrete approximation to the Divisia index is consistent in aggregation and superlative for a linear homogeneous trans-logarithmic production function. In the present study, Divisia-Tornqvist index has been used for computing the TFP indices for crops (for details *see* Kumar *et al.*, 2004a,b).

Review of Studies

A number of studies on the measurement of productivity have been carried out for India (Table1). These studies can be classified into two groups: (i) agriculture sector, and (ii) crop-specific analysis. Indian agriculture has made substantial gains in productivity with the introduction of high-yielding varieties, as measured by index of TFP (Rosegrant and Evenson, 1992; Dholakia and Dholakia, 1993; Evenson *et al*., 1999; Fan *et al*., 1999). These studies have shown that the TFP growth in agriculture has been the prime driving force behind the acceleration of overall growth in the Indian economy achieved during the 1980s.

Evenson *et al*. (1999) have analysed the trends and sources of TFP growth in India's agriculture, and have shown that the gains in productivity had contributed about 1.1 per cent per annum since 1956. The TFP and conventional inputs contribute roughly 2.3 per cent growth rate per annum in total crop output. Fan *et al.* (1999) have computed TFP for the agriculture sector for India and different states of India for the period 1970 to 1995. Five major crops (rice, wheat, sorghum, pearl millet and maize), 14 minor crops (barley, cotton, groundnut, other grains, other pulses, potato, rapeseed, mustard, sesame, sugar, tobacco, soybeans, jute, and sunflower), and 3 major livestock products (milk, meat, and chicken) were included in the measurement of output index. Five inputs (labour, land, fertilizer, tractors, and buffalos) were included in the measurement of input index. TFP for India grew at an average annual rate of 1.8 per cent. During the 1970s, TFP growth rate was 1.6, but it grew fast during the 1980s, at 2.5 per cent per annum. Since 1990, TFP growth in Indian agriculture has continued to grow but at a little slower rate (2.3% per annum), but still it is at a high level. Modern inputs such as HYV seed, fertilizer and irrigation were major contributors to TFP growth in Indian agriculture. Rapid adoption of new technologies and improved rural infrastructure induced productivity growth. The government spending on productivity-enhancing investments (especially agricultural research and extension), rural infrastructure (especially roads and education), and rural development targeted directly to the rural poor, all contribute to the growth in agricultural productivity. Avila and Evenson (2004) have utilized FAO published data on cropland, pastureland, labour used in agriculture, fertilizer, seeds, tractors and combine harvesters and animal

Table 1. Empirical studies on total factor productivity of agriculture in India

Author(s)	Commodity	Period	Total factor productivity	
			Annual growth (%)	Share of TFP in output growth (%)
Evenson, *et al*. (1999)	Crops	1956-65	1.10	46.8
		1966-76	1.39	50.2
		1977-87	1.05	48.8
Birthal *et al*. (1999)	Livestock	1951-70	-0.04	Negative
		1970-80	0.93	33.2
		1980-95	1.79	45.0
Fan *et al*. (1999)	Crops and livestock	1970-79	1.55	77.5
		1980-89	2.52	66.5
		1990-94	2.29	72.2
		1970-94	1.75	66.3
Coelli and Rao (2003)	Crops and livestock	1980-00	0.90	NA
Avila and Evenson (2004)	Crops	1961-80	1.54	68.1
		1981-01	2.33	85.7
	Livestock	1961-80	2.63	92.6
		1981-01	2.66	69.3
	Crops and livestock	1961-80	1.92	78.7
		1981-01	2.41	80.3
Joshi *et al*. (2003)	Rice (IGP)	1980-90	3.50	NA
		1990-99	2.08	NA
	Wheat (IGP)	1980-90	2.44	NA
		1990-99	2.14	NA
Crop sector in Indo-Gangetic Plains (IGP) of India				
Kumar *et al*. (2004b)	IGP	1981-90	2.02	43.7
		1990-96	-0.02ns	Negative
		1981-96	1.21	34.22
	TGP	1981-90	2.14	40.21
		1990-96	-0.06ns	Negative
		1981-96	1.40	34.25
	UGP	1981-90	1.10	29.28
		1990-96	0.36	14.12
		1981-96	0.89	25.81
	MGP	1981-90	1.17	36.12
		1990-96	-1.14	Negative
		1981-96	0.37	17.31

Contd.

