Ind. Jn. of Agri. Eco.
Vol.67, No.2, April.-June, 2012

RESEARCH NOTES

Rice and Wheat Crop Productivity in the Indo-Gangetic Plains of India: Changing Pattern of Growth and Future Strategies

I. Sekar and Suresh Pal*

I

INTRODUCTION

Agriculture continues to be the mainstay of the Indian economy because of its greater share in employment and livelihood although its relative contribution to the nation's gross domestic product (GDP) has declined over the years. Much of India's food grains supply particularly staple foods like wheat and rice comes from Indo-Gangetic Plain (IGP), which is the heart belt of green revolution contributed significantly towards India's food security. Since green revolution, the share of wheat production in the country has been consistently greater around 70-74 per cent and the share of rice to the total has been around 40-45 per cent. The rice-wheat production systems in IGP therefore assume paramount importance in contributing to the national pool as well as providing employment and livelihoods to millions of rural poor. Despite its importance and contribution, there have been concerns recently on deceleration in productivity growth in both rice and wheat crops. In addition, there has been wide disparity in yield within IGP region, which still remains unresolved and is continuously haunting IGP agriculture. Excessive utilisation of natural resources in the region is yet another concern, which can bring about environmental ill effects. Studies on productivity and resource use therefore can suggest policy directions for future from the present stagnation or plateau to a resurrecting phase. This study is an attempt to examine productivity and input use related issues in IGP, assess the trends and estimate growth of output and inputs of rice and wheat crops, decompose sources of output growth and provide strategies for enhancing the rate of growth of rice and wheat production in IGP.

II

METHODOLOGY

In this study, compound growth rates of area, production and yield of rice and wheat crops for both green revolution and economic reform periods were estimated.

*Principal Scientist and Head, respectively, Division of Agricultural Economics, Indian Agricultural Research Institute, New Delhi -110 012.

In addition, the rate of growth was also worked out for inputs use in rice and wheat crop production in IGP region. The estimation of compound growth rate seems more appreciable to analyse the movement of agricultural output rather than linear rate of growth (Dandekar, 1980).

Compound growth rates were estimated with the following exponential model.

$Y = a\, b^t$

In log linear form, $\log Y = \log a + t \log b$

Log equation can be rewritten as $Y = A + tB$ where $A = \log a$ and $B = \log b$

Since, $b = 1 + r$

C.G.R. $(r) = [b - 1] \times 100$.

The sources of production growth were examined using disaggregation method. Minhas and Vaidyanathan (1964) component analysis model was used in this study to measure the relative contribution of area and yield to the total output change for rice and wheat crops.

$$DQ = DYA_o + DAY_o + DADY$$

Whereas DQ = Change in production; DYA_o = Yield effect; DAY_o = Area effect; DADY = Interaction effect.

In this additive form, the total change in production is decomposed into three effects, viz., yield effect, area effect and the interaction effect due to change in yield and area, which is examined individually for green revolution period (1966-91) and economic reform period (1992-2008).

Growth with stability in crop production is important for achieving food security in the long run. To examine stability of rice and wheat crop production in IGP, an indexing method proposed by Ray (1983) was used. The instability index was constructed as the standard deviation of natural logarithm of ratio of a variable (Y) between t-th and t+1-th year. Y_t is the rice/wheat crop area/production/yield in the current (t-th) year whereas Y_{t+1} is in subsequent year. This index is unit free and very robust, and it measures deviations from the underlying trend (log linear in this case).When Y_t and Y_{t+1} are approaching the same value the ratio becomes nearing unity. When the ratio is closer to unity, standard deviation is less. When it is unity, standard deviation is zero. In other words, whenever the ratio is much deviated from unity, standard deviation is bigger showing high variability in the data. The instability analysis was undertaken with the time series data on yield, area, and production of rice and wheat crops in IGP region for the period 1961 to 2008. The data were collated from different sources: various issues of *Agricultural Statistics at a Glance*, Directorate of Economics and Statistics, Ministry of Agriculture, Commission for Agricultural Costs and Prices (CACP), and Centre for Monitoring Indian Economy (CMIE).

III

PRODUCTIVITY DIFFERENTIALS OF RICE CROP IN INDIA

Rice is the most important staple crop in India. The growth of rice crop was phenomenal in the initial phases of green revolution period but since 1980s there has been slow growth up until recent years. This could be because of no major technological breakthrough after green revolution period and the technologies developed in the late sixties and early seventies were of yield increasing type whereas technologies evolved after eighties were predominantly of yield stabilising type. The horizontal expansion of area under such staple crops is also limited due to urbanisation and competition from other sectors. On one hand, the area under expansion of these crops is very limited and on the other the growth of these crops is showing deceleration, which is a cause of concern. Still considerable land areas that are suited for rice production requires high cost of developing this land. Despite land suitability, decline in per capita availability of water resources is another hurdle in expanding the frontier of crop production. In such situations, sustaining yield and production growth seems to be a tough task.

