Sustainable Agriculture, Poverty and Food Security

Edited by

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Volume 2

ISBN 81-7033-725-9 (set)

Published by
Prem Rawat for ***Rawat Publications***
Satyam Apts., Sector 3, Jain Temple Road, Jawahar Nagar, Jaipur - 4 (India)
Phone: 0141 651748 / 657006 Fax: 0141 651748
e-mail : info@rawatbooks.com
www.rawatbooks.com

Delhi Office
G-4, 4832/24, Ansari Road, Daryaganj, New Delhi 110 002
Phone: 011-3263290

Typeset by Rawat Computers, Jaipur
Printed at Chaman Enterprises, New Delhi

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Measuring Sustainability of Rice-Wheat-Based Cropping System

P.K. Joshi, Laxmi Tewari and B.C. Roy

The rice-wheat-based cropping system (RWCS) is one of the most productive systems in India. It stretches from Punjab to West Bengal in the Indo-Gangetic Plain in an area of about 10 million hectares. The system has significant historical contribution in making India a food secure and self-sufficient nation. Foodgrain production in this system has increased more than four times from nearly 24 million tonnes in 1950-51 to 102 million tonnes in 1998-99. The system also contributed about 50 percent of the foodgrain production, and more than 75 percent of the total foodgrain procurement during the mid-1990s in the country (Kumar *et al.*, 1999). It is characterized as the backbone of the public distribution system (PDS) and a strong base for the food security of the country.

There are now reports that the system is showing signs of fatigue in terms of production (Abrol, 1996; Paroda, 1996; Pingali and Shah, 1999). Some estimates revealed that the annual growth in total factor productivity of the RWCS has declined from about 3 percent during 1976-85 to (-) 0.4 percent during 1985-92 (Kumar *et al.*, 1999). The productivity of rice and wheat in some parts has already ceased to increase and in few it has shown declining trends. Some regions have also shown that the cultivation rice and wheat has become less profitable over time (Chaudhary and Harrington, 1993).

Several ecological problems have also erupted as a result of past growth sources. Important among those are: (i) depletion/pollution of ground water resource, (ii) soil salinity and waterlogging, (iii) nutrient mining, (iv) increased incidence of insects pests and weeds, and (v) loss of biodiversity (Joshi *et al.*, 1998; Pingali and Shah, 1999). These emerging threats in this system may seriously jeopardize the agricultural growth and adversely affect the food security of those living within and outside the system.

Meeting additional foodgrain requirements for the growing population, which has already crossed one billion, is the real challenge for the country. How far the RWCS is sustainable to meet the future foodgrain demand will be debated in this paper in the light of growing ecological degradation and stagnating productivity. It is, therefore, necessary to analytically understand the system from the production and ecological points of view. The study is an attempt to diagnose historical status of sustainability in the RWCS. The specific objective of the study is to measure the temporal and spatial variation in the sustainability status of RWCS.

Study Area and Data

The study is confined to the Indo-Gangetic Plain (IGP) of India, which is divided into four agro-ecological zones: (i) trans-Gangetic plain, (ii) upper-Gangetic plain, (iii) middle-Gangetic plan, and (iv) lower-Gangetic plain. Each agro-ecological zone is further divided in to sub-zones depending upon soil and agro-climatic conditions. The salient characteristics of the sub-zones are presented in Table 1. It may be seen from the data that there is large diversity with respect to rainfall (385 to 1,800 mm), soils (sandy loam to laterite and alluvial), and irrigation development (25 to 90 percent). The study is mainly based on the secondary data, which were obtained from various published sources. District-wise data were collected on area, production and yield of rice and wheat and their irrigated area. Data were also acquired to estimate ground water utilization, land degradation and biodiversity. District-wise data were pooled for sub-zones in different agro-ecolozical zones.

