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Review Article

Agricultural Growth Accounting and Total Factor Productivity in South Asia: A Review and Policy Implications

Praduman Kumar[a]*, Surabhi Mittal[b] and Mahabub Hossain[c]
[a]Former Professor, Division of Agricultural Economics, Indian Agricultural Research Institute, New Delhi - 110 012
[b]Senior Fellow, Indian Council for Research on International Economic Relations, India Habitat Centre, Lodi Road, New Delhi - 110 003. Email: surabhi@icrier.res.in
[c]Executive Director, Bangladesh Rural Advancement Committee (BRAC), Dhaka, Bangladesh

Abstract

Productivity growth in agriculture is essential for the development of the sector. This paper has reviewed the developments in agricultural productivity related to the South Asian countries, namely Bangladesh, India, Nepal, Pakistan, and Sri Lanka. The TFP growth and its contribution in production growth have been summarised for South Asia over the past three decades. Crop-specific TFP growth figures have been updated for India by using more recent micro farm level data for three decades. A discussion and synthesis on changes in TFP and its sources of growth for the major crops, major crop systems, crops and livestock sectors for the countries of South Asia have also been presented. Methodological framework for computation of TFP and its growth has also been presented. Policies towards food-secure South Asia have been outlined under the sub-heads (i) Arresting deceleration in total factor productivity, (ii) Enhancing yield of major commodities, (iii) Accent on empowering the small farmers, (iv) Environment protection, and (v) Strenghtening of national agricultural research system. This paper would provide useful information to the people intrested in doing research on these issues. Some of the concerns raised in this paper on productivity would provide direction for future research in this area.

1. Introduction

South Asia, comprising Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka has high population pressure on land and other natural resources to produce food and meet other developmental needs. South Asia houses 22 per cent of the world population on 3 per cent of the land area. Half of the land area of South Asia is under arable and permanent crops, while in the world as a whole only 11 per cent of the total land area is under arable land and permanent crops. In spite of land constraint, South Asian countries have made remarkable progress in food production during the past three decades, transforming the region from a food-deficit to a food self-sufficient region. This could occur due to developments in agricultural research and effective dissemination of research output. These changes have been triggered by the Green Revolution in South Asia, involving the development and diffusion of high-yielding varieties (HYVs), especially of rice and wheat, from the mid-1960s. This has been accompanied by use of increased levels of inputs, particularly irrigation, fertilizers and tractors, and of policy support. Government investment in infrastructure, research and extension, price and other policies along with strategies for crop, livestock and fisheries production have significantly helped to increase food production and its availability. Notwithstanding these achievements, producing

* Author for correspondence,
Email: pkumariari@rediffmail.com

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 South Asian countries. At the same time, the food consumption pattern has been changing with wider availability of food choices, sustained economic growth and increasing urban population. Such changes in the consumption pattern are likely to influence the crop choice, production, productivity, prices, international trade and environment. This calls for an examination of the changes in the agriculture productivity and future sources of agricultural growth accounting.

In the past, major sources of growth in agricultural production were area and yield. However, the future growth has to be essentially driven by increase in yields. The evidence is that rapid growth in public investment in irrigation and other infrastructure, research and extension along with crop production strategy and policy support have helped to expand yield and agricultural production.

The slackness in investment on agricultural research and technology development as seen during the early-1990s, is a matter of concern in the context of continued increase in population, diminishing land and fresh water resources, expanding biotic and abiotic stresses, increasing soil salinity and waterlogging problems, and decelerating productivity growth in the recent past, particularly in India which accounts for roughly three-fourths of the sub-region's economy. On account of these factors, South Asia may experience a deficit in agricultural production to match its domestic need for most of the food commodities. India is the major producer and consumer of food in the South Asian region and possesses huge potential that remains highly under-realized. Therefore, India has to play a major role not only to maintain its own self-sufficiency in food production but also to meet the additional requirement of its neighbouring countries. However, much of the additional food demand in the next decades needs to be produced domestically, and the rate of total factor productivity (TFP) growth will be crucial in obtaining the necessary growth in food production. The right research priorities and production strategies will promote future growth in agriculture and ensure sustainable food and nutritional security. This calls for a review of the productivity performance, sources of production growth, and policy needs in the next 10-15 years in South Asia.

2. Conceptual Framework

Productivity growth in agriculture is both a necessary and a sufficient condition for its development and has remained a serious concern for intensive research over the past 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. The economists have computed agricultural productivity and have examined its growth over time and their differences among countries and regions. Productivity growth is essential to meet the food demand arising out of steady population and economic growth. TFP is a simpler concept than that of technological change and is, therefore, the most common measurement of technical progress.

Technical progress has two components: technical change and improvement in technical progress. The former represents improvements in best production practices, while the latter occurs when actual production practices move closer to the existing best practice. Substantial scope exists for raising TFP by enhancing the technical efficiency. Yanrui (1995) had demonstrated that technical efficiency in the state industry, rural industry and agriculture in post-reform China was 50 to 60 per cent between 1985 and 1991. Technical progress also appears to be more endogenous in nature and its important determinants are factors like human capital, infrastructure, vintage of capital, research and development (R&D) investments, technology purchase expenditures, extent of exposure of foreign competition, education level, learning by doing, etc. This has important implications on the strategy which need to be adopted for raising the TFP.

Relative sectoral growth rates of productivity are important determinants of structural transformation of economics, and the rate of growth of productivity in the industrial (Kuznets, 986) and agricultural

(Evenson and Jha, 1973) sectors has been put forward as a key variable. As pointed out by Lewis (1978), productivity is the 'engine of growth' in the long-run. Technological advancement has been a major contributing factor to economic growth. Since publication of the pioneering works of Schultz (1953), Solow (1957), and Griliches (1964), voluminous literature dealing with the measurement and analysis of productivity at different levels of aggregation has appeared. Three approaches for the measurement are most representative:

(i) 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) Accounting approach which approximates the technological change by the computation of factor productivity indices, mainly the rate of change of total factor productivity indices (Christensen, 1975); and

(iii) A more 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 technological change using linear programming. Data Envelopment Analysis (DEA) falls under this category. DEA is a linear-programming methodology, which uses data on the input and output quantities of a group of countries to construct a piece-wise linear production frontier for each year over the data points. Coelli and Rao (2003) used this approach and constructed the Malmquist TFP index for agriculture using FAO database of 93 countries, covering the period 1980-2000. However, the accounting approach is more popular because it is simple to calculate, requires no econometric estimations and data requirement is minimal. The use of TFP indices gained prominence since Diewert (1976, 1978) proved that Theil-Tornqvist discrete approximation to the Divisia index was consistent in aggregation and superlative to a linear homogeneous trans-logarithmic production function.

2.1. Total Factor Productivity Measurement

The increased use of inputs, to a certain extent, allows the agricultural sector to move along the production surface. The use of modern inputs may also induce an upward shift in the production function to the extent that a technological change is embodied in them. TFP measures the extent of increase in the total output, which is not accounted for by increases in the total inputs. TFP is defined as the ratio of an index of aggregate output to an index of aggregate input. One of the most defensible methods of aggregation in productivity measurement is Divisia aggregation. Divisia indices have two important attractive properties: (i) they satisfy the time reversal and factor reversal tests for index numbers, and (ii) it is a discrete of the components, so that aggregate could be obtained by the aggregation of sub-aggregates. For discrete data, the most commonly used approximation to the (continuous) Divisia index is the Tornqvist approximation. The DivisiaTornqvist or translog index of TFP is commonly used for computing the total output, total input and TFP indices by commodity/farm system/sector, etc. under different locations as outlined below:

Total output index (TOI)

$$TOI_t / TOI_{t-1} = \prod_j (Q_{jt} / Q_{jt-1})^{(R_{jt}+R_{jt-1})^1/2} \quad \ldots(1)$$

Total input index (TII)

$$TII_t / TII_{t-1} = \prod_i (X_{it} / X_{it-1})^{(S_{it}+S_{it-1})^1/2} \quad \ldots(2)$$

where,

R_{jt} is share of the 'j' th output in total revenue,

Q_{jt} is output of the 'j' th commodity,

S_{it} is share of the 'i' th input in total input cost,

x_{it} is quantity of the 'i'th input, and

t is the time period.

