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Total Factor Productivity of Crop Sector in the Indo-Gangetic Plain of India: Sustainability issues revisited

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ABSTRACT

The paper analyses the total factor productivity (TFP) of crop sector at the district/region levels and identifies the sources of TFP growth in the Indo-Gangetic Plain. The study concludes that TFP growth is decelerating and large areas under crops in a number of districts are showing clear signs of un-sustainability. Research, extension, education, infrastructure (roads, electrification, educational institutions, health facilities, banking, etc.) have been the major sources of TFP growth in the IGP. Preventing a fall in water table will enhance TFP.

JEL Classification: Q16, Q18

Keywords: TFP; Indo-Gangetic Plain; Crop Sector; Sustainability; Policy Implications.

1. INTRODUCTION

The irrigated agro-eco-system is the mainstay of India's agricultural economy. It is the backbone of the public distribution system and is a strong base for the food security of the country. Most of the irrigated agriculture in India is concentrated in the Indo-Gangetic Plain (IGP), which is one of the most fertile agricultural regions in the world. IGP accounted for nearly 44 million hectares of cultivated land in the year 2002 and is

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spread mainly over the states of Punjab, Haryana, Delhi, Uttar Pradesh, Bihar, and West Bengal, and parts of Jammu and Kashmir, Himachal Pradesh, and Rajasthan. The region is endowed with highly productive alluvial soils, rich groundwater resources, and favourable climatic conditions that permit growing of two or more crops in a year. IGP region is dominated by the rice-wheat cropping system, which has been the cradle of the "Green Revolution".

The indiscriminate exploitation of natural resources in these intensively cultivated areas has raised concern about the long-term sustainability of the agricultural production system and natural environment. Several studies have highlighted that the total factor productivity growth (TFPG) of important crops like rice and wheat in the IGP is decelerating (Kumar and Mruthyunjaya (1992), Kumar and Rosegrant (1994), Kumar *et al.* (1998), Joshi *et al.* (2003)). It is felt that if appropriate measures are not undertaken to address the problem of sustainability and natural resource degradation, the future growth of agriculture in the irrigated areas of the IGP would be jeopardized. With this backdrop, the present paper analyses the performance of irrigated agriculture by measuring TFP indices for the crop sector at district level. The district- level analysis captured the location-specific differentials at the micro-level. No study has been undertaken in recent years to analyse the trend in TFP at the disaggregated district level. Rosegrant and Evenson (1995) have used the district level data to study TFP at all-India level but they have not analysed TFP for the crop sector by districts, sub-regions, and regions. Secondly, they have covered post-green revolution period up to 1987 only, whereas the serious concerns of sustainability have emerged during the late 1980s and early 1990s. The present paper addresses this issue for IGP region.

IGP region has been geographically divided generally into four agro-ecological zones: (i) Trans-Gangetic Plain (TGP), (ii) Upper-Gangetic Plain (UGP), (iii) Middle-Gangetic Plain (MGP) and (iv) Lower-Gangetic Plain (LGP). Each agro-ecological zone is further divided into sub-zones depending upon the soil and agro-climatic conditions. A detailed list of districts included in different agro climatic regions has been given in Appendix Table 1. The TGP region comprises all the districts of Punjab, Haryana and Sri Ganganagar district of Rajasthan. It has been further classified into Foothills of Shivalik, Plain and Arid sub-regions. The UGP region consists of all the districts of Uttar Pradesh except those of Eastern U.P and Vindhyan region of the state. This agro climatic region has been classified into the sub-regions- Central Plain, South-western Plain and North-western Plain. The MGP region contains the North-eastern Plain, Eastern Plain, and Vindhyan region, North-Bihar Plain, North-east Plain and South-Bihar Plain. The first three are parts of the state of Uttar Pradesh, whereas the last three come under Bihar. The LGP region lies in the state of West Bengal. The salient characteristics of the sub-zones are given in Appendix Table 2. It may be seen that there is large variation with respect to rainfall (from 385 mm to 1800 mm), soils (sandy loam to laterite and alluvial), and irrigation (25 to 90 per cent of the cropped area).

In the present paper, the temporal and spatial variations in the sustainability status of the crop sector in the IGP have been analysed by using TFP growth estimates of crop sector in IGP in as many as 94 districts for the period 1980-81 to 1996-97[1]. Estimates of TFPG have also been presented for crop sector by agro-eco-regions /sub-regions of IGP. Further, sources of TFP growth have been identified and policy measures suggested for sustaining TFP growth of crop sector in this region.

Besides introduction, the paper has been organised as follows: Section 2 attempts to outline the conceptual framework of crop productivity; Section 3 provides the methodology of analysing sustainability in terms of TFP growth of the crop sector; Data sources are described in Section 4. Section 5 presents the results of TFP estimation by state, district, agro-climatic regions/sub-regions; The determinants of TFP are analysed in Section 6, and the last Section 7 highlights the conclusions and policy implications.

2. CONCEPTUAL FRAMEWORK OF CROP PRODUCTIVITY

Productivity growth in agriculture is both a necessary and sufficient condition for its development and has remained a serious concern for intense research over the last five decades. Solow (1957) was the first to propose a growth accounting framework, which attributes the growth in TFP to that part of growth in output, which cannot be explained by growth in factor inputs like land, labour and capital. Development economists and agricultural economists have computed productivity and have examined productivity growth over time and differences among countries and regions. Productivity growth is essential to meet the food demands arising out of steady population and economic growths.

TFP is an important measure to evaluate the performance of any production system and sustainability of a growth process. However, a number of complex conceptual issues are not adequately captured by an analysis of the kind described earlier. First, for example, agricultural research has contributed to breaking the seasonality in crop production. Second, a great deal of stability has been introduced in crop production by providing farmers with varieties that tolerate or resist adverse environmental conditions. Finally, quality improvements have added to the value of production as in the case of *Basmati* rice. All of these and many other contributions have been subsumed under a residual TFP measure. It would be worthwhile to identify these influences explicitly, which would lead to a more realistic assessment of the productivity of crop research.

Decomposition of growth in agricultural output in India has interested researchers and policy makers for long. Various attempts have been made to explain growth in agricultural output in terms of the area and yield components, beginning with the first

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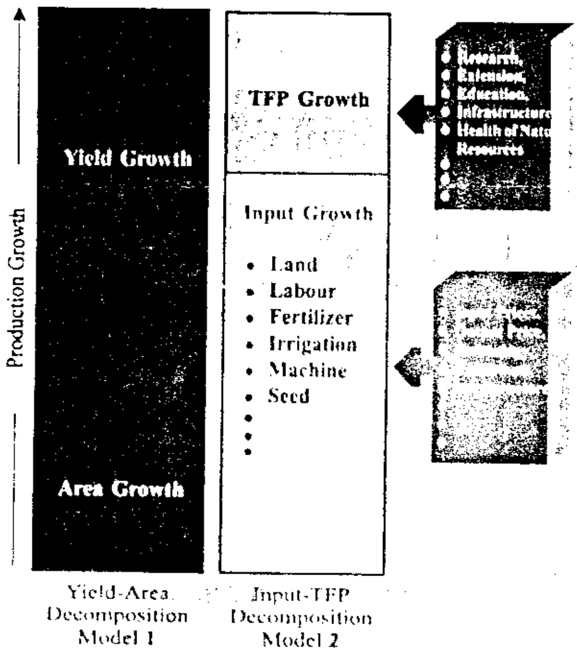
1 These districts cover five major states of IGP viz. Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal and pertain to the boundaries as in the year 1966. At the time of analysis, data was available upto the year 1996-97

systematic study by Minhas and Vaidyanathan (1965). Later, work on the decomposition of growth in agricultural output became more refined and invoked the total productivity concept. Contribution of Evenson and Jha (1973) followed by Dey and Evenson (1991), Sidhu 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 important parts of this genre. Yield-area decomposition model and Productivity growth accounting model are compared in Box 1.