Table 1 *Salient Features of Different Sub-regions in IGP*

Sub-regions	*Area under (%)*		*Irrigated area (%)*	*Normal rainfall (mm)*	*Soil type*
	Rice	*Wheat*			
		Trans Gangetic Plain Region			
Foothills of Shivalik	27	46	78	880	Sandy loam to clay loam
Plains	42	47	87	674	Calcareous and fine textured
Arid	31	54	89	385	Desertic soil
		Upper Gangetic Plain Region			
North western plain	17	33	81	933	Alluvial soils
South western plain	9	37	85	708	Alluvial soils
Central plain	27	38	69	1061	Alluvial soils
		Middle Gangetic Plain Region			
Eastern plain	35	40	75	1335	Light alluvial and calcareous clay
Vindyan	33	29	42	1335	Sandy loam and red yellow clay
South Bihar plain	50	13	40	1335	Alluvium
North Eastern plain	24	33	47	1335	calcareous clay to deep alluvial
North Bihar plain	43	28	48	1335	Sandy loam to clayey
North east plain	46	23	60	1335	Sandy to silty loam
		Lower Gangetic Plain Region			
Barind plain	61	7	71	1800	Alluvial soils
Central alluvial plains	62	4	60	1450	Alluvial soils
Rorh plain	79	2	25	1200	Laterite and lateritic soil
Alluvial coastal saline plain	75	1	26	1700	Alluvial soils

Note: * Figures related to 1996.

Analytical Approach

There are number of definitions of sustainable system. The essence of all the definitions is that an agricultural system would be sustainable if it satisfies the private entrepreneurs' needs (over time) while conserving the natural resources (Gomez *et al.*, 1994). Entrepreneurs' satisfaction includes issues such as production, productivity, profitability, stability, etc., while resource conservation is related with soil loss, soil nutrient budget, biodiversity, soil compaction, ground water, soil fertility, etc. It is not always necessary that while maximizing entrepreneur's satisfaction, resource conservation is being given due cognizance. Any system that fails to satisfy these two requirements is bound to change significantly over the short run, and therefore considered unsustainable. Sustainability issues encompass both entrepreneurs' satisfaction and resource conservation. Radar approach has been used to better understand sustainability issues in the RWCS by amalgamating entrepreneurs' satisfaction and resource conservation. Following steps were used to develop sustainability indices for different sub-ecological zones:

Step I: Identification of Indicators

Indicators for entrepreneurs' satisfaction and resource conservation should be easily measurable. In the context of present study, growth in production, yield levels and yield stability are considered to be the prime considerations for maximizing the private goals. The best indicator should have been the profit but lack of information has constrained us to use this indicator. Therefore, some proxy indicators have been used for assessing the private goals. On the other hand, the society is concerned with the conservation of soil and water resources, and the biodiversity. In the present analysis, extent of land degradation was computed by adding the season-wise current fallow, permanent fallow, culturable waste and permanent pasture. Share of ground water in the net irrigated area was taken as proxy for utilization of ground water resource. Biodiversity was estimated by computing the Simpson Index of Biodiversity. Often, in the race of maximizing private goals, the entrepreneurs ignore the social objectives of conserving soil and water resources and the biodiversity. All these indicators were measurable and easily available temporally, and have almost similar implications spatially. Quantitative values of all the indicators are given in Annexure I to VI.

Step II: Specifying Threshold Levels

Threshold levels are fixed to denote boundaries between sustainable and unsustainable system. Unless the threshold levels are defined, it would not be possible to distinguish between sustainable and unsustainable systems. These levels must satisfy the private entrepreneurs' needs and optimize social objectives. In the context of present study, the threshold levels for different indicators were decided as follows on next page.

Threshold levels can be changed depending upon the critical limits for maximizing private and social goals.

Indicator	*Threshold levels*
Growth in production	Equal or higher than population growth
Yield levels	At least 10 percent higher than the average of IGP level
Stability	At least average level of IGP level
Ground water use	Less than 65 percent of tubewell area to net irrigated area
Land degradation	Less than the average level of IGP level
Biodiversity	At least the average level of the IGP

Step III: Transforming Indicators into Sustainability Index

To transform indicators into sustainability index the following procedure was employed:

$$SI_t = [\{\Sigma\ w_i\ (I_t\ /T_i)\ + \Sigma\ w_j\ (J_t\ /T_j)\}/2]$$

where, SI_t is the sustainability index for t^{th} sub-zone; I_t is the value of indicator I (represented by production growth, yield levels, and stability) in the t^{th} sub-zone; J_t is the value of indicator J (represented by ground water use, land degradation and biodiversity) in the t^{th} sub-zone; T_i and T_j are the threshold values for i^{th} and j^{th} indicators; and w_i and w_j are the weights assigned to private and social goals.