For the productivity measurement over a long period of time, chaining indexes for successive time periods is preferable. With chain-linking, an index is calculated for two successive periods, t and t-1, over the whole period 0 to T (sample from time t=0 to t=T) and the separate indexes are then multiplied together:

TOI (t) = TOI (1).TOI(2)………………TOI(t-1) …(3)

and

TII (t) = TII (1).TII(2)………………TII(t-1) …(4)

Total factor productivity index (TFP) is given by Equation (5):

$TFP_t = (TOI_t / TII_t)$ …(5)

Chain-linking index takes into account the changes in relative values/costs throughout the period of study. This procedure has the advantage that no single period plays a dominant role in determining the share weights and biases are likely to be reduced. The above equations provide the indices of total output, total input, and TFP for the specified year 't'.

TFP trend indicates whether production growth was taking place in a cost-effective and sustainable manner. While growth in output can be achieved by using higher and higher level of inputs, this may not be sustainable in the long-run if incremental output involves increasing doses of incremental inputs. The sustainable growth in the long-run necessitates faster growth in output than inputs. It serves as an excellent indicator of the performance of any production system and sustainability of the growth process. It overcomes the limitations of partial input productivity measures as well as partial output productivity, especially when the production of one activity affects the production of other activities.

TFP is influenced by changes in technology, institutional reform, infrastructure development, human resource development and other factors. The crop-related technological changes that are often embodied in seed adoption by the farmer can be divided into two components: the "quality" and the "quantity". The former represents productivity improvement and cost reduction, while the latter is the extent of area on which the farmer adopts the technology. The "quality" reflects the research output that is determined by investment in R&D and is an exogenous variable in explaining TFP. The "quantity" of technology is linked to its adoption and is affected by the extension, literacy, infrastructural development, as well as on-farm and off-farm characteristics.

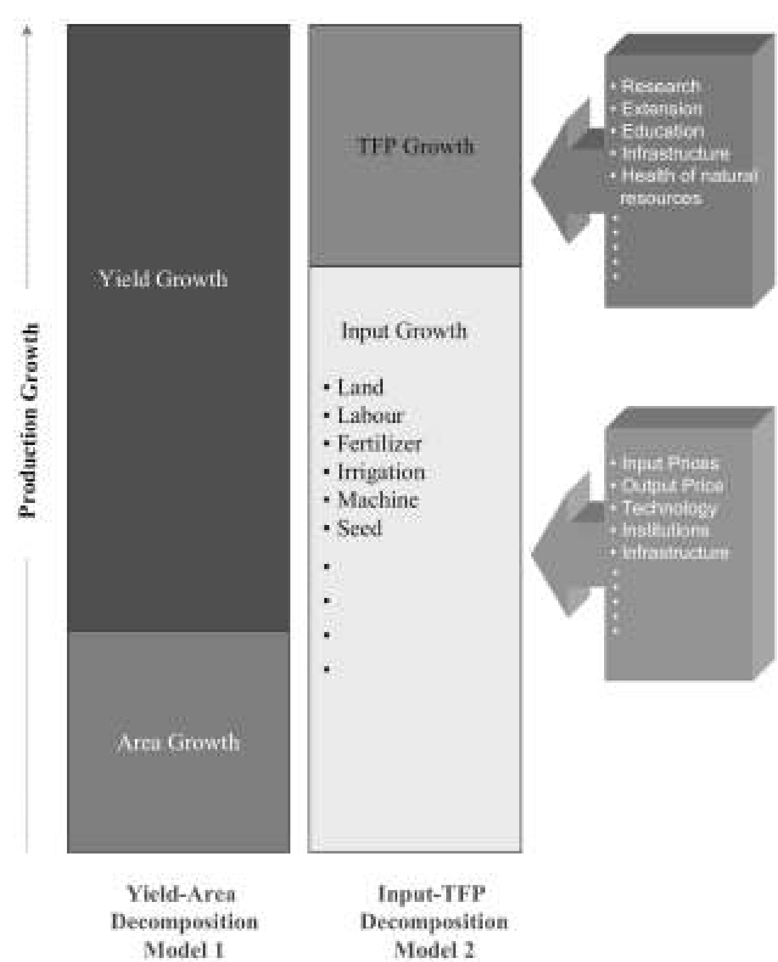
TFP is an important measure to evaluate the performance of any production system and sustainability of the growth process. However, a number of complex conceptual issues are not adequately captured by an analysis of the kind described earlier. First, for example, research in agriculture has contributed to the breaking of the seasonal barrier in crop production, and to a large extent, the shift in acreage has also been driven by research. 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 others contributions are subsumed under a residual TFP measure. It would be worthwhile to capture these influences explicitly, which would lead to a more realistic assessment of the productivity of crop research, otherwise we may continue to underestimate research contribution.

2.2. Production Growth Model

Decomposition of growth in agricultural output in India has remained of active interest to 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 by Minhas and Vaidyanathan (1965). Later, work on the decomposition of growth in agricultural output became more refined and invoked the 'partial productivity' concept. Studies by Evenson and Jha (1973) and later 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 listed in the text on this genre. Production growth accounting concept, which attributes the growth in TFP to that part of growth in output which cannot be

Box 1

Production Growth Models



Source: Kumar *et al*. (2004)

explained by growth in factor inputs has been illustrated in Box 1 through diagram.

In the 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 the growth in land is the main source of output growth. This was the situation till 1960s. Subsequently, as technological change and other (non-land) inputs become more important, an alternative approach is necessary. The 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, the second version is more comprehensive and easy to understand the measurement of TFP.

The sources of growth in TFP in agriculture can be understood through TFP decomposition analysis by following the multiple regression framework using pooled cross-section time series data with

Table 1. Empirical studies on TFP (Tornqvist index) of agriculture in Bangladesh

Author(s)	Commodity	Period	Total factor productivity	
			Annual growth (%)	Share of TFP in output growth (%)
Dey and Evenson (1991)	Crops	1952-71	0.72	32.1
		1973-89	0.96	46.2
	Rice	1952-71	0.98	43.4
		1973-89	1.15	61.8
	Wheat	1952-71	0.93	18.3
		1973-89	0.83	10.9
Coelli and Rao (2003)	Crops and livestock	1980-00	0.90	NA
Avila and Evenson (2004)	Crops	1961-80	-0.23	Negative
		1981-01	1.06	49.3
	Livestock	1961-80	0.75	42.9
		1981-01	2.65	71.8
	Crops and livestock	1961-80	-0.01	Negative
		1981-01	1.3	54.8

NA- Not available

correction for serial correlation and heteroskedasticity (Kmenta, 1981). The public investments in research, extension, infrastructure, human capital along with production strategies induced productivity are included in the analysis and important (location-specific) factors in boosting TFP of the commodity have been identified.

3. South Asian Experiences on TFP Studies

In this section, the paper reviews the recent literature on agricultural productivity related to the South Asian countries, mainly Bangladesh, India, Nepal, Pakistan, and Sri Lanka. TFP growth and its contribution in production growth have been summarised for South Asia over the past three decades, based on the results of major available studies. Crop-specific TFP growth figures have been updated for India by using more recent micro farm level data for three decades. A discussion and synthesis on changes in TFP and its sources of growth for the major crops, major crop systems, crops and livestock sectors for the countries of South Asia have also been presented. In most of the studies, Tornqvist-Theil index (a discrete approximation to the Divisia index) has been used for the computation of TFP.