Table 1. Empirical studies on total factor productivity of agriculture in India — *Contd.*

Author(s)	Commodity	Period	Total factor productivity	
			Annual growth (%)	Share of TFP in output growth (%)
	LGP	1981-90	5.13	67.64
		1990-96	1.25	36.22
		1981-96	3.08	56.83
Fisheries sector				
Kumar *et al*. (2004a)	Aquaculture	1992-98	4.40	71.66
	Marine fish	1987-98	2.01	48.43

NA: Data not available; ns: not significant

stocks for measuring the changes in TFP for crop production, livestock production and aggregate agricultural production for two periods, 1961-1980 and 1981-2001. Owing to the limitation of data on factor shares, the TFP growth rates seem to be on a higher side. Modern varieties of the Green Revolution, increase in the education level of labour force, and increases in dietary energy have been reported as sources of TFP growth in the paper. Modern varieties contributed maximum (64%) to TFP growth, followed by schooling (22 %) and nutrition (14 %).

An analysis of productivity of the crop sector in the Indo-Gengetic Plains (IGP) by Kumar *et al*. (2004a) has revealed that the TFPG of the crop sector in the IGP had risen at the rate of 1.2 per cent per annum during the period 1980-81 to 1996-97. The TFP results for different agro-eco-regions have shown considerable variations. The Low- Gangetic Plain (LGP) region has depicted the highest growth in TFP (3.1%) and MGP, the lowest (0.37%). The TFP growth rates were estimated at 1.4 per cent in the Trans-Gangetic Plain (TGP) and 0.9 per cent in the Upper-Gangetic Plains (UGP). In IGP, one-third of output growth was contributed by TFP. However, the contribution of TFP to output growth varied from as high as 57 per cent in the LGP to a meagre 17.3 per cent in the MGP. The shares of TFP in the output growth of the crop sector in the TGP and the UGP regions were observed to be 34 per cent and 26 per cent, respectively. The output growth in the UGP and the MGP was input-based, while in the LGP, it was technology-based. The output growth in the TGP was input- as well as technology-based. The analysis has confirmed that contribution of TFPG to output growth had started declining and was, in fact, showing a tendency of further deterioration in the process. Productivity growth, which picked up during the early-1980s, could not sustain during 1990s and this situation raised an alarm for the policymakers and researchers of the country.

Birthal *et al*. (1999) have analysed the trend in TFP for the livestock sector in India. The livestock output grew at the rate of 2.6 per cent per year over the period 1950-51 to 1995-96. The input index increased by 1.8 per cent per year and the TFP grew at about 0.8 per cent, implying that technical change contributed about 30 per cent to the overall growth over the past 45 years. Period-wise results were more revealing. There was no TFP growth during the first period (1950-51 to 1970-71), implying no progress in productivity. The real swing started during the 1980s when the sector's output touched nearly 4 per cent and the TFP growth jumped to nearly 1.8 per cent, contributing 45 per cent to the total output growth. Avila and Evenson (2004) have also reported the accelerating growth in the livestock TFP, growing at the rate of 2.7 per cent per year during 1981-2001 period, contributing 69 per cent to the total livestock output growth.

Kumar *et al*. (2004b) have analysed the trend in TFP for the aquaculture and marine sector of India. The TFP indices for aquaculture have revealed that the TFP indices grew by 4.4 per cent annually and accounted for two-thirds of the output growth. The growth in aquaculture was mainly technology-driven. The TFP growth of fish in the marine sector moved with 2.0 per cent annual growth and accounted for half of the output growth in the marine fisheries.

Most studies have focussed on the estimates of the effect of technological change for agriculture as a whole or total crop production. Owing to non-availability of input allocation data on individual crops, this may over- or under-estimate the TFP for the crop sector to the extent that rates of technical change differ across crops. Thus, the assessment of TFP change which is one of the most important factors influencing crop production, ought to be studied for individual crops. With the availability of micro-level farm data[3] in India, few crop-specific TFP studies have emerged since 1992 (Pinstrup *et al*., 1991; Sindhu and Byerlee, 1992; Kumar and Mruthyunjaya, 1992; Kumar and Rosegrant, 1994; Jha and Kumar, 1998; Kumar *et al*. 1998; Kumar, 2001; Joshi *et al*., 2003). The present analysis covered all the major crops grown in various states of India.