Box 1
Production Growth Models



In Model 1, growth in agricultural output is simply decomposed 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. This was the situation till 1960s, for example. Subsequently, as technological change and other (non-land) inputs become more important, an alternative approach becomes 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.

3. SUSTAINABILITY AND TFP: METHODOLOGY

Measurement of sustainability

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, 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) proposed a non-positive trend in TFP as a good indicator of lack of sustainability of a 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 TFP growth over time. In this paper, deceleration in TFPG has been taken as a proxy of unsustainability. The TFPG was classified into five categories, viz. negative (negative and statistically significant TFPG), stagnant (statistically non-significant TFPG), low (<1% TFPG), moderate (1-2% TFPG), and high (>2% TFPG).

Measurement of TFP

The relative sectoral growth rates of productivity are important determinants of structural transformation of economies, and the rate of growth of productivity in the industrial (Kuznets (1986) and agricultural sectors (Evenson and Jha (1973)) has been put forward as a key variable. Since the publication of the pioneering works of Schultz (1953), Solow (1957), and Griliches (1964), voluminous literature has appeared dealing with the measurement and analysis of productivity at different levels of aggregation. Three approaches for the measurement are the most representative: (i) the parametric approach which 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 which approximates technological change by the computation of factor productivity indices, mainly the rate of change of total factor productivity indices (Christensen (1975)); and (iii) a recent approach, termed as 'non-parametric' by Chavas and Cox (1988) and Cox and Chavas (1990), which 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. Coelli and Rao (2003) used this approach and constructed Malmquist TFP index for agriculture using FAO data base of 93 countries covering the period 1980-2000. However, 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.

Divisia-Tornqvist index has been used in the present study for computing the TFP for the crop sector by district, agro-eco-region and sub-region of the IGP. The output, input, and TFP indices were computed as:

Total output index (TOI)

$$TOI_t / TOI_{t-1} = \prod_j (Q_{jt} / Q_{jt-1})^{(R_{jt}+R_{jt-1})^{1}/2} = A_t \qquad \text{...........(1)}$$

Total input index (TII)

$$TII_t / TII_{t-1} = \prod_i (X_{it} / X_{it-1})^{(S_{it}+S_{it-1})^{1}/2} = B_t \qquad \text{...........(2)}$$

where,
R_{jt} is the share of j[th] crop output in total revenue in the year t,
Q_{jt} is the output of j[th] crop in year t,
S_{it} is the share of input i in total input cost in year t,
X_{it} is quantity of input i and
p_{it} is price of input i in year t.
Total output and input index in period t was computed from (1) and (2) as follows.

$$TOI\ (t) = A_1\ A_2 \ldots\ldots A_t \qquad \text{...........(3)}$$

$$TII\ (t) = B_1\ B_2 \ldots\ldots B_t \qquad \text{...........(4)}$$

Total factor productivity index (TFP)

$$TFP_t = (TOI_t\ /\ TII_t) \qquad \text{...........(5)}$$

Equations (3) to (5) provide the index of total output, total input, and TFP, respectively for year 't'. The estimation of input, output, and TFP growth rates for any specified period has been done by fitting an exponential (or semi-log) trend equation to the input output, and TFP indices, respectively.

In the present analysis, the following crops grown in IGP were included in the computation of total output index. These crops accounted for more than four-fifths of the gross cropped area (GCA) in various states.

State	Crops
Punjab	Paddy, Wheat, Pearl-millet, Maize, Barley, Chickpea, Rapeseed and Mustard, Sesamum, Sugarcane and Cotton
Haryana	Paddy, Wheat, Sorghum, Pearl-millet, Maize, Barley, Groundnut, Sesamum, Rapeseed and Mustard, and Chickpea

Uttar Pradesh*	Paddy, Wheat, Sorghum, Pearl-millet, Maize, Small millets, Barley, Chickpea, Pigeon-pea, Groundnut, Sesamum, Rapeseed and Mustard, Linseed, Soybean, Sunflower, Sugarcane, Cotton, Potato, and Onion
Bihar*	Paddy, Wheat, Maize, Barley, Murua, Small millets, Mung, Pigeon-pea, Chickpea, Lentil, Khesari, Pea, Rapeseed and Mustard, Sugarcane, Tobacco, Mesta, and Potato
West Bengal	Paddy, Wheat, Jute, Mustard and Potato

* Refer to undivided states.

For constructing the total input index, ten inputs (human labour, bullock labour, machine labour, farm yard manure (FYM), nitrogen, phosphorus, and potassium fertilisers, irrigation, plant protection and land) were included. Labour input was measured as the total number of workers employed in agriculture; land was measured as gross cropped area; rental value of land was taken as the cost of land; machine labour input as the number of four-wheel tractors; bullock input as the number of adult bullocks and male buffalos; and FYM input as the number of livestock. The data on these inputs were collected for individual districts. Cost share of each input was computed by dividing individual input cost by the total production cost for all principal crops at the state level based on 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 shares were used for districts belonging to the state. Input cost share and input quantity data for each district were used for computing the input index. The farm harvest price and production of crops at district level were used to compute the output index. The TFP index was computed by dividing the output index by the input index for each of the IGP districts.

4. DATA SOURCES

Crop outputs, Inputs and Prices

The data on quantity and price of important inputs and crop output, irrigated area by source and crop, net cropped area, gross cropped area, net irrigated area, agricultural labour and rural literacy, farm machinery, tractor, etc., infrastructure data like roads, markets, credit institutions and rural electrification, agro-climatic characteristics and investment in research and extension have been compiled for the period 1980-81 to 1996-97 for the IGP districts. The data on agricultural statistics and prices have been taken from the DES, GOI. Data on fertilizer have been collected from Fertilizer Statistics of the Fertilizer Association of India. The district level time series data on area, yield, production, irrigation and high-yielding varieties (HYVs) for crops under study have been taken from the various published reports available at the DES office in various states.