3.1. Bangladesh

Agricultural policies and projects in Bangladesh have expanded the use of high-yielding variety of rice seeds, fertilizers and shallow tube-wells for irrigation. Diffusion of HYV technology remained slow during the early-1980s. Irrigation coverage increased dramatically from 22.5 per cent in 1980-81 to 51.5 per cent in 2000-01. This has happened due to the private sector participation to invest in minor irrigation. Rice production increased with an annual growth rate of about 3 per cent during 1990s and the overall economy improved from 3.5 per cent GDP growth per year during 1971-80 to 4.8 per cent during 1991-2000. Very few studies have assessed the breakdown of agricultural output growth into factor accumulation and TFP (Table 1).

Dey and Evenson (1991) had estimated the TFP growth for rice at 0.98 per year for the period 1951-71 and a little higher (1.15 per cent) during 1973-89, the era of use of HYVs. The contribution of TFP to agricultural output growth was 40-60 per cent, which was quite high. For wheat crop, TFP growth rate was estimated at 0.93 per cent per year during the period 1952-71 and 0.83 per cent during 1973-89. It has contributed only 11 - 19 per cent in the growth of wheat production. For the crop sector, TFP growth rate was 0.72 per cent during the period 1952-71, which slightly improved with the adoption of HYVs and improvement in irrigation infrastructure. It is noteworthy that TFP growth for the crop, livestock and total agriculture sector had been accelerated and attained a level higher than 1 after 1980-81 and the technology contributed nearly half to this output growth (Avila and Evenson, 2004). Coelli and Rao (2003) have reported the TFP growth rate as 0.9 per cent per year during 1980-2000. The technological progress in Bangladesh remained satisfactory as compared to other countries in South Asia and this had happened even after relatively low investment in research, rural infrastructure, and extension by the government. However, accelerating growth in TFP productivity had occurred due to increase in the irrigated area as a result of policy change and private investment in minor irrigation. Evidence of slow TFP growth was not observed in the review, as was reported by Rosegrant and Hazell (2000, p. 149).

3.2. India

A comprehensive analysis of agricultural performance and productivity of Indian agriculture by Kumar (2001) has revealed that the changes in cropping pattern have been taking place as a result of substitution of low-productivity crops by those which have shown impressive performance in productivity growth. Some of these crops are paddy, wheat, maize, groundnut, rapeseed and mustard, and sugarcane. Coarse cereals and pulses have shown a steady decline in their area. Decomposition of output growth analysis into its sources of growth has revealed that most of the increase in output was due to yield growth (Table 2). Changes in the cropping pattern had contributed to output growth considerably. About 58 per cent increase in crop area was due to substitution effect and 42 per cent was due to expansion effect. Regional pattern in crop specialisation was increasing. The contribution of area to the incremental output had declined. Future source of food supply would be the enhancement of yield through technological change.

A number of studies on the measurement of TFP and its sources of growth have been carried out for India (Table 3). These studies have been reviewed for the agriculture sector for crops and livestock at aggregated level and at disaggregated level by crops.

Table 2. Growth accounting in crop output in India

(Per cent)

Sources of growth	1967-96	1967-81	1982-96
Area	10.4	20.7	7.7
Yield	50.3	48.4	57.4
Cropping pattern	19.0	20.1	21.9
Total individual effects	79.7	89.3	87.0
Area and cropping pattern	2.3	1.4	1.1
Area and yield	6.1	3.4	2.8
Yield and cropping pattern	10.5	5.6	8.7
Area, yield and cropping pattern	1.3	0 .4	0.4
Total interaction effects	20.3	10.7	13.0

Source: Kumar (2001)

A comprehensive crop-specific TFP analysis was done by using the micro farm level data for all the major crops grown in the states of India covering the 30-year period from 1970-71 to 2000-01. The TFP analysis for two periods, viz. 1971-1986 and 1986-2000, has been presented in the subsequent sections.

3.2.1. Agriculture Sector

Indian agriculture has made substantial gains in productivity with the introduction of high-yielding varieties, as measured by indexes of TFP (Rosegrant and Evenson, 1992; Dholakia and Dholakia, 1993; Evenson *et al.,* 1999, Fan *et al.,* 1999). The studies have shown that the TFP growth in agriculture has been the prime deriving force behind the acceleration of overall growth in the Indian economy achieved during the 1980s (Table 3). Evenson *et al.* (1999) have analysed the trends and sources of TFP growth in the crop sector of India. The TFP annual growth, estimated as 1.1-1.4 per cent since 1956, had contributed about half of the output growth. According to this study, public agricultural research had accounted for nearly 22 per cent of TFP growth in the years 1956-65 and increased its contribution to 41 per cent in the years 1977-87 (Table 4). In addition to the highly significant impact of public and private research and extension, a number of other investment variables (literacy and markets) had a strong positive effect on the TFP growth. For example, the number of markets, as proxy for

Table 3. 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	1.1	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
	Crop and livestock	1961-80	1.92	78.7
		1981-01	2.41	80.3
Joshi *et al*. (2003)	Rice (IGP)	1980-90	3.5	
		1990-99	2.08	
	Wheat (IGP)	1980-90	2.44	
		1990-99	2.14	

IGP: Indo-Gangetic Plains. NA: Data not available

Table 4. Sources of TFP growth in Indian agriculture: 1956-87

Sources	Share of TFP growth, %			
	1956-65	1966-76	1977-87	1956-87
High-yielding varieties	0.0	25.3	3.9	8.5
Public research	21.5	22.7	40.9	29.2
Private research	6.7	22.3	6.9	11.0
Extension	67.0	20.4	43.0	45.1
Literacy	0.7	0.8	0.7	0.8
Markets	4.2	8.5	4.5	5.5

Source: Evenson *et al*. (1999)

infrastructure and irrigation, had a large positive impact on productivity above and beyond its value as an input. The estimated effect of literacy was positive, showing the impact of human capital development on productivity growth.

The contribution of private sector research and development was significant. It accounted for about 11 per cent of the TFP growth during 1956-87. Removal of policy constraints on the private-sector research could make large payoffs. McKinsey and

Table 5. Effect of additional government expenditure on agricultural productivity in India

Sources of growth	TFP elasticity	Marginal impact of spending Rs 100 billion at 1993 prices
Research & Development	0.296* (1)	6.98* (1)
Irrigation	0.034* (4)	0.56* (3)
Road	0.072* (2)	3.03* (2)
Education	0.045* (3)	0.43* (4)
Power	0.0007 (5)	0.02 (5)

Note: Numbers within the parentheses are ranks. * Denotes significance at 5 per cent level
Source: Fan *et al.* (1999)

Evenson (2003) have analysed the impact of crop genetic improvement on Indian agriculture and observed that the productivity impacts of state research, private research, extension, and market development were positive. Extension and market development would not have made large impacts in the absence of modern varieties. Extension is productive when the extension service has new technology to extend. Similarly, the improvement of markets is important as it facilitates adoption and diffusion of modern varieties. The role of each sources of growth is complementary.

Fan *et al.* (1999) have computed TFP for the agriculture sector of India and its different states for the period 1970 to 1995. Five major crops (rice, wheat, sorghum, pearl millet and maize), 14 minor crops (barley, cotton, groundnut, pulses, potato, rapeseed, mustard, sesame, sugar, tobacco, soybean, jute, sunflower and others minor crops), and 3 major livestock products (milk, meat, and chicken) were included in the measurement of output index. Five inputs (labour, land, fertilizer, tractor, and buffalo) were included in the measurement of input index. It was found that TFP for India grew at an average annual rate of 1.75 per cent. During the 1970s, the TFP growth rate was 1.55 per cent, but it grew faster during the 1980s at 2.52 per cent per year. Since 1990, the TFP growth in Indian agriculture has continued to grow at a rate of 2.3 per cent per year which is slightly lower, but is still at a high level. The TFP growth in agriculture was the prime driving force behind the acceleration of overall growth in the Indian economy achieved during 1980s. Modern inputs such as HYV seed, fertilizer and irrigation had raised the TFP growth in Indian agriculture. Rapid adoption of new technologies and improved rural infrastructure had also induced productivity growth. Table 5 shows that the government spending on productivity-enhancing investments (especially agricultural research and extension), rural infrastructure (especially roads and education), and rural development had targeted directly to the rural poor, and these all contributed to the growth in agricultural productivity.