Low returns with rise in costs and efforts required to keep our rice farmers engaged in farming are some other supply side challenges. But the decline in per capita availability with increase in population is demand-driven and the impact of spiralling prices is already experienced. Although several reasons are cited for such soaring prices, supply demand mismatch is the major one. In countries like India, eliminating the spatial differences in yield and production can augment rice production and boost stock to avoid such crisis in future. An analysis on regional variation in rice crop yield therefore assumes greater significance. In this section of the paper, an overview of disparities of rice production in the country is given. Based on major rice growing states in the country, the country has been grouped in major five rice growing zones. Spatial and temporal changes in rice production across region are presented in Table 1.

TABLE 1. REGIONAL CHANGES OF RICE PRODUCTION IN INDIA

(*per cent*)

Year	Shares by region				
	South	North	West	East	North-east
(1)	(2)	(3)	(4)	(5)	(6)
1960-70	31.6	2.7	4.9	54.9	5.8
1971-80	31.7	7.0	5.0	50.7	5.6
1981-90	28.0	12.0	4.6	50.4	5.0
1991-2000	26.6	13.2	4.1	51.1	5.0
2000-08	25.2	16.8	4.7	48.3	5.0

Sources: Calculated from data of *FAO Statistics* and *Agricultural Statistics at a Glance, 2008*.

The share of rice production in the North region increased from 2.7 per cent during 1960s to 16.8 per cent during 2008 whereas it declined in the Southern region from nearly 32 per cent to 25 per cent during the corresponding period. The productivity of rice in the northern and southern regions enhances the national rice productivity in the country. Overall, the share of eastern region is more, which contributed significantly around 50 per cent; however this region showed a marginal decline in share to the total rice production from 55 per cent to 48 per cent in the last five decades. Despite such a lion share of this region, the average yield of rice ($2.45tha^{-1}$) continues to remain at a lower level when compared to other regions of the country. Quite similar to that the yield of rice in the north eastern region is also very low and contributes a thin share to the national pool. Identification and removal of rice production constraints would pave a way for stepping up the potential level of yield and thereby enhancing the rice economy in these regions. It is important to accelerate the efforts particularly in eastern region, where the contribution is large, to enhance rice productivity to the potential level so that the overall rice production in the country will improve further to match the growing demand of rice in future. If spatial disparity is removed and productivity level of low productive regions such as eastern region is enhanced to match with the highest productivity level of northern region, it is expected to get an additional 43.18 million tonnes from the eastern region alone. Similarly there is scope to increase the rice production to an additional 4.33 million tonnes in north eastern region from the existing level if strenuous efforts are taken to enhance the productivity level equivalent to that of northern region in the country. In the ensuing section, the trends in rice and wheat crop production, sources of production growth and productivity issues are analysed in detail with reference to the Indo-Gangetic Plain of India.

IV

TRENDS AND SOURCES OF PRODUCTION GROWTH

The Indo-Gangetic Plain of India registered a yield increase of 137 per cent in rice crop in the last four decades, which is above national average. However, it has been far below while comparing with the yield of rice crop in China over the years. China has consistently out performed India in rice productivity and production. It could be because of the pattern of land holdings or better irrigation facilities or better agricultural inputs, which requires profound exploration. As per 2008 estimate, the average yield of rice crop in IGP was 3.87 t/ha whereas for India as a whole (3.0t/ha) and China (6.07t/ha). Productivity of rice and wheat crops in IGP is not only low compared to other countries, but also there are considerable spatial variations within IGP. Barring Punjab and Haryana states, the productivity level of these two crops are poor in states like Bihar, Uttar Pradesh and West Bengal. If improved, then the overall rice and wheat yield levels in the IGP region will exhibit a better picture. Besides such a spatial disparity, there is a significant gap between the performance and potential as revealed by actual yield and the yield obtained with improved practices adopted by the farmers. It is very true that IGP has to play a pivotal role in

India's total rice production to meet the demand in future. It is high time to stress for technology development and push, which emphasises the importance of developing new path breaking high-yielding rice and wheat varieties and making sure it reaches the farmers.