Agricultural research and extension stock

Historically, agricultural research, extension and education in India have been in the public domain. India has one of the largest and institutionally mature agricultural research systems in the world.The construction of a time series on agricultural research and extension expenditures has been a challenging task, because much of the data sources have been inadequate in scope and coverage, difficult to access, no uniformity in quality and are varied in the degree of documentation. Pal and Singh (1997) have compiled government investment/expenditure in agricultural research and education from the various official documents of the Union and State Governments (Comptroller & Auditor General of India, Ministry of Finance and Reserve Bank of India). These data include all expenditures (plan and non-plan) on agricultural research and education, on revenue as well as on capital accounts. Ranjitha (1996) constructed the research expenditure series by commodity for each state. These data were updated during the study. Following Evenson (1991), the research and extension stock variables were constructed using distributed lag function of research and extension in the present and previous years. The time weight for the research variables has been imposed as 0.2 in t-3, 0.4 in t-4, 0.6 in t-5, 0.8 in t-6 and 1 in t-7. The time weights for the extension variables have been imposed as 0.5 in t-1 and 0.25 in both t-2 and t-3.

Infrastructure index

Adequate infrastructural support is a pre-requisite for accelerating the growth of Indian agriculture. A composite infrastructural development index by districts/ regions has been constructed to take into account the vast geographical dispersion of productivity and high degree of variability of infrastructural facilities visible in the IGP. In the light of availability of published data, six major factors of infrastructural facilities have been used - transport, energy, irrigation, banking, education and health. Energy, transport, irrigation, and finance are economic infrastructural facilities while education institutions and health facilities are considered as social infrastructure. The weights to individual factors of infrastructure as given below have been assigned as a fair measure as per our subjective understanding of the relative importance of a particular sector in the overall infrastructure requirements for India.

Sector	Weight (per cent)	Indicators used
Transport facilities	26	Surfaced roads per 100 sq km of area
Energy	24	Percentage of villages electrified
Irrigation facilities	20	Gross irrigated area as per cent of the gross cropped area
Banking facilities	12	Bank branches per lakh of population
Education institutes	6	Primary schools per lakh of population
Health facilities	12	Primary health centres per lakh of population

The infrastructure index for the j[th] district was computed as:

$$I_j = \Sigma_i (W_i . Y_{ij})$$
$$Y_{ij} = X_{ij}/X_{ia} * 100$$

where,

W_i = the weight of the i[th] indicator and the sum of weights across indicators is one

X_{ij} = value of the i[th] indicator for the j[th] district

X_{ia} = value of the i[th] indicator for all India.

The computation of infrastructure index by districts in relation to India has been done for the years 1980, 1985, 1990 and 1995 and interpolated and extrapolated for the remaining years[2].

The temporal growth of the infrastructure index in different sub-regions of the IGP vis-à-vis India is shown in Appendix Table 3. The infrastructure index of India has been assumed to be 100 in the base year 1980. Since then the score of infrastructure index in India has reached 147 and has thus registered 47 point increase in a span of fifteen years. The expansion of infrastructure requires heavy and continuous investment and hence its scores in different states/sub-regions depend upon the relative priority accorded by the states concerned. Looking at the current infrastructure status, it is observed that the index has been highest in the TGP (174-193), followed by the UGP (144-168), the MGP (125-158) and the LGP (85-135). The MGP and LGP regions have remained far behind the national average in the development of infrastructure.

The Barind plain and Coastal saline sub-regions have been the least developed sub-regions till 1990. Later on, the Coastal saline sub-region has improved its position in terms of infrastructure index and left behind the Rorh plain but the Barind plain have remained at the lowest rung of the ladder in terms of infrastructure development in the IGP. Further, it is clearly evident that all sub-regions of the IGP have registered improvement in the score of infrastructural indices. But, some 50 per cent of the sub-regions of the IGP are still lagging behind the overall average infrastructure of the country. The overall infrastructure index is still low in the sub-regions of the Eastern Uttar Pradesh, Bihar and West Bengal. The development of rural infrastructure is a pre-requisite for inducing the use of inputs and increasing the production. Several studies have established strong relationship between the infrastructure development and the agricultural productivity (Fan *et al* (1999) and Kumar (2001)).

5. TFPG ESTIMATES OF CROP SECTOR IN IGP

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 productivity growth per unit of land. The first post-Green Revolution phase (from late 1960s to mid 1980s) is marked by the continued growth in returns from land through

2 The data is collected from the agricultural census which was conducted once in five years.

the intensification of use of chemical inputs and machine labour. The second post-Gre Revolution phase (beginning in mid-1980s) is characterized by high input use a decelerating agricultural productivity. Consequently, several ecological problems ha cropped-up in the IGP. Productivity stagnation, nutrient and water imbalance, and increas pest and disease incidence may render the crop sector unsustainable. There are sor reports that the crop system in the IGP is showing signs of fatigue in terms of productivi (Paroda (1996), Kumar *et al* (1998)). This may jeopardize agricultural growth and advers affect the food security of those living within and outside the system. The role of the I in meeting the future needs in a sustainable manner is being debated in the light growing ecological degradation and stagnating productivity. The districts and regions the IGP are suffering from uneven TFP growth in the crop sector. In the present secti TFPG estimates of the crop sector by states, region, sub-region and agro-eco-region IGP were presented for the period 1981-82 to 1996-97 and sub-period I (1981-82 1990-91) and sub-period II (1990-91 to 1996-97).

TFPG estimates by state

Estimates of average annual TFP growth in the crop sector for IGP major five sta are shown in Table 1. West Bengal depicted the highest growth in TFP index at the r of 3.1%, whereas it was 2.2% in Haryana, 1.4% in Bihar, 1.2% in Punjab, and 0.6% Uttar Pradesh for the period 1981-82 to 1996-97. The TFP estimates indicate a signific growth in crop sector in the 1980s in almost all states. Also there is a clear indicat of the fall in the rate of growth of TFP in the 1990s as compared to that in the 198 Stagnating growth in the TFP is a matter of concern for Uttar Pradesh, Haryana, a Bihar. Deceleration in the growth of TFP as observed in the IGP states would influe the cost of production and adversely affect the profitability of the crop sector. Input-ba yield growth may not be sustained, if further productivity improvements do not oc This emphasizes the need for identification and implementation of sustainable source productivity growth in the crop sector. The finding of a decline in TFP growth in c sector in the 1990s is in agreement with the results presented by Kumar *et al.* (1998) rice-wheat cropping system in IGP states.