Avila and Evenson (2004) have utilized FAO published data on cropland, pastureland, human labour, fertilizers, seeds, tractors and combine harvesters and animal stocks for measuring the changes in TFP for crop production, livestock production and aggregate agricultural production in India for two periods, 1961-1980 and 1981-2001. Use of modern varieties, increase in the years of schooling of labour force, and enhances in the dietary energy were reported as sources of TFP growth in this study. The contribution to TFP growth was maximum of modern varieties (64 per cent), followed by years of schooling (22 per cent) and nutritional security (14 per cent). But, due to the limitation of data on factor shares, the TFP growth rates seem to be on a higher side.

The structural shift in consumption towards milk, meat, and poultry has accelerated the growth of livestock sector. At the all-India level, maximum increase in livestock production had occurred due to increase in the productivity. Birthal *et al.* (1999) have analysed the trend in TFP growth for the livestock sector in India. The livestock output was found to grow at a rate of 2.6 per cent per year over the period 1950-51 to 1995-96. The input index increased with annual growth of 1.8 per cent and TFP grew at about 0.8 per cent. Thus, technical change had contributed about 30 per cent to the overall growth over the past 45 years. Period-wise results have been more revealing. There was little growth in TFP 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 level 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 an accelerating growth in the livestock TFP at the rate of 2.7 per cent per year during the period 1981-01, contributing 69 per cent to the total livestock output growth.

3.2.2. Crop-specific Studies

These studies have been focussed largely on the estimation of effect of technological change on agriculture as a whole or total crop production. Due to non-availability of input allocation data for individual crops, this may over- or under-estimate the TFP for 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[1] in India, quite a few crop-specific TFP studies have emerged since 1992 (Pinstrup *et al.,* 1991; Sidhu 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 TFP results on the irrigated agro-ecosystem and disaggregated crop-specific TFP computed by the authors by using the long-term cost of cultivation data from 1970-71 to 2000-01 for different states of India, have been summarized in the subsequent section.

The Indo-Gangetic Plain (IGP) belongs to the irrigated agro-ecosystem and is the major production zone for both rice and wheat in not only India but the entire South Asia. It is the mainstay of India's agricultural economy, sharing 38 per cent of the net sown area and contributing more than 50 per cent to the total foodgrains production in India. Food grain production in this system has increased more than four-times, from nearly 24 million tonnes in 1950-51 to 107 million tonnes in 2000-01. The IGP is dominated by the rice-wheat cropping system (RWCS) with rich resource endowment and most fertile soil. It became popular during mid-1960s with the introduction of short-duration and high-yielding varieties of rice and wheat. Steep increases in the area and production of rice and wheat in IGP were achieved during the 'green revolution' period of the 1960s and 1970s. The system has made a significant historical contribution in making India a food-secure and self-sufficient nation. More than 75 per cent of the total food grain was procured from this system till the mid-1990s in the country (Kumar *et al.*, 1998). It is characterized as the backbone of the public distribution system and a strong base for the food security of the country.

A comprehensive productivity analysis in the irrigated agro-ecosystem concentrated in the Indo-Gangetic Plains (IGP) was carried out by Joshi *et al.* (2003) for the rice and wheat crops. The TFP growth of rice and wheat in the IGP has been found quite impressive during the past three decades, 1970-1999. The annual compound growth rate of TFP was 2.43 per cent for rice and 2.99 per cent for wheat during this period. The contribution of TFP to output growth was 56 per cent in rice and 70 per cent in wheat. This shows that technology played a key role in increasing the rice and wheat output in IGP.

On disaggregating the TFP growth in different time periods, it was observed that, by and large, it was quite high during the 1980s and was decelerated during the 1990s, but it was still more than 2 per cent for both rice and wheat crops. TFP was the major source of their output growth because the input growth was completed exhausted in the IGP. Contrary to the perception, the results showed that the intensification of input had ceased in the IGP for both rice and wheat during the 1990s, but their efficiency had increased, as was indicated by the rising TFP. The trend was observed after mid-1990s, when efforts were made to use resources more efficiently and judiciously. The public policies such as investment in research, extension, education and infrastructure (road, electrification, educational institutes, healthcare facilities, banking, etc.) have

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

Table 6. Sources of total factor productivity growth in the Indo-Gangetic Plains of India: 1980-96

Sources	Annual growth rate (%)	Elasticity of TFP	Share of TFP 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
Urbanisation	0.60	0.14770	1.5

Source: Kumar *et al*. (2004)

been the major sources of TFP growth in the IGP (Table 6). Preventing fall in watertable would enhance TFP but fall in watertable is a serious problem at present in the Upper Gangetic Plains (UGP).

Sustainability of rice-wheat cropping system (RWCS) in IGP is critical for the country's public distribution system (PDS) and food security. This crop system is predominant in the states of Punjab, Haryana and Uttar Pradesh, where the birth of Green Revolution had taken place. The use of modern inputs like adoption of high-yielding varieties, irrigation, chemical fertilizers, pesticides, etc. has reached a very high level in the IGP. The organic sources of nutrients like organic manure and legume are rapidly declining in the RWCS. A higher growth in yield and production of the RWCS can only be achieved through a better management of the existing soil and water resources. Legumes fix nitrogen from the atmosphere, improve soil fertility, and conserve water. Analysis of TFP growth showed that substitution of rice by legumes saved as much as 75 per cent of soil nitrogen, and 95 per cent of water used for irrigation (Joshi *et al.,* 2000). Application of chemical fertilizers met the needs of nutrients, but their imbalanced use has led to soil fertility related problems. Legumes can overcome such problems, provided they are remunerative compared to rice and wheat. In this context, high-yielding and short-duration pigeon pea, lentil as para cropping, disease-resistant chickpea and groundnut varieties have potential to augment income, save water and improve soil fertility status. There are evidences that legumes contributed to the increasing of TFP of RWCS in the IGP (Kumar *et al*., 1998). However, there are inherent constraints in cultivation of legumes: high yield-risks, fluctuating prices, and uncertain and thin markets. To promote legumes in the RWCS, high-yielding, more-stable and disease-resistant varieties need to be developed and introduced.

During the decade of 1990s, increasing trends in TFP growth for rice and wheat were observed. Adoption of modern varieties, investment in irrigation, infrastructure and research, and favourable input pricing policies appear to have lowered the unit cost, mainly of rice and wheat production and benefited both consumers and producers. Research, extension, literacy, rural electrification and irrigation are the most important instruments of growth in TFP (Table 7). For rice, rural electrification has accounted for about half of the TFP growth, followed by public research (20 per cent) and literacy (12.9 per cent). In the case of wheat, public research had accounted for about half of the TFP growth, followed by tubewell irrigation (36 per cent), and rural electrification (6.8 per cent). During the liberalized economic environment, farm situation has been characterized by reduction in farm labour, higher use of fertilizer and mechanisation. This has been improving the efficiency and productivity in Indian agriculture. Under the liberalized economic environment, efficiency and growth orientation would attract maximum attention.