The rate of growth of rice productivity in IGP was around 3.2 per cent till 1980, which was impressive after the green revolution period. However, there had been a deceleration in growth rate of rice productivity after 1980s, which was particularly more evident during 1990s (0.37 per cent). Several factors might have contributed to the rapid decline in yield growth since the early 1980s. Major technology breakthrough came in the mid-sixties and the technologies that came during and after eighties were of yield stabilising type, which has not provided any quantum jump in yield and thus lowered the production growth. Since the introduction of IR8 in 1966, no major technological breakthrough has occurred even though some early maturing varieties were developed. In addition, intensification of rice wheat system in IGP may be responsible for reduction in soil fertility and depletion of other natural resources and hence reduction in yield. Reports in the early 1980s revealed a yield decline in the intensively cultivated rice plots within research stations in the Philippines. Increased salinity resulting from long-term rice production in irrigated areas worldwide was reported by Pingali and Rosegrant (1996). Low rice yields due to salinity have also been reported in southern Spain (Aguilar *et al.*, 1997). Pressures from such abiotic stress with rice cultivation in continuum could result in deceleration in yield growth rate of rice. Soil fertility can be ameliorated with the introduction of summer pulses particularly mung bean potentially in the IGP region.

Extreme weather conditions such as drought and flood are often experienced in Bihar and eastern Uttar Pradesh may also be responsible for reduction in yield. Besides, biotic stresses can also cause modern rice varieties not to realise its full yield potential. It is estimated that diseases and insects cause yield loss annually up to 25 per cent. Apart from biotic and abiotic stresses, prices would have had an influence on yield growth. Output and relative input prices are not moving on par. International rice prices have declined markedly since 1995 (Calpe, 2003), while prices of production inputs increased. Recent rise in rice prices impacted the consumers more rather than benefiting rice producers. Eroding the profit level of farmers in such a way is a disincentive to the farmers to invest more and hence eventually results in reduction in yield. Rice yield growth in IGP could have contributed largely to production growth. However, it remains still unclear on the extent of contribution of each source of production growth. An attempt here therefore was made to decompose the production growth into area and yield effects separately for green revolution and economic reform periods. The results presented in Table 2 show that yield effect contributed more to overall production growth of rice in upper, middle and lower Gangetic plains whereas area effect was more in trans Gangetic plain.

TABLE 2. SOURCES OF PRODUCTION GROWTH IN RICE

(*per cent*)

	Green Revolution Period			Economic Reform Period		
IGP (1)	Area effect (2)	Yield effect (3)	Interaction effect (4)	Area effect (5)	Yield effect (6)	Interaction effect (7)
TGP	32.55	15.35	51.98	70.87	23.06	5.86
UGP	9.08	72.50	18.42	45.28	50.04	4.68
MGP	4.60	92.52	2.89	-11.85	114.01	-2.16
LGP	18.16	66.89	14.95	1.84	97.72	0.44

Sources: Calculated from data of *FAO Statistics* and *Agricultural Statistics at a Glance, 2008.*

Wheat productivity in IGP also exhibited quite a similar pattern as that of rice. As per the 2008 estimate, wheat productivity in IGP was 3.22t/ha which was above the national average (2.62t/ha) but lower than the average yield in China (4.76t/ha). In the beginning of green revolution, the average yield level of wheat in IGP was higher than the overall yield level of wheat in China. However the same momentum could not be sustained and the Chinese surpassed after 1980s. It is prudent to examine the factors that are attributed to increase in wheat productivity in China while it is also imperative to investigate into the reasons for the slump in productivity level of wheat in IGP after 1980s. Growth rates were computed over decadal intervals and were found that there had been a continuous deceleration. Though the productivity level of wheat appeared to be increasing in absolute terms, there has been deceleration in production growth over a span of four decades and it has become negative (-1.2 per cent) at the turn of this century, which is a matter of concern. It is important to sustain the level of growth at a healthy rate because nearly 75 per cent of the total wheat to the entire nation is supplied from IGP region.

From the technology perspective, quite similar to rice, there are no marked improvements in recent years in genetic manipulation in wheat crop and no major technology breakthrough. Besides lax in evolution of yield push technologies, both biotic and abiotic stresses might have also been responsible for such a decelerating growth in wheat output in recent years. In the middle and lower Gangetic plain, wheat crop productivity is comparatively lower than the upper and trans-Gangetic region and therefore removing the crop production constraints in low productivity regions can improve the overall wheat yield level in IGP region. Decomposition analysis on the sources of wheat production growth showed that yield effect contributed more to the overall production growth of wheat in the upper and middle Gangetic plain while area effect was more in trans and lower Gangetic plain during economic reform period (Table 3). During green revolution period, there was not much variation due to both yield and area effects except in lower Gangetic plain where area effect contributed more to the overall production growth of wheat.