The Data

For constructing the total input index, ten inputs [human labour, bullock labour, machine labour, farm yard manure (FYM), nitrogen, phosphorus, and potassium fertilizers, irrigation, plant protection and land] were included.

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[3] These data were collected under the "Comprehensive Scheme for the Study of Cost of Cultivation of Principal Crops", Directorate of Economics and Statistics, Ministry of Agriculture, Government of India.

* Refers to undivided states.

Cost share of each input was computed by dividing the individual input-cost by the total production-cost for all principal crops at the state level, based on the cost of cultivation data collected under the "Comprehensive Scheme for the Study of Cost of Cultivation of Principal Crops," of the Directorate of Economics and Statistics (DES), Ministry of Agriculture, Government of India (GoI). These data were used for computing the TFP for major crops of the state. The data on quantity and price of important inputs and crop output were compiled for the available years, covering the period 1971-2000.

Productivity Trends for Major Crops

Examining the TFP growth of major crops grown in different states of India, given in Table 2, one could see a strong perception that (a) technological gains have not occurred in a number of crops, notably coarse cereals, pulses, oilseeds, fibres, sugarcane, vegetables, etc. during the 1990s, and (b) crops and areas, where these gains occurred during early years of Green Revolution, have exhausted their potential. To validate these observations, we had undertaken the analysis with more disaggregated perspective on changes in output, input and TFP for major crops across states of India, based on more recent micro-farm level data covering the period 1971-72 to 1999-00. The results presented in Appendix I for 1971-1986 and in Appendix II for 1987-2000 reveal that all crops have benefited from the technological change in some parts of the country, but there are some exceptions in pulses and oilseeds where only a few states has performed well. Several states have recorded positive TFP growth. Paddy and wheat, the major staple food crops, have performed well in productivity gains. However, TFP of paddy has started showing deceleration in Haryana and Punjab but TFP of wheat is still growing in these two Green Revolution states. All eastern states have shown improvement in TFP of paddy after the mid-1980s.

Sustainability Issues

At the farmers' level, sustainability concerns are being expressed that the input levels have to be continuously increased in order to maintain the yield at the old level. This poses a threat to the economic viability and sustainability of crop production. A sustainable farming system is a system in which natural resources are managed so that potential yield and the stock of natural resources do not decline over time. However, each of the components of sustainable agriculture is complex and some quantifiable measures are needed to check whether a farming system is sustainable or not. Due to the multidimensional nature of the concept of sustainability and the difficulties in determining specific threshold values for these dimensions,

Table 2. Annual growth rate in input, output, TFP of crops grown in different regions of India: 1971-2000

(in per cent)

Crop	Region	Period	Input	Output	TFP	Share of TFP in output
Paddy (rice)	East	1971-86	1.46	1.60	0.15	9.31
		1986-00	1.45	2.73	1.28	46.80
	West	1971-86	1.64	0.39	-1.25	Negative
		1986-00	2.75	4.70	1.95	41.49
	North	1971-86	2.17	4.48	2.31	51.56
		1986-00	2.57	2.68	0.11	4.22
	South	1971-86	2.45	3.76	1.31	34.87
		1986-00	1.43	2.59	1.16	44.89
	India	1971-86	1.82	2.46	0.64	25.87
		1986-00	1.88	2.96	1.08	36.43
Wheat	East	1971-86	3.72	0.00	-3.72	Negative
		1986-00	0.75	0.94	0.19	20.45
	West	1971-86	1.25	2.02	0.77	38.07
		1986-00	4.84	5.72	0.88	15.45
	North	1971-86	3.04	5.33	2.29	43.02
		1986-00	2.35	3.01	0.66	22.04
	India	1971-86	2.64	3.93	1.28	32.64
		1986-00	2.91	3.59	0.68	18.98
Coarse cereals	West	1971-86	2.58	3.83	1.25	32.71
		1986-00	0.41	0.95	0.55	57.43
	North	1971-86	0.08	0.34	0.26	75.56
		1986-00	-0.77	-0.01	0.76	Negative
	South	1971-86	1.54	3.55	2.00	56.49
		1986-00	-1.29	-3.11	-1.82	58.47
	India	1971-86	2.14	3.49	1.36	38.82
		1986-00	-0.09	0.03	0.12	440.58
Pulses	East	1971-86	6.06	7.22	1.16	16.07
		1986-00	-10.9	-14.14	-3.22	22.81
	West	1971-86	1.81	1.99	0.18	8.97
		1986-00	3.40	3.31	-0.10	Negative
	North	1971-86	0.00	0.61	0.61	100.00
		1986-00	-2.08	-2.02	0.06	Negative
	South	1971-86	3.82	5.26	1.45	27.46
		1986-00	1.37	-0.26	-1.63	Negative
	India	1971-86	1.96	2.47	0.52	20.83
		1986-00	1.65	1.25	-0.39	Negative
Oilseeds	East	1971-86	6.06	5.59	-0.47	Negative
		1986-00	-4.93	-4.67	0.26	Negative

Contd.