A perusal of TFP growth at the aggregate level, given in Table 8, gives a strong perception that (a) technological gains had not occurred in a number of crops, notably coarse cereals, pulses, oilseeds, fibres,

Table 7. Sources of TFP growth in cereals in India: 1971-1995

Sources	Share of TFP explained, %			
	Rice	Wheat	Sorghum	Maize
Research	20.0	54.5	26.6	57.9
Extension	7.3	1.0	16.8	0.4
Literacy	12.9	0.0	26.6	0.0
Electrification	47.3	6.8	30.0	21.8
Irrigation	12.5	1.9	0.0	19.9
Tubewell	0.0	35.7	0.0	0.0

Source: Kumar (2001)

sugarcane, vegetables, etc. during the 1990s, and (b) crops and areas where these gains had occurred during the early years of green revolution, have exhausted their potential. To validate this observation, the authors had undertaken the analysis with more disaggregated perspective on changes in output, input and in TFP for major crops across the states of India, based on a more recent micro-farm level data covering the period 1971-72 to 1999-00. The results, presented in Appendix Ia for 1971-1986 and Appendix Ib for 1987-2000, revealed that all the crops had benefited from technological changes in some parts of the country, but there were some exceptions in pulses and oilseeds, wherein only a few states had performed well. Several states have recorded positive TFP growth. Paddy and wheat which are the major staple food crops, performed well in the productivity gains. However, TFP of paddy has already started showing deceleration in Haryana and Punjab, but TFP of wheat is still growing in these two green-revolution states. All the eastern states of India had shown improvement in TFP of paddy after the mid-1980s. 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 (Table 9). However, the area under stagnant TFP growth for paddy has declined from 31 per cent in 1971-1986 to only 15 per cent in 1987-2000. Even for wheat crop, the stagnated TFP growth area declined from 10 per cent in 1971-1986 to 3 per cent in 1987-2000.

The farmers growing rice-wheat had benefited with the modern varieties of the green revolution. The coarse cereals experienced more than one per cent TFP growth on 71 per cent of the total crop area during the1980s, which declined to 30 per cent during the 1990s, and about 60 per cent of the area is facing stagnated growth in TFP. Similarly, the productivity gains occurred for pulses and sugarcane during the early years of green revolution, have exhausted their potential. About 70 per cent area under pulses and 90 per cent area under sugarcane during 1990s was facing stagnated TFP status. 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 had generally pervaded the entire crop sector. There are, of course, crops and states where technological stagnation or decline is apparent and these are the priorities for the present and future agricultural research.

3.3. Nepal

Nepal is characterized by difficult agro-climatic environment; moreover, the limited funding available for research in Nepal was misallocated, with a heavy emphasis on crops that contributed relatively little to the total area or value of production, like tobacco and sugarcane (Thapa and Rosegrant, 1995). The priority setting in agriculture in Nepal must be guided by three principal objectives, namely (i) sustainable economic growth, (ii) poverty alleviation, and (iii) reduction in regional imbalances. However in the past, too many priorities depending on donor interest and the populist slogan of the government resulted in many projects. The available resources were scattered and failed to show any significant impact on the use of modern inputs, yield growth and overall economic growth in the country. A respectable TFP growth was reported by Avila and Evenson (2004) for the period 1980-2000 for crops (2.4 %), livestock (1.1 %) and both crop and livestock (2.1 %). Coelli and Rao (2003) have found that the TFP grew at the rate of 0.5 per cent per year for the combined crops and livestock sector in Nepal during the period 1980-2000 (Table 10). Low yield with traditional input-base will not be conducive to the economic growth even if impressive TFP growths were estimated by the researchers. Higher investments in agricultural research, and rural infrastructure are needed and priorities of research investment need to be shifted from crop to the livestock and horticultural sectors for a steady growth of agriculture and for providing livelihood to 93 per cent of the total labour force dependent on agriculture.

3.4. Pakistan

The introduction of green revolution technologies in wheat and rice in Pakistan during the mid-1960s witnessed a phenomenal growth in their productivity and produced impressive results in reversing the food crises and stimulating the agricultural and economic growth. The growth rate of Pakistani economy had plummeted from over six per cent during the decade of the 1980s to just over

Table 8. 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
	All-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
	All-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
	All-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
	All-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
	West	1971-86	5.52	5.38	-0.14	Negative
		1986-00	7.44	8.13	0.69	8.49

Contd

Table 8. 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
	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
	All-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
	All-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
	All-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
	All-India	1971-86	0.97	3.56	2.59	72.70
		1986-00	6.64	6.45	-0.19	Negative

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

Table 9. Distribution of crop area according to TFP growth in India during 1971-00

(Per cent share of crop area)

Crop	Period	Stagnation in TFP growth	< 1% TFP growth	> 1% 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

Table 10. Empirical studies on TFP (Tornqvist index) of crops and livestock sector in Nepal

Author(s)	Commodity	Period	Total factor productivity	
			Annual growth (%)	Share of TFP in output growth (%)
Coelli and Rao (2003)	Crops and livestock	1980-00	0.50	NA
Avila and Evenson (2004)	Crops	1961-80	0.2	13.2
		1981-01	2.42	66.1
	Livestock	1961-80	1.36	51.3
		1981-01	1.11	48.5
	Crops and livestock	1961-80	0.5	27.0
		1981-01	2.1	64.4

NA: Not available

four per cent during the 1990s. However, questions are now being asked about the sustainability of high use of external inputs and productivity. Degradation of natural resource base due to intensive use, over the long-term, may contribute to the declining productivity growth rates. Little emphasis has been placed on the impact of changes in TFP on the overall growth of crop and livestock sectors in Pakistan. Fewer compressive studies have been undertaken to quantify the trend in TFP in Pakistan on the overall growth of crop and livestock sectors and sources of TFP growth accounting (Ali and Byerlee, 1999; Coelli and Rao, 2003; Avila and Evenson, 2004). These studies have addressed the critical issues of long-term productivity and sustainability of irrigated agriculture of Pakistan's Punjab province which is the agriculturally-dominant province in the country, with a farming population of over 60 million people, and is often described as Pakistan's food bowl.

The TFP analysis of crops and livestock has been done covering a long-term period 1966-94[2]. The overall growth in TFP was 1.26 per cent and 1.25

per cent per annum for crops and livestock, respectively, contributing about one-third to the output growth. TFP was negative during the early period of green revolution till 1974. Thereafter, an accelerating growth was observed in TFP for both crop and livestock sectors. The contribution of technology to output growth had attained a level of more than 50 per cent by the year 1994. There were no significant technological innovations in the livestock as in the case of crops but the improved fodder supply, substitution of milk animals for draught animals, and the one-time slaughter of draught animals, could explain this jump in TFP. However, these sources of livestock productivity may not be available in the future. The combined TFP of crop and livestock grew at the rate of 1.51 per cent per year, higher than that for the crop or livestock sector alone.

The decomposition of total change in the crop sector in Punjab (Pakistan) during 1971-94, given in Table 11, revealed that deterioration in soil and water quality had a negative impact on the TFP growth. Cropping intensity, adoption of modern varieties of wheat, public investment on roads and literacy were found to be the major sources of TFP growth for crops. The deterioration in the health of agro-ecosystem, depicted by the declining trend in the resource stock variables, is in itself a cause for concern. Degradation in soil and water quality tends to drag the TFP growth and needs to be checked for long-term sustainability. Improvement in human and physical infrastructure will help in productivity improvement.

Pasha *et al.* (2002) have also found an accelerated TFP growth in the agriculture sector (crops and livestock) of Pakistan in different Plan periods. It had grown at an annual rate of 2.7 per cent in the Fifth Plan Period (1977-78 to 1982-83). With a slight drop in the Sixth Plan (1.9%), it again picked up to a level of 2.7 per cent in the Seventh Plan Period and attained the peak of 4.2 per cent in the Eighth Plan period (1992-93 to 1997-98). In the growth accounting analysis of TFP growth, a number of explanatory variables were considered. Human capital (which was measured by the average number of years of schooling of employed persons in agriculture); physical infrastructure (transport and communication, energy, etc. was captured by the real public sector development expenditure), non-factor inputs (fertilizer, water, etc.), and cotton yield were included in the model. Human capital explained three-fourths of the TFP growth in agriculture. An accelerating growth of TFP in the livestock and total agriculture sectors was also reported by Avila and Evenson (2004) in their analysis covering the periods 1961-80 and 1981-01. In the crop sector, TFP growth rate was computed to be 1.48 per year and which slightly slowed down during the period 1981-01. Declining public investments in the agricultural research during 1990s in Pakistan could be a

Table 11. Decomposition of the total change in the crop sector productivity in Pakistan's Punjab during 1971-94

Sources	Crop sector TFP
Soil and water quality deterioration	
Water electro-conductivity	-0.0073
Soil phosphorous	-0.0487
Soil organic matter	-0.1374
Total soil soluble salts	-0.0265
Other factors	-0.3140
Total	-0.5343
Technological change	
Cropping intensity and modern varieties of wheat	0.4970
Public investment	
Road and literacy	0.4434
Net effect	0.4061

Source: Ali and Byerlee (1999).