TABLE 3. SOURCES OF PRODUCTION GROWTH IN WHEAT

(*per cent*)

	Green Revolution Period			Economic Reform Period		
IGP (1)	Area effect (2)	Yield effect (3)	Interaction effect (4)	Area effect (5)	Yield effect (6)	Interaction effect (7)
TGP	29.00	35.94	35.08	57.29	37.79	4.92
UGP	31.38	38.67	29.95	10.79	86.62	2.59
MGP	32.06	33.15	34.79	12.21	87.01	0.78
LGP	55.10	14.23	30.66	62.19	27.98	9.83

Sources: Calculated from data of *FAO Statistics* and *Agricultural Statistics at a Glance, 2008.*

In addition to lower production growth, yield gap in both rice and wheat crops of IGP region is also not encouraging. There exists a distinct gap between the performance and potential as revealed by actual yield and yield with improved practices adopted by the farmers. Yield gap was examined and found to be too low in Bihar and Uttar Pradesh states in IGP. Actual yield in Table 4 is the average yield (A) obtained by the farmers at field level across locations, seasons and varieties within the state. Farmers' practice yield (F) is the progressive farmers' yield obtained by rice and wheat farmers of Bihar and Uttar Pradesh states whereas improved practice yield (I) is the yield obtained with improved farm practices. As it is evident from the table, yield gap between the actual (A) and improved practices (I) in rice crop run as high as 222 per cent in Bihar. This suggests a tremendous scope for improving yield with better crop management and input use efficiency. As far as wheat crop is concerned, yield gap is wider in Bihar state (105 per cent). Rice and wheat production in IGP region would be better-off if the yawning yield gap is reduced.

TABLE 4. YIELD GAP (ACTUAL AND FARMER PRACTICE) IN IGP

Crops (1)	State (2)	Improved practice (I) (kg/hectare) (3)	Farmer practice (F) (kg/hectare) (4)	Actual yield (A) (kg/hectare) (5)	Gap (per cent) I and F (6)	Gap (per cent) I and A (7)
Wheat	Bihar	3651	2905	1783	25.7	104.8
	Uttar Pradesh	4206	3324	2794	26.5	50.5
Rice	Bihar	4883	4158	1516	17.4	222.1
	Uttar Pradesh	7050	5200	2187	35.6	222.4

Source: *Economic Survey 2007-08.*
Note: Yield gap was calculated for the years 2002-03 to 2004-05.

A simulation modeling by Aggarwal *et al.*, (2004) also showed that the yield gap was wide between actual and simulated potential yield (Table 5). To bridge such big yield gaps, management options such as supplementary irrigation, ensuring timely planting and improved nitrogen management practices were suggested. Boosting the rice and wheat crop productivity in disadvantaged areas is possible through providing timely input and credit supply to resource poor farmers in marginal areas and also through improving basic infrastructural facilities which can make the farmers accessible to smooth flow of inputs supply and marketing access.

TABLE 5. YIELD GAP (ACTUAL AND SIMULATED POTENTIAL YIELD) IN IGP

($t\ ha^{-1}$)

State	Average actual yield,			Average potential yield*			Yield gap		
	Rice-Wheat	Rice	Wheat	Rice-Wheat	Rice	Wheat	Rice-Wheat	Rice	Wheat
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Punjab	9.76	5.44	4.32	18.29	10.60	7.69	8.53	5.16	3.37
Haryana	8.22	4.19	4.03	17.87	10.53	7.34	9.65	6.34	3.31
Uttar Pradesh	5.70	3.01	2.69	17.48	10.34	7.14	11.78	7.33	4.45
Bihar	3.97	2.00	1.97	16.43	9.73	6.70	12.46	7.73	4.73
West Bengal	5.94	3.65	2.29	13.37	8.07	5.30	7.43	4.42	3.01
IGP	6.72	3.66	3.06	16.70	9.88	6.82	9.98	6.22	3.76

Source: *Aggarwal *et al.*, 2004.

V

INSTABILITY IN RICE AND WHEAT PRODUCTION IN IGP

The instability analysis shows the volatility and risky nature of crops in a particular region. Yield and production instability in rice crop showed similar pattern in IGP. Rice production was fairly stable in trans and lower Gangetic Plain whereas high instability was witnessed in the middle and upper Gangetic Plain region, which could be due to higher yield instability. The middle Gangetic Plain experienced the highest instability in rice production (32 per cent) and yield instability was estimated to be 27 per cent, followed by upper Gangetic plain where the respective figures were 25 per cent and 22 per cent respectively.

Wheat production in lower Gangetic Plain was highly unstable (34 per cent) and middle Gangetic plain (24 per cent) respectively. Both these regions also exhibited much variation in yield. On the other hand, trans and upper Gangetic Plain experienced relatively less instability in wheat yield and production.