Table 2. Annual growth rate in input, output, TFP of crops grown in different regions of India: 1971-2000 — *Contd.*

(in per cent)

Crop	Region	Period	Input	Output	TFP	Share of TFP in output
	West	1971-86	5.52	5.38	-0.14	Negative
		1986-00	7.44	8.13	0.69	8.49
	North	1971-86	6.06	7.22	1.16	16.07
		1986-00	3.47	3.30	-0.17	Negative
	South	1971-86	2.69	3.24	0.55	16.88
		1986-00	1.37	1.01	-0.36	Negative
	India	1971-86	4.50	4.64	0.14	2.98
		1986-00	5.22	5.55	0.33	5.90
Fibres	East	1971-86	3.31	3.44	0.13	3.90
		1986-00	-3.36	-2.76	0.60	Negative
	West	1971-86	3.64	5.18	1.54	29.80
		1986-00	3.67	4.73	1.06	22.37
	North	1971-86	2.67	2.70	0.03	1.19
		1986-00	3.84	-0.57	-4.42	Negative
	South	1971-86	3.08	3.67	0.59	16.07
		1986-00	4.70	4.04	-0.66	Negative
	India	1971-86	3.38	4.41	1.03	23.30
		1986-00	3.09	3.04	-0.05	Negative
Sugarcane	East	1971-86	0.00	0.00	0.00	Negative
		1986-00	2.22	11.90	9.68	81.34
	West	1971-86	4.74	4.46	-0.28	Negative
		1986-00	6.47	5.97	-0.50	Negative
	North	1971-86	0.90	1.35	0.45	33.10
		1986-00	3.60	3.11	-0.49	Negative
	South	1971-86	0.66	3.48	2.82	81.05
		1986-00	6.27	5.84	-0.43	Negative
	India	1971-86	1.24	2.02	0.79	38.92
		1986-00	4.36	4.26	-0.10	Negative
Vegetables	East	1971-86	1.36	2.16	0.80	37.04
		1986-00	6.57	-0.56	-7.13	Negative
	West	1971-86	0.00	2.91	2.91	100.00
		1986-00	5.12	6.98	1.86	26.65
	North	1971-86	0.97	4.30	3.33	77.44
		1986-00	6.94	9.47	2.53	26.72
	India	1971-86	0.97	3.56	2.59	72.70
		1986-00	6.64	6.45	-0.19	Negative

East: Includes states of Bihar, Orissa, Assam and West Bengal of India
West: Includes states of Rajasthan, Madhya Pradesh, Maharashtra and Gujarat
North: Includes states of Punjab, Haryana, Uttar Pradesh and Himachal Pradesh
South: Includes states of Andhra Pradesh, Tamil Nadu, Karnataka and Kerala

Table 3. Distribution of crop area according to TFP growth in India: 1971-2000

(per cent share of crop area)

Crop	Period	Stagnation TFP < 0 %	Less than 1% annual TFP growth	Greater than 1% annual TFP growth
Paddy (Rice)	1971-86	30.5	25.9	43.6
	1987-00	15.0	32.8	52.2
Wheat	1971-86	10.3	17.3	72.4
	1987-00	2.8	74.7	22.5
Coarse cereals	1971-86	19.8	9.6	70.5
	1987-00	60.2	9.8	30.1
Pulses	1971-86	42.8	36.6	20.5
	1987-00	69.2	26.6	4.2
Oilseeds	1971-86	35.6	18.3	46.1
	1987-00	28.3	10.6	61.1
Sugarcane	1971-86	20.3	61.0	18.6
	1987-00	90.9	5.4	3.7
Fibres	1971-86	53.8	7.2	39.0
	1987-00	32.5	1.4	66.1
Vegetables	1971-86	0.0	27.5	72.5
	1987-00	27.5	0.0	72.5

it may be even too ambitious to seek the absolute level of sustainability. We should probably be satisfied with the relative ranking. Lynam and Herdt (1989) had proposed a non-positive trend in TFP as an indicator of lack of sustainability of the production system. This has been widely accepted and used as an indicator of unsustainability of production (*see* Ethui and Spencer, 1993; Cassman and Pingali, 1995; Kumar *et al.,* 1998). The farming system is sustainable if it can maintain the TFP growth over time.