[2]The outputs were valued at farm-gate harvest prices. Input for the crop sector included land, labour, water, machinery (separately for tractor, thresher and harvester), bullock, fertilizer (separately for nitrogen, phosphorus, and potash), and pesticide (separately for aerial and ground spray) costs, and for the livestock sector, labour, fodder and feed, and interest and maintenance costs (shed, medicine) and other costs. All inputs were converted to flow values. Land was evaluated at its rental value. Labour stocks were converted into a flow variable by multiplying the stock value with a year- and gender-specific participation rate (number of days labour used in agriculture in a year), based on household survey data collected annually by the Punjab Economic Research Institute.

probable cause for the slowing down of crop TFP growth. Green revolution modern varieties, increase in years of schooling of labour force, and enhances in dietary energy were identified as sources of TFP growth.

3.5. Sri Lanka

Despite high irrigation infrastructure, the agricultural growth in Sri Lanka was the lowest among the South Asian countries. The agriculture economy faltered for a number of reasons. First, the country's ongoing civil conflict, which escalated after 1983, diverted public resources and discouraged foreign investments. Second, bad weather, including periodic droughts, hampered the agricultural production and exports. Third, the stabilization policies aimed at containing the fiscal deficit and controlling the inflation, suppressed demand and slowed the economic growth. TFP growth rates and its share in output for crops and livestock sectors have been given in Table 12.

In Sri Lanka, a negative or stagnated TFP growth was caused due to low R&D investments and negative rates of growth in agricultural research expenditures during the 1980s and the intensive civil war (Coelli and Rao, 2003; Avila and Evenson, 2004). Some important policy reorientations such as opening of the seed multiplication and distribution section to the private sector; provision of legal instrument to the government-sponsored farmers organisations to conduct the affairs more independently, introduction of reforms in the Agrarian Services Act, enabling wider crop choices in lands, where, by law, only paddy cultivation was permitted ; divesting of several government agencies performing commercial operations; and introduction of certain institutional reforms aimed at scaling down government involvement were given consideration. These new indicatives may act as the source of TFP growth in Sri Lanka.

Summing-up

To sum-up, most of the countries in South Asia had concentrated on enhanced production of a few food commodities like rice and wheat, which could quickly contribute to their total food and agricultural production. The rice-wheat based cropping system, spread in the most fertile areas, is the backbone of food security in South Asia. Encouraging TFP growth for crop and livestock sectors has been noticed for Bangladesh and Pakistan. More and more cases of deceleration in total factor productivity growth are being reported in India, except for rice in its eastern and southern states. Sri Lanka has experienced a negative growth of TFP.

All the efforts in future have to be concentrated on breaking the yield plateau by conserving natural resources and promoting ecological integrity of the agricultural system. Producing more with less of inputs will be the major challenge in the next two decades. Most often the suggested measures to accelerate and sustain growth in TFP are jacking up investment in research and infrastructural facilities,

Table 12. Empirical studies on TFP of agriculture in Sri Lanka

Author(s)	Commodity	Period	Total factor productivity	
			Annual growth (%)	Share of TFP in output growth (%)
Coelli and Rao (2003)	Crops and livestock	1980-00	0.20*	NA
Avila and Evenson (2004)	Crops	1961-80	-0.39	Negative
		1981-01	-1.21	Negative
	Livestock	1961-80	-2.19	Negative
		1981-01	1.3	50.4
	Crops and livestock	1961-80	-0.93	Negative
		1981-01	-0.92	Negative

*Malmquist Index; NA: Not available

and increasing input-use efficiency. Biotechnology research to address biotic and abiotic stresses should be paid more attention. Given the declining trend in public investment in agriculture which needs to be reversed, the only option to accelerate growth in TFP is increasing yield potential by developing appropriate technology, both for irrigated and rainfed areas. Research problems in the rainfed unfavourable ecosystems and breaking of the current irrigated yield ceilings are more complex and challenging. To make headway in them will require mobilization of the best of science and the best of scientists in the National Agricultural Research System in partnership mode. This needs higher investment in agricultural research which has been convincingly justified in several studies.

An integrated approach of developing crop varieties with greater efficiency in utilization of nutrients and other natural resources, ameliorating soil-related problems, incorporation of legumes in the cropping systems, and enhancing water-use efficiency will be required to develop location-specific management practices to improve the factor productivity growth in the rice-wheat system. Legumes play an important role in improving the sustainability of the system. Ironically, rice and wheat have replaced the principal legumes over a period of time. With the availability of high-yielding and short-duration varieties of improved legumes, there is a need to incorporate them in the rice-wheat cropping system to improve its sustainability. The growth in TFP has accounted for nearly one-third of the total agricultural production growth. Investment on research and extension has accounted for nearly two-thirds of this TFP growth. Therefore, future rate of investment in agricultural research will be the driving force for productivity growth in South Asia.

4. Policies towards Food Secure South Asia

If the existing trends in high population growth, low agricultural development, wide disparities in income, huge environmental degradation, and high incidence of poverty continue, South Asia's food, agriculture, environment, and quality of human life will be seriously threatened in the coming years. Poverty and malnutrition are likely to remain the major problems. Pressure to produce more food from less land, use of more natural resources, enormous growth in the population, and unequal distribution of income will harm the environment in the years to come.

4.1. Arresting Deceleration in Total Factor Productivity

Public investment in irrigation, infrastructure development (road, electricity), research and extension and efficient use of water and plant nutrients are the dominant sources of TFP growth. A sharp decline in total investment, and more so in public sector investment, in agriculture is the main cause for the deceleration. This has resulted in the slow-down in the growth of irrigated area and a sharp deceleration in the rate of growth of fertilizer consumption. The most serious effect of deceleration in total investment has been on agricultural research and extension. This trend must be reversed and the projected increase in food and non-food productions must accrue essentially through increasing the per hectare yield.

Recognising that there are serious yield gaps and there are already proven paths for increasing productivity, it is very important for India to maintain a steady growth rate in total factor productivity. As the TFP increases, the cost of production decreases and the prices also decrease and stabilize. Both producer and consumer share the benefits. The fall in food prices will benefit the urban and rural poor more than the upper income groups, because the former spend 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 agricultural system. More than half of the required growth in yield to meet the target of demand must be met from research efforts by developing location-specific and low input-use technologies with emphasis on the regions where the current yields are below the national average yield.

Role of education in improving farm efficiency and technology adoption has been well established (for comprehensive review, refer Lockheed *et al.*, 1980; Feder *et al.*,1985; Phillips, 1994). In a changing technological environment, farmers have to be actively engaged in search and learn activities to find and adopt better technologies. This tendency among farmers to search for new information will improve technical and allocative efficiencies, and raise farm income. As agriculture transforms from subsistence to commercial level, farmers seek information on a wide range of issues to acquire knowledge or upgrade their skills and entrepreneurial ability. These are related to production technologies, input availability, input-output prices, input-output markets, etc. To discern the role of education on adoption pattern of modern technologies and agricultural productivity, researchers have used either literacy rate or the level of formal education of head of the household as one of the explanatory variables, besides other agro-biological and socio-economic variables. A number of these studies have concluded that formal education did not directly contribute to increase in productivity, while it did influence the efficient allocation of inputs.