State wise analysis throws more light on temporal variability in different periods. Rice and wheat crop production in Bihar state have turned to be less volatile during liberalisation period than that of green revolution period. Wheat production instability in the state has shown a marked decline from 29 per cent to 9 per cent which could be due to decline in both area and yield instability. It is important to note here that concerted developmental efforts have been taken up in Bihar state of late to improve the state of affairs in agriculture. As hypothesised, the agriculturally advanced states like Punjab and Haryana also witnessed less volatility in liberalisation period. The overall instability index has dipped from 20 per cent to 11 per cent during green revolution and liberalisation periods, respectively in Haryana and the underlying factor has been decline in yield instability. Similar pattern is observed in Punjab state too, where rice and wheat production is far less risky now, which is largely due to yield stability.

Uttar Pradesh state has witnessed higher instability in rice yield (26 per cent) during green revolution period. However, it has improved during liberalisation period. As seen from Table 6, wheat production in Uttar Pradesh overall is not a riskier one while comparing with rice crop production.

TABLE 6. INSTABILITY INDICES OF RICE AND WHEAT CROPS IN IGP OF INDIA

		Rice			Wheat		
States (1)	Periods (2)	Area (3)	Production (4)	Yield (5)	Area (6)	Production (7)	Yield (8)
Bihar	1966-1991	0.08	0.38	0.32	0.19	0.29	0.23
	1992-2008	0.09	0.21	0.15	0.02	0.09	0.08
Haryana	1966-1991	0.10	0.20	0.16	0.06	0.13	0.10
	1992-2008	0.07	0.11	0.13	0.03	0.06	0.04
Punjab	1966-1991	0.07	0.12	0.10	0.04	0.10	0.08
	1992-2008	0.04	0.06	0.05	0.01	0.07	0.06
Rajasthan	1966-1991	-	-	-	0.13	0.18	0.12
	1992-2008	-	-	-	0.14	0.24	0.15
Uttar Pradesh	1966-1991	0.05	0.28	0.26	0.04	0.13	0.10
	1992-2008	0.06	0.15	0.10	0.01	0.06	0.06
West Bengal	1966-1991	0.05	0.15	0.13	-	-	-
	1992-2008	0.05	0.07	0.04	-	-	-

Sources: Computed from data of *FAO Statistics* and *Agricultural Statistics at a Glance, 2008*.

Notes: (i) Rice and wheat in Rajasthan and West Bengal respectively are not major crops and hence instability indices were not computed.

Rice is the major food crop in West Bengal, wherein yield and production stability have improved noticeably. Yield risk has declined from the earlier 13 per cent to 4 per cent recently and the yield risk is essentially responsible for the decline in instability of rice production in the state. Wheat production in Rajasthan state is observed to be rather more unstable now due to both yield and area instability. Both these causal factors have led to 6 per cent increase in instability while comparing both periods.

VI

FACTOR PRODUCTIVITY IN INDO GANGETIC PLAIN

Rice-wheat systems in IGP have undergone changes over the years from conventional to modern input intensive method of production more so in the trans-Gangetic plain. Intensive input use is providing lower marginal returns (Ladha *et al.*, 2000). We estimated the productivity in terms of agricultural output per unit of inputs and found that these varied spatially and temporally. During the initial phases, intensive use of farm inputs has led to increases in land, labour and water productivity in IGP region. However, the rate of growth has shown a deceleration in recent years. Land productivity is low in the middle Gangetic plain though it is endowed with fertile soils but often subject to extreme weather conditions. The trans Gangetic Plain contributes to the overall performance of IGP, which has witnessed nearly double the rice and wheat productivity level in the past four decades. It implies successful research and technology development and dissemination in enhancing yields. However, the rate of growth at disaggregate level has shown a declining trend and therefore it is not prudent to be complacent on past laurels.

An estimate on labour productivity can reveal the efficiency of labour use for crop production purpose. Labour productivity[1] is higher in the trans Gangetic Plain in both rice and wheat crops. In case of wheat crop, labour productivity is around 14 and 11 kg per man hour respectively in Punjab and Haryana states. High labour productivity is not necessarily a reflective of amiable agricultural environment but it is mainly influenced by the opportunity cost of labour, off-farm opportunities and employment available and the consequent magnitude of shift towards off-farm work. Labour productivity in rice cultivation in Punjab and Haryana states are estimated to be 11 kg and 6 kg per man hour respectively. Labour productivity is observed to be very low in the middle and lower Gangetic plains despite more available labour and is mainly because of less yield level of rice wheat production system. The average labour use in IGP is quite high in rice crop in comparison with wheat. There is a wide variation in labour use among IGP states. While labour use in West Bengal is above thousand man hours per hectare in both crops, it is nearly half in Punjab state. The rate of growth of labour productivity was around 5 per cent during 1980s and now declined to 3 per cent in wheat and 1.5 per cent in rice, which could be due to labour shift from agriculture to non-agricultural sector. Owing to increasing opportunity cost of labour, labour shift and consequent labour shortage in rice wheat production system can have widespread repercussions on sustainable crop production in IGP. Efforts are therefore required to contain such shift before it extends to a much greater scale.