As can be seen in Table 3, the area under rice with more than 1 per cent TFP growth was 44 per cent in 1971-86 and it increased to 52 per cent in 1987-2000. However, the area under stagnant TFP for paddy declined from 31 per cent in 1971-86 to 15 per cent in 1987-2000. Even for wheat, the stagnated TFP area declined from 10 per cent in 1971-86 to 3 per cent in 1987-2000. The coarse cereals experienced more than one per cent TFP growth on 71 per cent of the total crop area during the 1980s, which declined to 30 per cent during the 1990s. About 60 per cent of the area under coarse cereals is facing stagnated TFP. Similarly, the productivity gains which occurred for pulses and sugarcane during the early years of Green Revolution, have now exhausted their potential. About 70 per cent area under pulses and 90 per cent area under sugarcane during the 1990s have depicted stagnated TFP. The sign of improvement in productivity gains has been observed for oilseeds, fibres and vegetables in the recent years. Thus, there is a strong evidence that technological change has generally pervaded the entire crop sector. The crops and states where technological stagnation or decline is apparent need to be focused on research, extension and natural resource management strategies (Fan *et al*., 1999; Kumar *et al*., 2004a).

Conclusions and Policy Implications

The sustainability issue of the crop productivity is fast emerging. The productivity attained during the 1980s has not been sustained during the 1990s and has posed a challenge before the researchers to shift the production function by improving the technology index. It has to be done by appropriate technology interventions, judicious use of natural resources and harnessing biodiversity. During the Green Revolution era, large investments were made on research and development for the irrigated agriculture. The promotion of HYV seed - fertilizer - irrigation technology had a high pay-off and rapid strides of progress were made in food production. However, in recent years, agriculture has been experiencing diminishing returns to input-use and a significant proportion of the gross cropped area has been facing stagnation or negative growth in TFP. The sharp fall in the total investment, more so in the public sector investment, in agriculture has been the main cause for the deceleration of agricultural growth and development (Kumar, 2001). Moreover, the ratio of amount spent on extension to that on research has been falling. A vast untapped yield potential still exists in the country. This coupled with the second-generation technologies and heterogeneity in production environment warrants much more intensive extension efforts. The slowing-down of emphasis on extension will further widen the gap in the adoption of technology. Extension services need to be strengthened by scaling-up investment levels and improving the quality of extension. The first step in this direction should be to increase the availability of operating funds. This will result in accelerating the TFP growth, improving sustainability of the crop sector and minimizing the yield gap in the region.

The problems of waterlogging and soil salinity may develop sooner or later in many irrigation project areas due to over-irrigation and deep percolation and seepage losses in the absence of a suitable drainage system. The problem is likely to aggravate further in future if proper soil management practices, including provision of suitable field irrigation channels and drainage system, are not undertaken. Due to the degradation problems, growth in TFP has not made headway across a substantial area of the country for major food crops. Over-irrigation and alarming rates of groundwater depletion in the IGP have caused land degradation and other environmental problems. Further, the quality of available water has been deteriorating (Singh *et al*., 2000).

The findings of the study have significant policy implications on the supply of agricultural commodities, and the national food and household nutritional security. An increase in agricultural investments, especially in research and development, is urgently needed to stimulate growth in TFP. Recognizing that there are serious yield gaps and that there are already proven paths for increasing productivity, it is highly pertinent for India to maintain a steady growth rate in TFP. As TFP increases, the cost of production would decline and the market prices would stabilize at a lower level. Both the producers and consumers will benefit. The fall in food prices will benefit the urban and rural poor more than the upper income groups, because the former spends a much larger proportion of its income on cereals than that by the latter. All efforts need to be concentrated on accelerating growth in TFP to fight poverty, whilst conserving natural resources and promoting ecological integrity of the agricultural system. More than half of the required growth in yield to meet the target of demand must be achieved from research efforts by developing location-specific and low input-use technologies with emphasis on the region/sub-regions/districts where the current yields are below the potential national average yields. The districts/ sub-regions/regions where TFP stagnation or decline has taken place, as identified in the paper, must get priority in agricultural research and development.