TABLE 1

TFP GROWTH IN CROP SECTOR, 1981-82 TO 1996-97 BY STATES (PER CENT PER ANNUM)

State	1981-82 to 1990-91	1990-91 to 1996-97	1981-82 to 1996-9
Punjab	1.24	1.20	1.22
Haryana	3.22	0.10^{ns}	2.22
Uttar Pradesh	1.44	-0.54^{ns}	0.63
Bihar	1.47	0.24^{ns}	1.43
West Bengal	5.13	1.25	3.08

ns: Statistically non-significant

TFPG estimates by agro-eco-region/sub-region

As seen in Table 2, aggregate output and aggregate input exhibited 3.5 per cent and 2.3 per cent growth per annum, respectively in the IGP. Thus, TFP 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. TFP results for different agro-eco-regions showed considerable variations. The LGP region depicted the highest growth in TFP (3.1 per cent) and MGP the lowest (0.37 per cent). The growth in rice productivity was the main vehicle of agricultural growth in the LGP (Kumar and Rosegrant (1994), Joshi et al. (2003)). The TFP growth rates were estimated at 1.4 per cent in the TGP and 0.9 per cent in the UGP. In IGP, one third of

TABLE 2

AVERAGE ANNUAL GROWTH IN INPUT USE, OUTPUT, AND TFP OF THE CROP SECTOR BY REGIONS OF IGP: 1981-1996

Agro-eco-region/ Sub-region	Input (%)	Output (%)	TFP (%)	Share of TFP growth in output growth (%)
Trans-Gangetic Plain				
Foothills of Shivalik	2.29	3.59	1.30	36.21
Plain	2.40	3.40	1.01	29.56
Arid	3.06	4.87	1.81	37.17
All sub-regions	**2.68**	**4.07**	**1.40**	**34.25**
Upper-Gangetic Plain				
Central Plain	3.17	3.57	0.39	10.98
North-Western Plain	2.40	3.29	0.88	26.92
South-Western Plain	1.93	3.42	1.49	43.60
All sub-regions	**2.55**	**3.44**	**0.89**	**25.81**
Middle-Gangetic Plain				
North-eastern Plain	3.00	2.12	-0.88	-41.28
Eastern Plain	2.73	2.94	0.21	7.18
Vindhyan	1.46	2.28	0.82	35.96
North-Bihar Plain	1.00	1.87	0.87	46.29
North-east Plain	1.05	2.01	0.96	47.68
South-Bihar Plain	0.34	1.38	1.04	75.40
All sub-regions	**1.77**	**2.14**	**0.37**	**17.31**
Lower-Gangetic Plain				
Barind Plain	3.08	5.40	2.32	42.94
Central Alluvial	2.07	5.55	3.49	62.80
Alluvial Coastal Saline	1.96	5.45	3.49	64.04
Rorh Plain	3.06	4.86	1.80	37.08
All sub-regions	**2.34**	**5.42**	**3.08**	**56.83**
Indo-Gangetic Plain	**2.33**	**3.54**	**1.21**	**34.22**

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 the output growth was technology-based. The output growth in the TGP was input- as well as technology-based.

In the TGP, the use of inputs rose by 2.3 per cent in Foothills of Shivalik and 3.1 per cent in the Arid sub-region. Aggregate annual output growth was found to vary from 3.4 to 4.9 per cent. TFP growth was highest in the Arid sub-region (1.8 per cent), followed by Foothills of Shivalik (1.3 per cent) and was minimum in the Plain sub-region (1.0). TFPG had contributed almost equally, by about one-third of the crop output growth in the sub-regions of the TGP. In the sub-regions of the UGP, the growth in input-use varied widely from 1.9 per cent in the South-Western Plain to 3.2 per cent in the Central Plain. However, the output growth was almost the same in all the sub-regions. TFP growth was high in the South-Western Plain (1.5 per cent), followed by the North-Western Plain (0.9 per cent) and the Central Plain (0.4 per cent). In the Central and North-Western Plain of the UGP, the output growth had been input-based which may not be sustainable in future. A relatively high contribution of technology to crop productior was observed in the South–Western Plain of the UGP.

In the MGP, wide variations in input use, output, and TFP growth across sub-region were observed. The rise in input growth was high in the North-Eastern (2.7 per cent) an Eastern Plain (3.0 per cent) and low in other sub-regions (0.3 to 1.5 per cent). Outpu growth was about 2 per cent across the sub-regions in the MGP. TFPG was negative i the North-Eastern Plain, despite the high growth in input use. This showed that the crc production in the North-Eastern Plain was input-based and the crop system was headir towards un-sustainability. All other sub-regions showed moderate growth in the TF TFPG revealed that the crop production was input-based and the earlier gains from t green revolution technologies had already been attained and the return to crop wou decline and the crop system in the MGP would not be sustainable. The low input a output growths environment would not be viable to attain household nutritional securi An urgent need therefore has arisen to develop appropriate technologies for the regi to shift upward the production frontiers.

In the LGP, a relatively high growth in inputs, crop production and TFP was obser in all the sub-regions. The TFP had contributed its share ranging from 38 per cent in Rorh Plain to 64 per cent in the Alluvial Coastal Saline Plain of the LGP. During 1980s, the region had witnessed a turning point in the history of agricultural developm This region achieved an unprecedented output growth rate of more than 5 per cent annum during the period 1980-81 to 1996-97, and this growth rate was the highest am all the regions of the irrigated agro-eco-system.

Results of output, input and TFP growth over different time spans 1981-90 (1980s) and 1990-96 (1990s) are presented in Table 3. Over the entire period of the study the crop sector output grew at the rate of 3.5 per cent per annum, input index at 2.3 per cent per annum and TFP, 1.2 per cent. However, sub-period wise, the results were more revealing. There was relatively higher growth in input, output and TFP indices during the1980s.

TABLE 3

AVERAGE ANNUAL GROWTH IN INPUT USE, OUTPUT, AND TFP OF THE CROP SECTOR BY AGRO-ECO -REGIONS AND SUB-REGIONS DURING 1981-90 AND 1990-96 OF THE INDO-GANGETIC PLAIN

Agro-eco-region/Sub-region	Input (%)		Output (%)		TFP (%)		Share of TFP in output growth (%)	
	I	II	I	II	I	II	I	II
Trans-Gangetic Plain								
Foothills of Shivalik	2.69	1.40	3.91	2.16	1.22	0.75	31.11	34.89
Plain	2.94	1.28	4.47	1.60	1.53	0.32	34.25	20.18
Arid	3.56	1.63	6.55	0.98	3.00	-0.65	45.70	neg
All sub-regions	**3.18**	**1.45**	**5.32**	**1.39**	**2.14**	**-0.06ns**	**40.21**	**neg**
Upper-Gangetic Plain								
Central Plain	3.14	2.84	3.86	2.56	0.71	-0.28	18.43	neg
North-Western Plain	2.54	2.15	3.22	2.61	0.68	0.46	21.12	17.78
South-Western Plain	2.19	1.51	4.16	2.57	1.98	1.06	47.46	41.07
All sub-regions	**2.66**	**2.21**	**3.76**	**2.58**	**1.10**	**0.36**	**29.28**	**14.12**
Middle-Gangetic Plain								
North-eastern Plain	2.68	2.71	4.50	-2.06	1.81	-4.76	40.28	neg
Eastern Plain	2.93	2.31	4.41	0.71	1.48	-1.60	33.57	neg
Vindhyan	1.78	1.03	1.60	3.43	-0.18	2.40	neg	69.97
North-Bihar Plain	1.41	0.44	2.23	1.11	0.82	0.67	36.71	60.24
North-east Plain	1.51	0.43	2.40	-0.71	0.90	-1.14	37.35	neg
South-Bihar Plain	1.37	-0.63	2.08	0.67	0.71	1.30	34.31	194.08
All sub-regions	**2.07**	**1.24**	**3.23**	**0.10**	**1.17**	**-1.14**	**36.12**	**neg**
Lower-Gangetic Plain								
Barind Plain	2.10	4.40	6.40	3.94	4.30	-0.46	67.17	neg
Central Alluvial Plain	2.45	1.63	7.69	3.85	5.24	2.22	68.15	57.77
Alluvial Coastal Saline Plain	1.65	2.29	7.42	2.82	5.77	0.53	77.76	18.79
Rorh Plain	3.64	2.09	8.61	1.74	4.97	-0.34	57.70	neg
All sub-regions	**2.45**	**2.20**	**7.58**	**3.45**	**5.13**	**1.25**	**67.64**	**36.22**
Indo-Gangetic Plain	2.6	1.7	4.61	1.68	2.02	-0.02ns	43.7	neg