Water productivity can be a surrogate measure of water use efficiency. Groundwater is the major source of irrigation water for rice and wheat crops in Punjab, and Haryana states and its continuous use led to decline in groundwater levels. Since sustainability of water resources is increasingly becoming an issue, there is an urgent need to improve use efficiency and to maximise the productive use of water. Water productivity in wheat cultivation in states of Haryana and Bihar are estimated to be 0.11 and 0.14 tonne per hour irrigation. Although wheat crop productivity in Haryana is more than that of Bihar, water productivity is less in Haryana which revealed the extent of water use in Haryana. The water productivity is significantly influenced by the method of cultivation in wheat. As there is considerable difference in water use between zero tillage and conventional methods, zero tillage has potentials in water saving in IGP region. Water productivity in zero tillage adopted farms in Haryana state is 0.17 tonne per hour irrigation whereas in Bihar it is 0.22 tonne per hour irrigation. In view of such notable increase in water productivity levels, steps must be taken to upscale such resource conservation technologies in IGP region.

Over a span of four decades, the area under surface irrigation has declined in IGP while area of groundwater irrigation has shown an upward trend. Ground water use has become indispensable over the years with increasing need of water for competing sectors. Consequent to the installation of increasingly more number of tube wells, the extraction rate and exploitation level have gone up while the recharge rate has not been on par with it. The percentage coverage of irrigated area under rice and wheat crops in Haryana state is 99.9 per cent and 99.5 per cent respectively. Similarly in Punjab it is 99.4 per cent and 98.6 per cent respectively. While the percentage of irrigation under these principal crops is almost 100 per cent, the major share is from ground water source. The share of tube wells in net irrigated area in states like Punjab and Uttar Pradesh has ballooned more than 70 per cent. In Bihar, its share is currently around 65 per cent. Continuous ground water mining may lead to a stage when future generation may be deprived of fresh water resources.

Excessive extraction of ground water and over-exploitation in many blocks of Punjab and Haryana states are reported. In Punjab state, nearly 75 per cent of the blocks are already designated as over-exploited and therefore critical. In trans Gangetic Plain, the irrigation intensity[2] increased from 148 to 180 per cent over the last four decades. Similarly in lower Gangetic plain, irrigation intensity has increased from nearly 100 per cent in 1960 to 178 per cent in 2008. Decadal analysis showed that a sudden upsurge is witnessed in lower Gangetic plain after 1990s. Increasing irrigation intensity is a factor which shifts production frontier up, however increasing level of environmental degradation and associated health hazards due to excessive withdrawal of ground water cannot be neglected for too long. It is not only the availability of water under threat but also degradation of water, reported in Haryana and West Bengal states is to be viewed seriously. The problems arising from salinity and arsenic contamination are already reported in Haryana and West Bengal states respectively. It has profound impacts from health and environmental angles. Lack of appropriate policies on natural resources and laxity in regulatory mechanisms to guide ground water development and use have resulted in over-exploitation of this precious resource to a greater extent and therefore corrective measure is required.

Decadal growth rate in surface and ground water irrigation in IGP (Table 7) showed that negative growth in area under surface water irrigation is observed in IGP since 1980s, which is not a good sign. It is important to explore ways to augment the share of surface water sources. It can be possible through installation of farm ponds, revitalisation of defunct tanks, and resuscitation of community based water management in canal and tank command areas. Water harvesting during monsoon season can be a better strategy for water augmentation and to use the harvested water during lean season. Watershed method of water augmentation and conservation may be undertaken and use of frontier technologies of Remote sensing and GIS can be helpful for efficient water resource management and decision making. Growth of tube well irrigation in IGP during 1970-80 had been 8.76 per cent and the reason being favourable policy atmosphere prevailing in credit and agriculture sectors. The growth was around 5 per cent till last decade and now it has come down to 1.27 per cent. It showed that ground water irrigation occupied a major share in total irrigation and poised towards a potential threshold. Recent declining growth could be due to combined effect of reduced availability of water and increasing awareness among farmers on judicious use of irrigation water. Over use of ground water must be curtailed by encouraging conjunctive use of water. Even though the rate of growth of installation of new tube wells has come down during the last few years, deepening of existing wells has been increasingly happening in IGP, which can emanate negative externalities.