References

Avila, A.F.D. and R.E. Evenson, (2004) *Total Factor Productivity Growth in Agriculture: The Role of Technological Capital*. Economic Growth Centre.

Ali, M. and D. Byerlee (Eds.), (1999) Technological change and productivity in Pakistan's Punjab: Econometric evidence. In: *Sustaining Rice-Wheat Production Systems: Socio-Economic and Policy Issues: Rice-Wheat Consortium*, Paper Series 5. New Delhi, India: Rice-Wheat Consortium for the Indo-Gangetic Plains, p. 99.

Birthal, P.S., A. Kumar, A. Ravishankar and U.K. Pandey, (1999) *Sources of Growth in Livestock Sector*. Policy Paper No. 9, New Delhi: National Centre for Agricultural Economics and Policy Research (NCAP).

Cassman, K.G. and P.L. Pingali, (1995) Extrapolating trends from long-term experiments to farmers' fields : The case of irrigated rice systems in Asia. In: *Agricultural*

Sustainability in Economic, Environmental, and Statistical Terms. Eds: V. Barnett, R. Payne and R. Steiner. London: John Wiley and Sons, Ltd.

Chavas, J.P. and T.L. Cox, (1988) A nonparametric analysis of agricultural technology. *American Journal of Agricultural Economics*, **70:** 303-310.

Christensen, L.R., (1975) Concepts and measurement of agricultural productivity, *American Journal of Agricultural Economics,* **57:** 910-15.

Coelli, Tim J. and D.S. Prasada Rao, (2003) *Total Factor Productivity Growth in Agriculture: A Malmquist Index Analysis of 93 Countries, 1980-2000*. International Association of Agricultural Economics Conference held in Durban, August.

Dey, M.M. and R.E. Evenson, (1991) *The Economic Impact of Rice Research in Bangladesh*. Economic Growth Center. New Haven: Yale University, Mimeo.

Dholakia, R.H. and B.H. Dholakia, (1993) Growth of total factor productivity in Indian agriculture. *Indian Economic Review*, **28(1):** 25-40.

Diewert, W.E., (1976) Exact and superlative index numbers. *Journal of Econometrics*, **4:** 115-145.

Diewert, W.E., (1978), Superlative index numbers and consistency in aggregation, *Econometrica*, **46:** 883-900.

Ethui, S.K. and D.S.C. Spencer, (1993) Measuring the sustainability and economic viability of tropical farming systems: A model from Sub-Saharan Africa. *Agriculture* **9:** 279-296.

Evenson, R.E. and D. Jha, (1973) The contribution of the agricultural research system to agricultural production in India. *Indian Journal of Agricultural Economics,* **28(4):** 212-230.

Evenson, R.E., C. Pray and M.W. Rosegrant, (1999) *Agricultural Research and Productivity Growth in India*. Research Report No. 109. Washington, D.C: International Food Policy Research Institute.

Fan, S., P.B.R. Hazell and S. Thorat, (1999) *Linkages between Government Spending, Growth, and Poverty in Rural India*. Research Report No. 110. Washington, D.C: International Food Policy Research Institute.

Griliches, Z., (1964) Research expenditures, education and the aggregate agricultural production function. *American Economic Review,* **54:** 961-974.

Jha, D. and Praduman Kumar, (1998) Rice production and impact of rice research in India, In: *Impact of Rice Research.* Eds: Prabhu L. Pingali and Mahabub Hossain, TDRI and IRRI.

Joshi, P.K., L. Joshi, R.K. Singh, J. Thakur, K. Singh and A.K. Giri, (2003) *Analysis of Productivity Changes and Future Sources of Growth for Sustaining Rice-Wheat Cropping System*. National Agricultural Technology Project ((PSR 15; 4.2), New Delhi: National Centre for Agricultural Economics and Policy Research (NCAP).

Kumar, P. and Mruthyunjaya, (1992) Measurement and analysis of total factor productivity growth in wheat, *Indian Journal of Agricultural Economics,* **47(7):** 451-458.