Assigning values to weights is very critical. Different entrepreneurs or group of entrepreneurs may assign different weights to various indicators to maximize their satisfaction. Similarly, different regions may decide different weights to various social objectives. In the present analysis, we have assigned equal weights to all indicators. In the equation given above, the first computation is index of private goals, whereas the second component is the index of social goals. Assigning equal weights to each index will yield the sustainability index. If the index is greater than one, the system will be characterized as sustainable. If it is less than one, it will be an unsustainable system. Even if the sustainability index is greater than one, the sufficient condition is that the index of private goals must be greater than one. It means that a system can be sustainable only if the entrepreneurs are maximizing their satisfaction, and also meeting the social objectives.

The sustainability indices for rice and wheat for all sub-zones were computed for three time periods, which coincided with the agricultural performance in the IGP. These periods were: (i) Stage I: 1966-67 to 1975-76, which was characterized as the early adoption of improved technology; (ii) Stage II: 1976-77 to 1985-86, which was considered to be the late adoption of improved technologies; and (iii) Stage III: 1986-87 to 1995-96, which was viewed as saturation of improved technologies. Growth rates in rice and wheat production, yield levels and de-trended coefficient of variation in rice and wheat yields were computed for these three time periods. Similarly, area under ground water irrigation, land degradation and biodiversity were confined to these periods.

Results and Discussion

Composite indices were computed for both private and social goals in different sub-zones of the IGP during three periods (Tables 2 and 3). The composite indices for

Table 2 *Indices of Private Objectives with Respect to Rice and Wheat*

Sub-region	*Rice*			*Wheat*		
	1967-76	*1977-86*	*1987-96*	*1967-76*	*1977-86*	*1987-96*
		Trans-Gangetic Plain Region				
Foothills of Shivalik	2.01	1.59	1.09	1.56	1.38	1.08
Plains	2.85	2.02	0.98	1.44	1.40	0.75
Arid	3.87	2.79	2.17	1.40	1.56	1.19
		Upper-Gangetic Plain Region				
North-western plain	1.44	1.34	0.63	1.14	1.50	0.81
South-western plain	1.18	1.38	1.77	1.19	1.43	0.72
Central plain	1.33	1.62	1.24	1.43	1.52	1.05
		Middle-Gangetic Plain Region				
Eastern plain	1.06	1.97	1.25	2.07	1.79	1.09
Vindyan	0.90	1.25	1.38	1.28	2.13	1.91
South Bihar plain	0.97	0.92	-0.17	2.86	1.21	1.00
North-eastern plain	1.13	1.74	1.35	0.99	1.56	0.98
North Bihar plain	1.06	0.88	0.13	2.58	1.05	1.42
North-east plain	1.56	0.80	0.53	1.73	1.37	1.01
		Lower-Gangetic Plain Region				
Barind plain	0.79	0.88	1.22	4.67	2.41	1.26
Central alluvial plains	1.07	1.18	1.07	3.30	1.82	1.33
Rorh plain	0.81	1.10	0.90	2.64	1.21	0.48
Alluvial coastal saline	0.86	0.98	0.90	4.25	1.32	-0.86
Unsustainable area with respect to private objective (%)	34.00	43.00	46.00	9.00	0.00	46.00

rice during the Green Revolution (1966-77) period showed that private objectives were higher than the threshold levels in all the sub-zones, except Vindyan and south Bihar plains in the middle-Gangetic plain, and Barind, Rorh and Alluvial coastal saline plains in the lower-Gangetic plain. Although the yield levels of rice were below than the threshold levels in majority of the sub-zones of IGP, the growth in production and stability in yields have made it possible that the composite indices were greater than one. About 66 percent of the rice area in IGP was showing the composite index of private objectives greater than one. Comparing the results for the 1987-96 period, it was noted that plain sub-zone in trans-Gangetic plain; north-western plain in upper-Gangetic plain; south Bihar, north Bihar and north-east plain in middle Gangetic plain; and Rorh and Alluvial coastal saline plains in lower-Gangetic plain were not qualifying to satisfy the private goals. These sub-zones cover roughly 46 percent of the rice area in IGP – an increase of about 84 percent area in a period of three decades. The growth in production, yield levels and stability was lower than the threshold levels during 1987-96 than was during the Green Revolution period (see Annexure I, II and III).