TABLE 7. RATE OF GROWTH OF SURFACE AND GROUND WATER IRRIGATION IN IGP

Period (1)	Surface water (2)	Ground water (3)	Canals (4)	Tanks (5)	Tube wells (6)	Other wells (7)	Other sources (8)	Total irrigation (10)
1970-80	1.07	4.11	1.79	-0.58	8.76	1.19	0.65	2.51
1981-90	-0.11	2.24	0.80	-1.93	4.25	1.55	2.19	1.78
1991-00	-1.47	2.73	-0.06	-2.38	4.93	2.18	-0.01	1.97
2001-08	-1.34	1.07	-1.13	-1.82	1.27	2.37	11.15	1.75

Source: Calculated from the data of Central Ground Water Board, Ministry of Water Resources, Government of India.

The results of this study shows that there has been deceleration in growth of partial productivities of factor inputs. Our study results are further bolstered by a study undertaken by Kumar *et al.* (2004) who analysed rice-wheat cropping system using the data from 1981-1996. It was reported that growth of total factor productivity in crop sector invariably in all the states of IGP region is declining (Table 8). It is not only decelerating but also in state like Uttar Pradesh, growth of total factor productivity is negative.

TABLE 8. TFP GROWTH IN CROP SECTOR, 1981 TO 1997 BY STATES IN IGP

(*per cent per annum*)

State (1)	1981-82 to 1990-91 (2)	1990-91 to 1996-97 (3)
Haryana	3.22	0.10
Punjab	1.24	1.20
Uttar Pradesh	1.44	-0.54
Bihar	1.47	0.24
West Bengal	5.13	1.25

Source: Kumar *et al.* (2004).

As far as inputs growth in IGP are concerned, the area under high-yielding variety of rice has increased at a rate of 2 per cent while pesticide consumption in the region has declined at a rate of 1.8 per cent. These are considered to be good while looking at from economic and environmental angles. The estimate on economic gain from high-yielding varieties particularly wheat is substantial and hence the importance of HYV seed input cannot be undermined. Besides the visible impact of HYV in IGP region, there has been sizeable increase in complementary inputs like fertiliser in IGP region in a span of last four decades and the consumption of fertiliser has grown at a rate of 3 per cent. Lack of scientific testing of soil for fertility status can lead to continuously larger scale application of fertiliser which could impact the environment adversely. Excessive application of fertiliser beyond the threshold level not only reduces crop productivity but also impacts land and water resources. While the ideal ratio of NPK is 4:2:1, the application is highly skewed towards nitrogenous fertilisers in the region. Balanced NPK fertiliser application, adoption of integrated nutrient management practices in IGP region can be therefore recommended for environmental sustainability.

VIII

OUTLOOK ON STRATEGIES

Past achievements of green revolution have put India in a strong position of self reliance in rice and wheat production. Despite such achievements, there are still some challenges that are to be confronted. To mention a few, spatial productivity differentials, low yield, deceleration in growth rate, etc. Declining growth rate in yield levels of rice and wheat crops can have far reaching impact on GDP growth in agriculture. Efforts are therefore required to step up the growth rate before it has a dampening effect on GDP. As food security in India greatly depends on this IGP region, deceleration of growth in the region cannot be taken lightly. It necessitates working towards enhancing productivity levels and improving forward and backward linkages so as to ensure better utilisation of available resources and better facilities for marketing of farmers’ produce.

While reducing the spatial disparity to achieve equitable growth, technology push to sustain growth level of these two crops in IGP region is important. A right policy mix for technology development, uptake and dissemination with the aim of achieving inclusive growth can improve the overall performance in IGP region. Improvement in technology development and bridging the gap should go hand in hand, which requires more investments in research and development and technology dissemination. Factor productivity in IGP region is not so impressive because of inefficiency in utilisation of factor inputs. Land productivity can be enhanced with the help of identification and elimination of location-specific production constraints in rice and wheat crops. Labour productivity can be improved with increased spending on training and skill development activities for young farm labourers who will form the nuclei of future agriculture. While doing so, greater penetration of technology and avoidance of labour migration from the region especially from Bihar and Uttar Pradesh.

There is scope to improve water productivity in IGP. Besides technology development through genetic manipulation, which can produce more grain with less water, water productivity can be increased by adopting different water-saving practices. Bouman and Tuong (2001) advocated improved irrigation management for increasing water productivity. In IGP, there is great potential for adopting resource conservation techniques like zero/reduced tillage and land levelling to enhance water productivity. While zero tillage potentially possesses water saving benefits and has been a success in wheat farms of IGP, efforts are required to upscale this technology to rice crop as well. Zero tillage is reported to have been adopted in trans Gangetic plain, further upscaling can be done in middle Gangetic plain. There is also a need to advocate collective management and decision making particularly in custom hiring services of expensive zero drill and land leveler machines for improving adoption rate of these water productivity enhancing/water conserving technologies and also achieving inclusive growth accommodating small and marginal farmers making these technologies accessible to them. In the IGP states, wherever surface irrigation is dominant, efforts on revamping irrigation infrastructure is required and also efficient irrigation governance is required for managing ground water resources in over-exploited regions of IGP. Community based on-farm irrigation management can be followed in IGP.