Kumar, P., (2001) Agricultural performance and productivity, In: *Indian Agricultural Policy at the Crossroads*, Eds: S.S. Acharya and D.P. Chaudhri, New Delhi: Rawat Publications.

Kumar, P. and Mark W. Rosegrant, (1994) Productivity and sources of growth for rice in India, *Economic and Political Weekly*, **29(52):** A183-A188.

Kumar, P., P.K. Joshi, C. Johansen and M. Asokan, (1998) Sustainability of rice-wheat-based cropping system in India, *Economic and Political Weekly*, **XXXIII:** A-152-A-158.

Kumar, P., D. Jha, A. Kumar, M.K. Chaudhary, R.K. Grover, R.K. Singh, R.K.P. Singh, A. Mitra, P.K. Joshi, Alka Singh, P.S. Badal, S. Mittal, J. Ali, (2002) *Economic Analysis of Total Factor Productivity of Crop Sector in the Indo-Gangetic Plain of India by District and Region*-NATP Project under Irrigated Agro-Ecosystem, Production System Research, Indian Council of Agricultural Research, New Delhi.

Kumar, P., A. Kumar and C.P. Shiji, (2004a) Total factor productivity and economic impacts of fisheries technology in India. *Agricultural Economics Research Review*, **17**(Conference number): 131-144.

Kumar, P., A. Kumar, and Surabhi Mittal,(2004b) Total factor productivity of crop sector in the Indo-Gangetic Plain of India: Sustainability issues revisited. *Indian Economic Review*, **39(1):**169-201.

Lynam, J.K. and R.W. Herdt,(1989) Sense and sutainability: Sustainability as an objective in international agricultural research. *Agricultural Economics,* **3:** 381-398.

Minhas, B.S. and A. Vaidyanathan, (1965) Growth of crop output in India, 1951-54 to 1958-61: An analysis by component elements, *Journal of the Indian Society of Agricultural Statistics*, **17(2):** 230-252.

Mittal, Surabhi and P. Kumar, (2000) Literacy, technology adoption, factor demand and productivity: An econometric analysis. *Indian Journal of Agricultural Economics*, **55(3):** 490-499.

Mittal, Surabhi and R.C. Lal, (2001) Productivity and sources of growth for wheat in India. *Agricultural Economic Research Review*, **14** (Conference No.): 109-120.

Paroda, R.S., (1996) *Sustaining the Green Revolution: New Paradigms*. B.P. Pal Commemoration Lecture. 2nd International Crop Science Congress, 22 November, New Delhi.

Pinstrup, Andersen P., M. Jaramillo, P.B.R. Hazell and C. Ramasamy (Eds), (1991) *The Impact of Technological Change in Rice Production on Food Consumption and Nutrition. The Green Revolution Reconsidered: The Impact* *of High Yielding Rice Varieties in South India*, 85-104. Johns Hopkins University Press; Maryland; USA.

Rosegrant, M.W. and R.E. Evenson, (1992) Agricultural productivity and sources of growth in South Asia. *American Journal of Agricultural Economics*, **74(3):** 757-61.

Rosegrant, Mark W. and Robert E. Evenson, (1995) *Total Factor Productivity and Sources of Long-term Growth in Indian Agriculture*, International Food Policy Research Institute, Washington, EPTD discussion paper No. 7.

Rozelle, S. Jin, J. Huang and R. Hu, (2003) The impact of investments in agricultural research on total factor productivity in China. Crop variety improvement and its effect on productivity. In: *The Impact of International Agricultural Research*, Eds: R.E. Evenson and D. Gollin. UK: CABI Publishing.

Schultz, T.W., (1953) *Economic Organization of Agriculture*, New York: McGraw-Hill Co.

Sindhu, D.S. and D. Byerlee, (1992) *Technical Change and Wheat Productivity in the Indian Punjab in Post-GR Period*. Working Paper 92-02, Economics, Mexico: CIMMYT.

Singh, R.K., G.N. Singh, D. Kumar, G. Babu, R. Kishor and P. Kumar (2000) *A State-of-the-Art Report on Waterlogging and Sodic Soil in Indo-Gangetic Plains of UP*. NATP Project (ICAR). Department of Agricultural Economics & Statistics, C.S. Azad University of Agriculture & Technology, Kanpur. p. 15.

Solow, R.M., (1957) Technical change and aggregate production function, *Review of Economics and Statistics,* **39**(3): 312-320.