I: Period 1981-90; II: Period 1990-96. neg: Negative; ns: Statistically non-significant

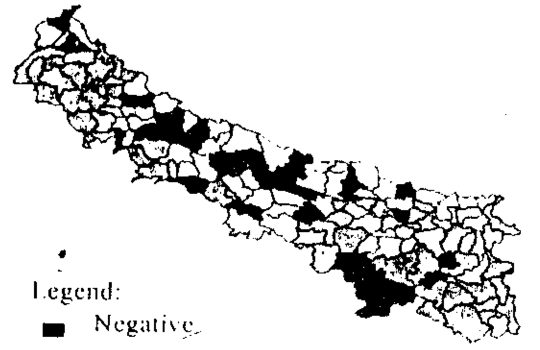
The higher growth, especially in TFP, implied higher contribution of technical change to output growth. A decline in growth of input, output, and TFP indices was observed during the 1990s. In the IGP, the growth in input index was 2.6 per cent per annum during 1980s and it declined to 1.7 per cent during 1990s. The output growth which was 4.6 per cent during 1980s, declined to 1.7 per cent during the 1990s.

The TFP of the crop sector in the IGP witnessed 2.0 per cent growth per annum in 1980s and it turned out to be negative in 1990s.

A similar pattern was also observed in almost all the regions and sub-regions. The growth in TFP had declined in 1990s in all the sub-regions of the agro-eco-regions, except in the South-Bihar Plain of the MGP. The growth in output also witnessed the declining trend in all sub-regions with the sole exception of Vindhyan sub-region of the MGP. Similarly, a decline in input index was observed during 1990s with the exception of Barind Plain and Alluvial Coastal Saline Plain of the LGP. During 1980s, the growth in TFP was 5.1 per cent in the LGP, 2.1 per cent in the TGP, 1.2 per cent in the MGP, and 1.1 per cent in the UGP. During 1990s, the TFP decelerated to -1.1 per cent in the MGP and to 0.06 per cent in the TGP, implying a negative contribution of TFP to the output growth in the crop sector in these regions. The TFP growth in the LGP during 1990s was comparatively appreciable (1.2 per cent per annum) though the decline in growth was very sharp (from 5.1 per cent in 1980s). The TFP in the UGP had maintained a negligible positive growth rate during 1990s (0.36 per cent). Several studies conducted at the national or state level either crop-specific or agriculture had reported a decline in the contribution of TFP to the agricultural output growth since 1988. Since this study used the latest years' data, the more pronounced decline seemed to have occurred during 1990s, which could not be reflected in the earlier studies. The results present a gloomy picture of the agricultural growth during the 1990s. The performance in terms of the contribution of TFP to output growth was very poor in the crop sector during 1990s as compared to 1980s. This was true for all the sub-regions of IGP. The sharp decelerating growth in the crop sector has been a major cause of concern and there is an urgent need to adequately address the issues of sustainability and technical change in the agricultural sector reforms.

TFPG estimates by districts

In this sub-section, we have sought to measure changes in TFP across districts of the IGP. This perspective is valuable in identifying the districts, which are showing the clear signs of un-sustainability for crop production. Using TFP indices for all the districts of IGP, the average annual compound growth rates of TFP indices for each district were computed. Growth rates in the crop sector are shown in Appendix Table 4 for the period 1981-82 to 1990-91 and 1990-91 to 1996-97 and for the entire period 1981-82 to 1996-97. The results revealed that the magnitude of TFP growth varied from -2.5 per cent (highest decline) per annum in Deoria district of Uttar Pradesh to 6.3 per cent in Mahendergarh district of Haryana. In the 15 best performer districts in terms of TFP growth in the IGP, seven (out of 11) were from West Bengal, two (out of 23) from Bihar, two (out of 7) from Haryana, two (out of 11) from Punjab and two (out of 41) were from Uttar Pradesh. The districts were classified according to TFPG performance into five categories and shown in Map 1.



Map 1: TFP growth of crop sector in IGP (1981-96)

The districts showing clear signs of unsustainability are distributed as follows: 5 (out of 18) were in the Trans-Gangetic Plain (TGP), 10 (out of 28) in the Upper-Gangetic Plain (UGP), 21 (out of 36) in the Middle-Gangetic Plain (MGP) and 2 (out of 11) in the Lower-Gangetic Plain (LGP). In the IGP, the high growth in TFP for the crop sector was observed in about one-third of GCA during 1981-1996. A moderate growth in TFP was recorded in 22.9% and low growth in 12.1% of the GCA. About one-fourth of the GCA had not witnessed of TFPG, while 8.8% of the GCA showed the sign of declining trend in TFP (Table 4). The LGP ranked top as beneficiary of the productivity growth in the crop sector, followed by the TGP, UGP, and MGP. The TGP and the UGP have already experienced a number of second generation problems, like increased incidence of insect pests, problem of weeds, etc., which induced indiscriminate use of pesticides and herbicides. In the TGP, the Roopnager district in the Foothills of Shivalik, and the three districts, namely Jalandhar, Karnal, and Patiala of the Plain sub-region of the TGP region have witnessed TFP stagnation. In the UGP, the performance of the North-Western Plain was satisfactory. The TFP was falling or stagnating in more than half of the districts in the Central Plain agro-climatic zone, which has salt-affected soils. It may be mentioned that a large part of the TGP and the UGP has been the non-traditional rice growing area. Indiscriminate groundwater utilization and declining biodiversity have severely affected the TFP growth in these regions. Groundwater utilization has been increasing excessively without any provision of recharge. The over-utilization of groundwater has caused a steep fall in the water table, which in turn has escalated the water cost. Less utilization of groundwater in the MGP, where rainfall ranges between 1500 and 2000 mm, has caused waterlogging conditions, which has suppressed the rice and wheat production (Singh et al. (2000)). The electrical conductivity of water has also been quite high in the MGP (Sidhu (2001)). These factors resulted in stagnation of TFP in the crop sector. The LGP, which was earlier characterized as a mono-crop area due to the extensive rice cultivation, has now embraced crop diversification, leading to high growth in TFP.