Mittal and Kumar (2000) did more rigorous analysis by applying the Three-Stage Least Square technique to capture the direct and indirect effects of literacy on adoption of inputs, agricultural productivity and on the total factor productivity. Using the time series data for rice and wheat at the all-India level, the authors have concluded that literacy has a positive and significant relationship with farm modernization and agricultural productivity. Literacy emerged as an important source of growth on adoption of improved technology components and production. The role of literacy was more pronounced during the liberalization era than pre-1990 period, where knowledge-based decisions influenced input-use efficiency and productivity. Literacy emerged as an important source of growth in adoption of technology, and use of modern inputs like machines and fertilizers. Recognising that in the liberalized economic environment, efficiency and growth orientation will attract maximum attention, literacy will play a far more important role in the globalised world than it did in the past. An educated workforce is easier to train and acquire new skills and technologies required for productivity growth. Thus, the contribution of literacy, through TFP, will be substantial on yield growth and domestic supply of food.

As future agriculture will increasingly be science-led and will require modern economic management, high returns to investment on education are expected. Education has to be recognised as a pre-requisite for development, both economic and human resource. Investment in education is synergistic, leading to greater utilization and deeper impact of investment in other areas of social infrastructure such as healthcare, nutritional security, sanitation, and the environment (ADB, 2003).

The investments that are good for agricultural growth-technology and its dissemination, rural infrastructure (roads), education, and irrigation amount to a 'win-win' strategy for reducing rural poverty by increasing non-farm economy and raising rural wages. Creating infrastructure in the less-developed areas, better management of infrastructure and introduction of new technologies can further enhance resource productivity and TFP. Generation and effective assessment and diffusion of packages of appropriate technologies involving system- and programme-based approach, participatory mechanisms, greater congruency between productivity and sustainability through integrated pest management and integrated soil-water-irrigation-nutrient management should be aggressively promoted to bridge the yield gaps in most field crops. Besides, efforts must be made to conserve the existing gains and make new gains, particularly through the congruence of gene revolution, informatics revolution, management revolution and eco-technology.

Barriers in technology transfer should be removed to stimulate technology transfer and growth. A large degree of real technology 'slack' exists, especially in the developing regions and countries. It requires the development of 'new' and refinement of the existing technology suited to location-specific conditions. It needs a higher investment on research and extension services. Productivity of research would be much lower if extensions were not undertaken. Investments in technological capital require long-term commitments to investment by national governments and aid agencies.

4.2. Enhancing Yield of Major Commodities

The yields of major crops and livestock commodities are much lower in the region than rest of the world. Considering that the frontiers of expansion of cultivated area are almost closed in the region, the future increase in food production to meet the continuing high demand must come from increase in yield. There is a need to strengthen adaptive research and technology assessment, refinement and transfer capabilities of the countries so that the existing wide gaps in technology transfer could be bridged. For this, an appropriate network of extension service will have to be created to stimulate and encourage both top-down and bottom-up flows of information among farmers, extension workers, and research scientists to promote the generation, adoption, and evaluation of location-specific farm technologies. Ample scope exists in increasing genetic yield potential of a large number of vegetables, fruits as well as other food crops and livestock and fisheries products. Besides maintenance of breeding, greater effort should be made towards developing hybrid varieties as well as export-oriented varieties.

The agronomic and soil research in the region need to be intensified to address the location-specific problems as factor productivity growth is decelerating in the major production regimes. Research on coarse grains, pulses and oilseeds must achieve a production breakthrough. Hybrid rice, single cross hybrids of maize and pigeon pea hybrids offer new opportunities. Soybean, sunflower and oil palm will help in meeting the future oil demands successfully. Forest cover must be preserved to keep off climatic disturbances and to provide enough of fuel and fodder. Milk, meat and draught capacity of our animals needs to be improved through better management practices.

4.2.1. Integrated Nutrient Management

Attention should be given to the balanced use of nutrients. Phosphorus-deficiency is now the most widespread soil fertility problem in both irrigated and un-irrigated areas. Correcting the distortion in relative prices of primary fertilizers could help correct the imbalances in the use of primary plant nutrients ¾ nitrogen, phosphorus, and potash ¾ and use of bio-fertilizers. To improve efficiency of fertilizer-use, what is really needed is the enhanced location-specific research on efficient fertilizer practices (such as balanced use of nutrients, correct timings and placement of fertilizers, and, wherever necessary, use of micronutrients and soil amendments), improvement in soil testing services, development of improved fertilizer supply and distribution systems, and development of physical and institutional infrastructure (Kumar and Desai, 1995).

4.2.2. Making Grey Areas as Green

Resource-poor farmers in the rainfed ecosystems practise less-intensive agriculture; they depend on local agriculture for their livelihood and benefit little from increased food production in the irrigated areas. To help them, efforts must be increased to disseminate the available dryland technologies and to generate new ones. It will be necessary to remove pro-irrigation biases in the public investment and expenditure, as well as credit flows for technology-based agricultural growth. Watershed development for increasing productivity of rainfed crops can be an option along with seed revolution for oilseeds, pulses, fruits and vegetables. Farming system research to develop location-specific technologies must be intensified in the rainfed areas. Strategy to make grey areas green will lead to 'Second Green Revolution', which would demand three-pronged strategy, watershed management, hybrid technology and small farm mechanisation. Access to even the limited irrigation water may overcome the drought conditions during the critical crop growth stages, which would substantially reduce the number of undernourished farm-households (Singh *et al.,* 2002). The Government of India has already extended a high priority to the watershed development programs in the rainfed areas. Similarly, water saving technologies receive high subsidies to expand irrigated land in the rainfed areas.

4.2.3. Water for Sustainable Food Security

Countries in South Asia being crop-based need to produce more and more from less and less of land and water resources. Alarming rates of groundwater depletions and increasing environmental and social problems pose acute threats to mankind. Benefits of better management of irrigation water in enhancing the production and productivity, food security, poverty alleviation, though well known, need to be further elaborated. In India, water availability per capita was over 5000 cubic metres (m^3) per annum in 1950. It now stands at around 2000 m^3 and is projected to decline to 1500 m^3 by 2025. Further, the quality of available water is deteriorating fast. Also, there are gross inequalities between basins and geographic regions.

Agriculture is the biggest user of water, accounting for about 80 per cent of the water withdrawals. There are pressures for diverting water from agriculture to other sectors. A study has warned that re allocation of water out of agriculture can have a dramatic impact on global food markets. It has been projected that availability of water for agricultural use in India may be reduced by 21 per cent by 2020, resulting in a drop of yields of irrigated crops, especially rice, leading to price rise and threat to food security of poor masses. Immediate policy reforms are needed to avoid the negative developments in food production in the years to come. These reforms may include establishment of secure water rights to users, decentralization and privatization of water management functions at appropriate levels, pricing reforms, markets in tradable property rights, and introduction of appropriate watersaving technologies.

The needs of other sectors for water cannot be ignored. Therefore, it is necessary that an integrated water-use policy is formulated and judiciously implemented. Several international initiatives on this aspect have been taken in recent years. Each country should critically examine these initiatives and develop its countryspecific system for judicious and integrated use and management of water. A national institution on water management should be established to assess the various issues, regulatory concerns, laws and legislations, research and technology development and dissemination, social mobilisation and participatory and community involvement, including gender and equity concerns and economic aspects. This institution should function in a trusteeship mode and seen as the flagship of a national system for sustainable water-security.

Although the past growth sources met the producers' needs (in terms of high production, food security and stability), these led to over-exploitation of groundwater, extensive land degradation (due to soil salinity, nutrient mining, etc.) and eroded biodiversity. A large part of the RWCS has become unsustainable as a result of mismanagement of natural resources.