The disadvantaged and low productivity regions need to be accorded higher priority. Targeted developmental efforts should be on those districts where the rice and wheat productivity is very low. Improving institutional mechanisms in input delivery, monitoring mechanism to ensure the input subsidy reaching the target group and needy, ensuring timely planting, providing supplemental irrigation, efficient extension services to remove technology gaps and improve technology dissemination and market access are some areas that need to be further strengthened. Besides tangible inputs, providing timely technical information input to farmers in undertaking rice and wheat crop production activities is equally important, which is so easy in this modern information era. Appropriate mechanism should be in place in order to make sure agricultural information system work effectively. As inputs use is intensive in IGP, education and awareness among farmers on adverse impacts of overuse of inputs and the need for its optimal use can also help sustainability. It is important to enhance the productivity of rice and wheat crops in the IGP region but not at the cost of environmental degradation. Critical recommendations for INM and IPM modules for each state in the region can be adhered to.

While area expansion has very limited scope in the region, much of the production increase has to come from yield growth increase. While IGP being a food basket of India, any dip in area and yield growth of rice and wheat crops in IGP can impact India’s food security. Concerted efforts are therefore required to work on technology domain while managing the resources in an efficient manner. Unless significant progress is made in technology breakthrough which could greatly reduce the production costs and pushing the production frontier significantly upwards, the concerns may remain. Efforts on enhancing adoption of environment friendly resource conservation technologies in rice and wheat crops are required so that sustainable production of these crops in IGP can be achieved.

Received February 2011. Revision accepted May 2012.

NOTES

1. Labour productivity has been computed as the ratio of crop yield to labour use.
2. Irrigation intensity as the ratio of gross irrigated area to net irrigated area and expressed in percentage.

REFERENCES

Aggarwal, P.K., K.K. Talukdar and R.K. Mall (2000), *Potential Yields of the Rice Wheat System in the Indo Gangetic Plains of India*, Rice-Wheat Consortium Paper Series 10, Rice-Wheat Consortium for the Indo-Gangetic Plains, New Delhi and Centre for Applications Systems, Indian Agricultural Research Institute, New Delhi.

Aguilar, M.D., M. Grau and J.M. Contreras (1997), “Effect of Pre-Seeding Nitrogen Fertilisation on Rice Yield Components Under Water High Salinity Conditions in Southern Spain”, in paper presented at the International Symposium on Rice Quality, Nottingham, U.K., 24–27 November.

Bouman, B.A.M. and T.P. Tuong (2001), “Field Water Management to Save Water and Increase Its Productivity in Irrigated Lowland Rice”, *Agricultural Water Management*, Vol.49, pp.11–30.

Calpe, C. (2003), “Status of the World Rice Market in 2002”, in Proceedings of the 20th Session of the International Rice Commission, 23-26 July 2002, Bangkok, Thailand, FAO, Rome, Italy, pp.35-40.

Dandekar, V.M. (1980), “Introduction”, Paper presented at the Seminar on Data and Methodology for the Study of Growth Rates in Agriculture, *Indian Journal of Agricultural Economics*, Vol.35, No.2, April-June, pp.1-12.

Kumar, P., A. Kumar and S. Mittal (2004), “Total Factor Productivity of Crop Sector in the Indo-Gangetic Plain of India: Sustainability Issues Revisited”, *Indian Economic Review*, Vol.39, No.1, pp. 169-201.

Ladha, J.K., K.S. Fischer, M. Hossain, P.R. Hobbs and B. Hardy (Eds.) (2000), *Improving the Productivity and Sustainability of Rice-Wheat Systems of the Indo-Gangetic Plains: A Synthesis of NARS-IRRI Partnership Research*, IRRI Discussion Paper Series No. 40, International Rice Research Institute, Los Banos, Philippines.

Minhas, B.S. and A. Vaidyanathan (1964), “Growth of Crop Output in India, 1951-54 to 1958-61. Analysis by Component Elements”, *Journal of Indian Society of Agricultural Statistics*, Vol. 28, No.2, pp. 230-252.

Pingali, P.L. and M.W. Rosegrant (1996), “Confronting the Environmental Consequences of the Green Revolution”, in Proceedings of the 18th Session of the International Rice Commission. 7–9 September 1994, Rome, Italy, pp. 59–69.

Ray, S.K. (1983), “An Empirical Investigation of the Nature and Causes for Growth and Instability in Indian Agriculture: 1950-80”, *Indian Journal of Agricultural Economics*, Vol.38, No.4, October-December, pp. 459-474.