TABLE 4
DISTRIBUTION OF SHARE OF GCA BY TFP GROWTH IN DIFFERENT SUB-REGIONS OF IGP DURING 1981-90 AND 1990-96

(per cent share of GCA)

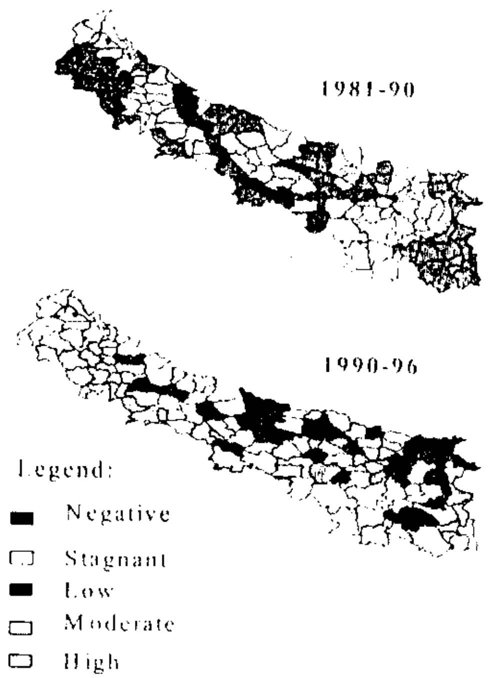
Sub-region	Period	TFP Growth					GCA
		Negative	Stagnant	Low	Mode-rate	High	(000ha)
Indo-Gangetic Plain	1981-90	4.4	28.4	3.9	21.0	42.4	47865
	1990-96	22.5	39.3	7.5	16.8	13.9	47865
	1981-96	**8.8**	**26.3**	**12.1**	**22.9**	**29.9**	**47865**
Trans-Gangetic Plain	1981-90	0.0	18.4	0.0	38.8	42.8	12800
	1990-96	21.2	37.4	0.0	36.3	5.1	12800
	1981-96	**3.5**	**23.9**	**7.9**	**23.5**	**41.2**	**12800**
Upper-Gangetic Plain	1981-90	13.2	30.5	7.8	19.8	28.8	13884
	1990-96	6.3	55.7	16.8	11.4	9.8	13884
	1981-96	**11.8**	**21.4**	**27.9**	**28.7**	**10.2**	**13884**
Middle-Gangetic Plain	1981-90	1.8	50.7	5.5	16.9	25.0	13838
	1990-96	42.4	35.3	5.1	2.9	14.2	13838
	1981-96	**15.2**	**43.0**	**6.7**	**25.7**	**9.5**	**13838**
Lower-Gangetic Plain	1981-90	0.0	0.0	0.0	0.0	100.0	7342
	1990-96	17.8	18.8	7.3	19.5	36.6	7342
	1981-96	**0.0**	**8.4**	**0.0**	**5.9**	**85.7**	**7342**

Negative: negative and statistically significant TFPG, Low: less than 1% TFPG; Moderate: 1-2 % TFPG; High: greater than 2% TFPG, Stagnant: statistically non-significant TFPG
GCA: Gross cropped area.

Sustainability of crop sector

In this sub-section a comprehensive view has been provided of the distribution of districts based on the performance of TFP indices. The details about the spatial distribution of districts according to their TFPG are given in Table 5 and name of the districts under each category in sub-period 1981-90 and 1990-96 are presented in Appendix Table 5.

The performance of district wise TFPG during 1980s and 1990s is given in Appendix Table 4 and illustrated through Geographic Information System (GIS) in Map 2. The performance of TFP growth pattern in IGP was more spectacular in 1980s as compared to that in 1990s. 42.4 per cent of the GCA which recorded a high TFP growth



Map 2: TFP growth of crop sector in IGP

TABLE 5

DISTRIBUTION OF DISTRICTS ACCORDING TO GROWTH CATEGORIES OF TFP BY AGRO-ECO-REGION OF INDO-GANGETIC PLAIN IN 1981-90 AND 1990-96

(number of districts)

Sub-region	Period	TFP Growth					No. of districts
		Negative	Stagnant	Low	Mode-rate	High	
Indo-Gangetic Plain	1981-90	4	33	4	18	35	94
	1990-96	23	40	6	11	14	94
Trans-Gangetic Plain	1981-90	0	5	0	7	6	18
	1990-96	3	8	0	5	2	18
Upper-Gangetic Plain	1981-90	3	10	2	5	8	28
	1990-96	2	16	4	3	3	28
Middle-Gangetic Plain	1981-90	1	18	2	6	10	37
	1990-96	15	14	1	1	6	37
Lower-Gangetic Plain	1981-90	0	0	0	0	11	11
	1990-96	3	2	1	2	3	11

Negative: negative and statistically significant TFPG. Low: less than 1% TFPG; Moderate: 1-2 % TFPG; High: greater than 2% TFPG, Stagnant: statistically non-significant TFPG

during 1980s, declined to 13.9 per cent during 1990s (Table 4). The area under moderate TFP growth had also declined, while the area under low TFP growth increased. The area under stagnant TFP had increased from 28.4 per cent during 1980s to 39.3 per cent during 1990s. The TFP indices did not improve in more than 39.3 per cent of the GCA during 1990s and on the contrary, they had declined in 22.5 per cent of the GCA. In fact, quite a significant proportion of the cropped area in the IGP is turning to be unsustainable.

In the TGP region, the area under high TFPG was about 42.8 per cent, which came down to just 5.1 per cent of GCA during 1990s. Similar pattern was the observation in other sub-regions. The area under high TFPG was 28.8, 25.0 and 100 per cent during 1980s in the UGP, MGP and LGP respectively. Corresponding figures for the 1990s were estimated to be only 5.1, 9.8 and 14.2 per cent respectively. More and more cropped area was falling in the classes with lower TFP growth. Thus, the area under negative TFP growth had increased in the latter period. In the MGP, as high as 42.4 per cent area was found to be witnessing decline in TFP during 1990s. Thus overall, there was a substantially diminished performance in the contributions of TFPG in the output growth, which was broadly held true across regions. Hence, the 1990s was a period of disappointing performance in productivity. It appears that due to rapid expansion of seed-fertilizer technology in MGP and LGP and its consolidation in TGP and UGP, there occurred a significant growth in TFP in 1980s. But unfortunately the trend could not sustain and was reversed in 1990s.

A similar pattern in the TFPG was observed in all the agro-eco-regions. As seen in Appendix Table 6, the situation had deteriorated very seriously in the Arid sub-region of the TGP; Central Plain of the UGP; North-Eastern and Eastern Plain of the MGP; and Barind, Alluvial Coastal Saline Plain, and Rorh Plain of the LGP. The findings of Kumar and Rosegrant (1994) and many other studies based on the performance during the 1980s have concluded that the eastern part of India would serve as the major potential region for the foodgrains supply in future but it may not hold true now as most of the sub-regions in the LGP are tending to move from the sustainable to unsustainable cropping system. In fact, quite a significant proportion of the cropped area in IGP has become unsustainable in the 1990s.