Appendix Ia

Trends in total factor productivity for various crops in selected states of India, before 1971-86

Crop	Total factor productivity				
	Increasing			No change	Decreasing
	< 1%	1-2%	> 2%		
Paddy		Andhra Pradesh, Assam	Haryana, Punjab, Tamil Nadu, Uttar Pradesh	Bihar, Karnataka, Madhya Pradesh, West Bengal	
Jowar	Rajasthan, Tamil Nadu	Andhra Pradesh, Karnataka, Maharashtra		Madhya Pradesh	
Bajra		Rajasthan	Gujarat	Haryana, Uttar Pradesh	
Maize		Himachal Pradesh		Madhya Pradesh, Rajasthan	
Ragi			Tamil Nadu	Karnataka	
Wheat		Punjab, Rajasthan	Haryana, Uttar Pradesh	Madhya Pradesh, West Bengal	Bihar
Barley			Rajasthan		
Moong			Andhra Pradesh, Orissa	Madhya Pradesh, Rajasthan	
Urad			Andhra Pradesh	Madhya Pradesh, Tamil Nadu	
Arhar				Karnataka, Madhya Pradesh	
Gram			Uttar Pradesh	Haryana, Madhya Pradesh, Rajasthan	
Groundnut			Karnataka, Madhya Pradesh	Andhra Pradesh, Gujarat	Tamil Nadu
Linseed					
Rapeseed & mustard			Haryana, Rajasthan	Assam	
Sunflower			Maharashtra		
Soyabean			Madhya Pradesh		
Cotton		Haryana	Gujarat, Karnataka, Madhya Pradesh, Tamil Nadu	Andhra Pradesh, Maharashtra, Punjab	
Jute			Orrisa	Bihar, West Bengal	Assam
Sugarcane			Andhra Pradesh, Karnataka	Haryana, Maharashtra, Tamil Nadu, Uttar Pradesh	Bihar
Onion				Maharashtra	
Potato				Bihar, Uttar Pradesh	

Source: Computed by the authors from data on cost of cultivation, Directorate of Economics & Statistics, Govt. of India.

Appendix Ib

Trends in total factor productivity for various crops in selected states of India, 1986-2000

Crop	Total factor productivity				
	Increasing			No change	Decreasing
	< 1%	1-2%	> 2%		
Paddy	West Bengal	Andhra Pradesh, Bihar, Madhya Pradesh, Tamil Nadu		Assam, Karnataka, Uttar Pradesh	Haryana, Punjab
Jowar	Tamil Nadu,	Andhra Pradesh		Madhya Pradesh, Maharashtra	Karnataka, Rajasthan
Bajra			Haryana, Rajasthan, Tamil Nadu	Gujarat, Maharashtra, Uttar Pradesh	
Maize		Madhya Pradesh		Rajasthan, Uttar Pradesh	Himachal Pradesh
Ragi					Karnataka, Tamil Nadu
Wheat	Madhya Pradesh, Rajasthan, West Bengal	Haryana, Punjab		Bihar, Uttar Pradesh	Himachal Pradesh
Barley			Uttar Pradesh	Rajasthan	
Moong				Andhra Pradesh	Madhya Pradesh, Orrisa, Rajasthan
Urad			Maharashtra	Madhya Pradesh, Uttar Pradesh	Andhra Pradesh, Orrisa, Tamil Nadu
Arhar		Gujarat	Madhya Pradesh		Karnataka, Uttar Pradesh
Gram	Madhya Pradesh, Uttar Pradesh			Haryana	Rajasthan
Groundnut		Andhra Pradesh, Tamil Nadu		Gujarat, Maharashtra, Orrisa	Karnataka
Linseed				Madhya Pradesh	
Rapeseed & mustard				Assam, Haryana, Rajasthan, Uttar Pradesh	Punjab
Sunflower				Maharashtra	Karnataka
Safflower				Karnataka	Maharashtra
Soyabean			Madhya Pradesh		
Cotton		Gujarat, Maharashtra	Andhra Pradesh	Haryana	Karnataka, Madhya Pradesh, Punjab, Tamil Nadu
Jute		West Bengal		Assam, Bihar, Orrisa	
Sugarcane			Bihar	Andhra Pradesh, Haryana, Karnataka, Maharashtra, Tamil Nadu	Uttar Pradesh
Onion		Maharashtra			
Potato			Uttar Pradesh		Bihar