4.2.4. Delineating Potential Areas

A wide spatial disparity exists in yield levels and technology adoption. The pre-requisite for delineating the potential areas is the identification of low-yielding but promising areas in the region based on micro data planning. Future sources of growth for each region/cluster will be different and therefore strategies for different clusters would not be the same. While new research frontiers and advanced technologies would be the possible strategy in the high-yielding and high-growth regions, it is diversification in the favour of high-value commodities that would be preferred in high-yielding and low-growth regions. Strengthening input delivery system needs to be given high priority in low-yielding and high-growth regions, while alleviating abiotic and biotic constraints should be the key focus in low-yielding and low-growth regions. In all the production environments, strong technology generation and dissemination program should be the pre-requisite.

The new research frontier may include development of hybrids and application of biotechnology for quality improvement. More focus in high-yielding and high-growth quadrangle may be on quality improvement and resource conservation. Diversification of agriculture in favour of high-value commodities, namely fruits, vegetables, dairy products, poultry, fish, etc., would augment income of farming community located in high-yielding and low-growth quadrangle. These commodities being perishable in nature, must be marketed, consumed or processed quickly. It requires revamping of the research, development and investment strategy in the region. Appropriate infrastructure and marketing arrangements are needed to promote diversification of agriculture; failing to that the benefits of high-value agriculture would be ruined.

4.3. Accent on Empowering the Small Farmers

Contributions of small farm holders in securing food for the growing population have increased considerably even though they are the most insecure and vulnerable group in the society. Specific human resource and skill development programs will make them better decision-makers and highly productive. Human resource development for increasing productivity of these small farm holders should be given high priority. Thus, awareness generation and skill development of rural people in both agriculture and non-agriculture sectors is essential for achieving economic and social goals.

Raising agricultural productivity requires continuing investments in human resource development, agricultural research and development, improved access to information, better extension services, markets, roads and other infrastructure development, efficient small-scale, farmer-controlled irrigation technologies, and custom hiring services. Such investments would provide small farmers the options and flexibilities to adjust and respond to market conditions.

Identification of need-based productive programs is very critical, which can be explored through characterization of production environment. There is a need to develop demand-driven and location-specific programs to meet the requirements of food and nutritional security of most vulnerable population in the rural areas. Improved technology for agriculture, irrigation, and livestock and higher literacy levels are the most important instruments for improving the food and nutritional security of the farm-households. Watershed development and water-saving techniques will have far reaching implications in increasing agricultural production and raising calorie intake in the rainfed areas. Livestock sector should be given high priority with multiple objectives of diversifying agriculture, raising income and meeting the nutritional security of the poor farm households.

4.3.1. Diversification of Agriculture and Value Addition

In the face of shrinking natural resources and ever increasing demand for more food and agricultural production arising due to high population and income growths, agricultural intensification is the main course for future growth of agriculture. Research for product diversification should be yet another important area. Besides developing technologies for promoting intensification, South Asian countries must give greater attention to the development of technologies that will facilitate agricultural diversification, particularly towards intensive production of fruits, vegetables, flowers and other high-value crops which are expected to increase income growth and generate effective demand for food. The per capita availability of arable land in South Asia is quite low and declining over time. Diversification towards these high-value and labour-intensive commodities can provide adequate income and employment to the farmers dependent on small size of farms. Due importance should be given to quality and nutritional aspects. High attention should be accorded to post-harvest management, agro-processing and value-addition technologies to reduce the heavy post-harvest losses and improve quality through proper storage, packaging, handling and transportation. The role of biotechnology in post-harvest management and value addition deserves appropriate enhancement.

Farm-producers in South Asia have little access to improved technologies mainly due to (i) lack of knowledge, (ii) weak input delivery system, (iii) lack of appropriate technology suiting the resource endowments of producers, (iv) lack of credit, and (v) high risk and absence of insurance management. A majority of the producers in these regions are resource-poor and poverty-ridden, and therefore, technologies, policies and institutional support need to be tuned to their socio-economic profile. A large untapped production potential of rice and wheat is to be harnessed through appropriate technology and policy intervention.

4.3.2. Safety Nets to Small Farmers

With the advent of globalization and liberalization reforms and the WTO regime, the small farmers are liable to be more vulnerable and disadvantaged by the sheer scale of economy. Necessary safety nets need to be built in the structural adjustment processes. Since the marketed surplus of the small farmers is small, domestic markets must be insulated through appropriate tariffs to meet the temporary shocks from international markets on import of certain agricultural commodities and food items such as pulses, oilseeds and edible oils. If it is not ensured, then it may be a deterrent to crop diversification. The policy of minimum guaranteed prices, subsidy on food and some degree of subsidization in modern inputs need to be targeted to small farmers, and the rural poor, in the short- and medium-term. If need be, the subsidies enjoyed by non-poor in the non-farm sector be phased out to release more resources for agricultural and social development in the rural areas.

4.3.3. Support for Risk Management

Small farmers not only have few resources to invest, but also face higher level of risk in any capital investment, as compared to wealthy farmers. It is a tenet of gambling that a rational decision on whether a risk is justified or not depends on an evaluation, not only of potential losses versus potential gains, but also of whether those potential losses are manageable in relation to assets already owned. Otherwise, risk will lead them to take the extreme steps as has been seen in recent past, in the form of suicides by some marginal and small farmers. The small farmers can be prevented to take such extreme steps by creating the necessary policy environment to reduce risk, like diversification, generation of new livelihoods, off-farm income, institutional support, access to information, technology, inputs, credit, crop insurance, etc.

4.4 Protecting the Environment

Environmental protection and sustainability are the major interventions today in the overall planning for agricultural growth and development. Although the high-yielding varieties of rice and wheat are generally blamed for causing environmental degradation, these varieties had saved million of hectares of forests from being cleared to produce food to feed the burgeoning population. Given below are the priority research options in the region in the field of environment protection:

- Development and management of agro-chemicals, including neem products.
- Strengthening of Integrated Plant Nutrient System (IPNS) for reducing the use of agro-chemicals without compromising yield enhancement.
- Monitoring of climate change and its impact on agricultural productivity and sustainability; some countries regularly monitor methane emission from rice/paddy fields and aquatic bodies and are devising technologies to minimize the release of green house gases from agricultural fields into the atmosphere.
- Ecological and environmental studies through GIS and remote sensing.

4.5. Strengthening National Agricultural Research Systems and Macro Policies

There has been a considerable expansion in international and national support for agricultural research during the past three and half decades. However, annual growth in total research expenditure has declined in real terms (Rosegrant and Pingali, 1994). Agriculture assumes much more importance in South Asia (agricultural share in GDP ranges from 21 per cent to 39 per cent), yet very little resource allocation is made to it (about 8-12 per cent of the total government expenditure). In the light of resource depletion, degradation of land and water resources, and increasing food demand, more spending on agricultural research and rural infrastructure development is required.

Even though the countries recognise that research is the engine for growth of agriculture, the allocation of resources to agricultural research by the national governments has declined in real terms in the South Asian countries (in terms of constant price). Some countries have realized this shortcoming and have accordingly sought in their next development plans an increase of 3 to 4-times in research allocations, raising the level to at least 1 per cent of the agricultural GDP. All the countries in the region are strengthening their informatics and databases and can now easily be interlinked with each other. The SAARC countries on the basis of their identified common priorities and commitments should constitute selected networks of research, technology assessment, and transfer to facilitate sharing of the existing and future technologies. Reforms in marketing and macroeconomic policies are needed to encourage long-term investment and technological changes in the agricultural sector.

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Appendix Ia. Trends in total factor productivity (TFP) for various crops in the selected states of India: 1971-86

Crop	Total factor productivity in states				
	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	
Black gram			Uttar Pradesh	Haryana, Madhya Pradesh, Rajasthan	
Groundnut			Karnataka	Andhra Pradesh, Gujarat	Tamil Nadu
Linseed			Madhya Pradesh		
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, Government of India, New Delhi.

Appendix Ib: Trends in total factor productivity (TFP) for various crops in selected states of India: 1986-1999

Crop	Total factor productivity in states				
	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

Source: Computed by the authors from data on cost of cultivation, Directorate of Economics & Statistics, Government of India, New Delhi