During the 1980s, 35 districts recorded a high growth in TFP; this number was reduced to 14 districts during1990s. The number of districts registering even moderate TFP growth had also declined. However, the number of districts recording a low and stagnant growth in TFP had increased. Forty districts of the IGP did not register any growth in TFP during 1990s; and the corresponding figure was 33 during 1980s. Furthermore, in as many as 23 districts, the TFP had actually declined, while this number was only 4 during 1980s. The districts, as listed in appendix Table 5, falling in categories of negative and stagnant growth of TFP are the priority districts where the problem of sustainability is serious. These districts needed long-term investment for the development of physical and institutional infrastructure and natural resource management. The analysis confirmed that contribution of TFPG to output growth had started declining and had been in fact, showing a tendency of further deterioration in the process. Productivity growth, which picked up during early 1980s, was not sustained during 1990s and this situation raised an alarm for the policy makers and researchers of the country, in spite of the illusory food surpluses in the country. About 63 per cent cropped areas during 1980s were sustainable which has declined to a level of about 30 per cent during 1990s in entire of IGP. The unsustainable-cropped area, which was 33 per cent of the GCA during 1980s had increased to a level of 62 per cent of the GCA during 1990s. The situation was reported to be more serious in the MGP where the unsustainable-cropped area increased from 53 per cent of GCA during 1980s to 88 per cent of the GCA during 1990s.

6. DETERMINANTS OF TFP

Increases in productivity can be induced by such factors as research, extension, human capital, infrastructural and climatic factors. As an input into public investment decisions, it is useful to understand the relative importance of these productivity-enhancing factors in determining productivity growth. Infrastructure induced input-output market interface and created a suitable environment for the adoption of technology. Checking of water table depletion would enhance TFP. This problem was found so severe that it warrants immediate attention in the UGP. Urbanization creates not only demand for value-added agricultural products but provides opportunities also for non-farm employment and income generation. Additional investments in research, extension, education, infrastructure development, and water conservation measures in the IGP have been found to be evidently very productive and rewarding and would go a long way in stepping up the growth of input, output and TFP in all the regions of the IGP.

Multiple regression analysis was carried out to study the factors influencing TFP in crop sector of IGP. In order to assess the determinants of TFP, the TFP index was regressed on the following variables

TFP = f (RES_STOK, EXT_STOK, INF, LIT_R, UR, WT_F, KVK, TGP, UGP, MGP)

Where,
RES_STOK: Research (total research stock per hectare of cropped area);
EXT_STOK: Extension (total extension stock per hectare of cropped area);
INF: Infrastructure (rural infrastructure index constructed in the study);
LIT_R: Literacy (rural literacy rate in per cent);
UR: Urbanisation (share of urban population to total population);
WT_F: Dummy for the water table (it takes one if water table is falling otherwise zero);

TABLE 6

DETERMINANTS OF TOTAL FACTOR PRODUCTIVITY IN THE CROP SECTOR OF THE IGP: 1981-1996

Dependent variable: TFP index at the district level

Variable	Regression coefficient	Standard error	't' Statistic	Level of significance	Elasticity
Constant	112.16	7.04248	15.93	0.000	-
Research	0.00051	0.00016	3.24	0.001	0.19776
Extension	0.00085	0.00031	2.77	0.005	0.16325
Literacy	0.59418	0.14412	4.12	0.000	0.26395
Infrastructure	0.16629	0.03846	4.32	0.000	0.30301
Urbanisation	4.97538	2.32442	2.14	0.033	0.14770
Dummy variables					
KVK	-1.18018	2.10506	0.56	0.575	-0.02626
Water Table	-0.05223	0.03467	1.51	0.133	-0.07961
TGP	-11.63351	5.34222	2.18	0.030	-0.19424
UGP	-9.15695	4.56664	2.00	0.457	-0.18871
MGP	-9.57866	4.23820	2.26	0.0244	-0.20895
R-Square	0.30561				
No. of districts	94				
No. of observation	1504				

Panel data for districts is used for the years 1981-82 to 1996-97

KVK: Dummy for *Krishi Vigyan Kendras* (it takes one if KVK existed in the district otherwise zero);
TGP, UGP, MGP, LGP, are the dummy variables for agro-eco-regions.
District wise time series data from the different agro-eco-regions were pooled, and dummy variables are included for regions, keeping the LGP as the reference region. Estimation was undertaken using a fixed effects approach for the pooled cross-section time series district level data set, with correction for serial correlation and heteroscedasticity (Kmenta (1981)). The estimated parameters of the TFP decomposition model for the crop system in the IGP are presented in Table 6.

Results indicate that research, extension, literacy and infrastructure are the most important sources of growth in TFP. Urbanization improves input-output market interface and it is of crucial importance for growth in productivity. Over-exploitation of groundwater has led to depletion of the storage resulting in uneconomical pumping and declining TFP (-0.79). Using the TFP elasticities with respect to research, extension, literacy, infrastructure, and urbanization, and growth rates of each variable, the contribution of each of the significant variables to TFP growth was computed and given in Table 7. In the IGP region, extension accounted for about 45 per cent of the TFP growth, followed by public research (36 per cent), literacy (10 per cent), infrastructure (8 per cent), and urbanization (1.5 per cent). Similar results were obtained by several other studies (Kumar and Rosegrant (1994), Evenson *et al.* (1999), Fan, *et al* (1999)).

Government expenditure on research, extension, and literacy has literally served as the engine of agricultural growth. The benefits have trickled down to the poor in the development process (Fan, *et al* (1999)). The impact of infrastructure on the input and output growth was evident in the LGP. Infrastructure induced input-output market interface and created a suitable environment for the adoption of technology. Checking of water table depletion would enhance TFP. This problem was found so severe that it warrants immediate attention in the UGP. Urbanization creates not only demand for value-added agricultural products but provides opportunities also for non-farm employment and income

TABLE 7

SOURCES OF TFP GROWTH IN CROP SECTOR OF INDO-GANGETIC PLAIN DURING 1981-82 TO 1996-97

Sources	Annual growth rate (%)	Elasticity of TFP	Share of TFP growth explained (%)
Research	10.45	0.19776	35.6
Extension	15.86	0.16325	44.7
Literacy	2.26	0.26395	10.3
Infrastructure	1.51	0.30301	7.9
Urbanization	0.60	0.14770	1.5

generation. Additional investments in research, extension, education, infrastructure development and water conservation measures in the IGP have been found to be evidently very productive and rewarding and would go a long way in stepping up the growth of TFP in all the regions of the IGP and will have significant impact on food supply (Kumar and Mittal (2003)).

7. CONCLUSIONS AND POLICY IMPLICATIONS

The TFP index of the crop sector in IGP rose by 1.2 per cent annually during 1981-1997. It was the highest in the LGP (3.1 per cent) followed by the TGP (1.4 per cent), UGP (0.9 per cent) and lowest in the MGP (0.4 per cent) respectively. Productivity alone contributed one-third to the total output growth in the IGP. The performance of TFP was more impressive during the 1980s than in 1990s. GCA with relatively high TFP growth, which was 42 per cent during 1981-90, declined to 14 per cent during 1991-96. The sustainability issue of the crop sector in IGP is fast emerging; it is more serious in the MGP. The productivity growth attained in 1980s was not sustained in 1990s and this situation poses a challenge for the researchers. The public policies such as investment in research, extension, education and infrastructure (roads, electrification, educational institutions, health facilities, banking, etc.) have been the major sources of TFP growth in the IGP. Preventing a fall in water table will enhance TFP. It is a serious problem at present, particularly in the UGP.

The ecological problems have cropped-up in a large number of districts in the IGP as a result of depletion/pollution of groundwater resources, build-up of soil salinity and waterlogging, nutrient mining, micronutrient deficiencies, deteriorating water quality, formation of subsoil compaction, and increased pest build-up. At the farm level, long-term changes in the biophysical environment have manifested in terms of declining TFP growth. Due to degradation problems, growth in TFP has not made headway across a substantial area in the MGP. The crop system in the North-Eastern Plain, Eastern Plain and North-Bihar Plain warrants a major concern of sustainability. The problems of waterlogging, soil salinity, deteriorating quality of water, etc. are serious in the MGP especially in the North-eastern Plain. One-fourth of the cultivated land in this sub-region is under flood and waterlogging (Singh et al. 2000). The TFP growth in the North-eastern Plain has been ranging from 0 to –2.5 per cent per annum. Nonetheless, there is a huge reserve of potential for raising the yield levels in the MGP and the LGP. It has to be exploited by appropriate technology interventions, judicious use of natural resources and harnessing biodiversity. The high TFP growth of the past in the districts of the LGP may not be sustained if future technological improvements are not supported by public resource allocations to infrastructure, research and development. 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 suitable drainage. 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.

During the green revolution era, large investment on research and development was made in 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, the IGP 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 as also a number of environmental problems.

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). This has resulted in the slow-down in the growth of irrigated area and a sharp decline in the rate of growth of fertilizer consumption. The most serious effect of deceleration in the total investment has been on agricultural research and extension. This trend must be reversed if the projected increases in food and non-food production are to be achieved essentially through increasing yield per unit of land. Recognizing that there are serious yield gaps and that there are already proven paths for increasing productivity, it is very important for India to maintain a steady growth rate in TFP. As TFP increases, the cost of production decreases and the prices will also decrease and stabilize at a lower level. Therefore, 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 their income on cereals than the latter. All the efforts need to be concentrated on accelerating growth in TFP, 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 yield. The districts/sub-regions/regions in the IGP where TFP stagnation or decline has taken place, as identified in the study, must get priority in agricultural research now.

The ratio of amount spent on extension to that on research has been falling (Kumar (2001)). A vast untapped yield potential still exists. 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 should 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 TFP growth, improving the sustainability of the crop sector and in minimising the yield gap in the region.

Research and extension contributed more than 80 per cent to TFP growth. Returns to investment in public research and extension have been highly rewarding. Undoubtedly, further productivity gains in crop output will have to be achieved by more efficient use of inputs and a better natural resource management. The area under modern varieties has already reached a plateau in most of the agro-eco-regions of the IGP. Unless new varieties are evolved, yield breakthrough cannot be realized. Thus, the first priority for crop research ought to be the breaking of the current irrigated yield ceiling. There is an urgent need for intensive and extensive increase in investment to undertake research not only for variety turnover but also for resource management in order to exploit the yield potential of the IGP in a sustainable manner. There is also an urgent need to explore the potential of the LGP. Several ecological problems have also cropped-up as a result of past growth sources. These emerging threats in the irrigated agriculture system call for greater emphasis on research supported by extension, infrastructure and education.

Future agriculture would increasingly be science-led, demanding modern economics management. Literacy has a positive and a significant relation with crop productivity and constitutes a strong link between literacy and farm modernization (Mittal and Kumar (2000)). Efficiency and growth orientation would attract maximum attention; literacy would play a far more important role than it did in the past. High investment in education and skill development in low-growth areas will be a useful approach.

Over-irrigation and alarming rates of groundwater depletion in the IGP have been causing land degradation and other environmental problems. Further, the quality of available water has also 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. Further, institutional changes should focus on achieving greater regional specialization based on the comparative advantage to break the conventional approach of self-sufficiency in every region (Kalirajan and Shand (1997)). These reforms may include the establishment of secure water rights to users, the decentralization and privatization of water management functions up to certain appropriate levels, pricing reforms, markets in tradable property rights, and the introduction of appropriate land and water-saving technologies.

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APPENDIX TABLE 1

REGIONS, SUB-REGIONS AND DISTRICTS FALLING UNDER THE INDO-GANGETIC PLAIN

Agro-Climatic Region	Sub-region	State/District
Trans-Gangetic Plain (TGP) Total Geographical Area = 12.5 million hectare	(a) Foothills of Shivalik	Punjab: Gurdaspur, Hoshiarpur and Rupnagar Haryana: Ambala, Chandigarh
	(b) Plains	Punjab: Amritsar, Kapurthala, Jalandhar, Ludhiana and Patiala Haryana: Kurukhetra, Karnal, Jind, Sonipat, Rohtak, Faridabad and Gurgaon
	(c) Arid	Haryana: Mahendragarh, Bhiwani, Hisar and Sirsa Punjab: Firozpur, Faridkot, Bhatinda and Sangrur Rajasthan: Shri Ganganagar
Upper-Gangetic Plain (UGP) Total Geographical Area = 13.87 million hectare	(a) Central Plains	U.P: Allhabad, Fatehpur, Unnao, Rai Bareli, Lucknow, Sitapur, Sultanpur, Barabanki, Khiri, Pilibhit and Hardoi
	(b) North-Western Plain	U.P: Shahjahanpur, Barli, Rampur, Moradabad, Bijnore, Saharanpur, Muzzafarnagar, Meerut, Ghaziabad, Haridwar and Bulandshahar
	(c) South-Western Plain	U.P.: Badayun, Aligarh, Mathura, Agra, Etah, Farrukhabad, Mainpuri, Etawa, Kanpur
Middle-Gangetic Plain (MGP) Total Geographical Area = 17.03 million hectare	(a) North-Eastern Plain	U.P.: Baharaich, Gonda, Basti, Gorakhpur, Deoria
	(b) Eastern Plain	U.P. : Faizabad, Sultanpur, Pratapgarh, Jaunpur, Azamgarh, Balia, Ghazipur, Varanasi
	(c) Vindhyan	U.P.: Mirzapur
	(d) North-Bihar Plain	Bihar: Paschim Champaran, Poorvi Champaran, Gopalganj, Siwan, Saran, Sitamarhi, Muzzaffarpur, Vaishali, Madhubani, Darbhanga and Samastipur
	(e) North-Eastern Plain	Bihar: Madhepura, Purnia, Katihar, Khagaria, Begusarai and Saharsa
	(f) South-Bihar Plain	Bihar: Bhojpur, Rohtas, Patana, Aurangabad, Nalanda, Gaya, Nawada, Munger and Bhagalpur
Lower-Gangetic Plain (LGP) Total Geographical Area = 6.94 million hectare	(a)Barind Plain	West Bengal: West Dinapur, Malda
	(b) Central Alluvial Plain	Murshidabad, Nadia, Bhardhman, Hoogly, Hawarah and Midnapur
	(c) Coastal Saline Plain	North 24 Parganas, South 24 Parganas, Metropolitan City of Calcutta
	(d) Rorh Plain	Birbhum and Bankura