In case of wheat, all the sub-zones, except north-eastern plain in the middle-Gangetic plain, were qualifying for sustainable private objective during the Green Revolution period. This was due to much higher growth in wheat production than that of population growth rate, although many sub-zones were below the threshold levels with respect to yield and stability. The situation changed during 1987-96 period, when about 46 percent of wheat area in IGP was not meeting the minimum requirements of private objectives. It was due to fast deceleration in growth in wheat production (see Annexure I). In all the sub-zones, growth in wheat production has sharpely decelerated during 1987-96 period as compared to 1977-86 period.

The composite indices of social objectives were indicating that all the sub-zones in IGP, except foothills of Shivaliks in the trans-Gangetic plain, were utilizing natural resources, and conserving biodiversity above the threshold limits. Negligible rice area was unsustainable with respect to meeting the social objectives during the Green Revolution period. Situation changed sharply during 1977-86 period, when 32 percent of rice area was unable to meet the social objectives (Table 3). This was largely due to overuse of ground water resource beyond the threshold limit. During this period, share of ground water in net irrigated area has rapidly increased in areas

Table 3 *Indices of Social Objectives with Respect to Rice and Wheat*

Sub-region	*Rice*			*Wheat*		
	1967	*1977*	*1996*	*1967*	*1977*	*1996*
	Trans-Gangetic Plain Region					
Foothills of Shivalik	0.87	0.87	0.94	0.90	0.93	0.93
Plains	1.06	0.95	0.99	1.28	1.34	1.52
Arid	2.39	1.11	1.05	2.72	1.48	1.34
	Upper-Gangetic Plain Region					
North-western plain	1.23	1.04	0.91	1.28	1.15	1.08
South-western plain	1.27	0.98	0.87	1.35	1.18	1.06
Central plain	2.07	1.13	0.97	2.14	1.18	1.13
	Middle-Gangetic Plain Region					
Eastern plain	1.47	0.99	0.89	1.46	1.00	0.98
Vindyan	3.00	1.77	1.45	2.97	1.75	1.40
South Bihar plain	1.86	0.97	0.99	1.83	0.94	0.90
North eastern plain	1.45	1.00	0.83	1.41	0.96	0.79
North Bihar plain	1.94	1.01	1.11	1.79	0.88	0.90
North-east plain	1.75	1.15	1.16	1.64	1.03	0.85
	Lower-Gangetic Plain Region					
Barind plain	3.17	1.45	1.10	3.22	1.50	1.13
Central alluvial plains	3.47	1.29	0.82	3.49	1.27	0.81
Rorh plain	12.18	4.58	3.04	12.32	4.50	2.95
Alluvial coastal saline	16.40	1.96	1.20	16.42	1.92	1.16
Unsustainable area with respect to social objective(%)	1.00	32.00	59.00	3.00	27.00	38.00

where rainfall was scanty, and ground water extraction was much higher than the recharge. In one of the sub-zones (namely, eastern plain of middle-Gangetic plain), it was due to excessive land degradation. The situation further worsened during 1987-96 period, when nearly 60 percent of the rice area was not meeting the minimum requirements of social objectives. In case of wheat, the situation was better than rice. About 38 percent of wheat area during 1987-96 period was not meeting the social objectives. It was because land degradation during wheat growing season was of less severity, particularly in upper-Gangetic plain. On the other hand, a large area is kept fallow in the middle-Gangetic plain due waterlogging conditions as a result of high rainfall and poor drainage provisions. During 1987-96 period, excessive ground water use was the main cause of not meeting the social objectives in many sub-zones. Utilization of ground water is undoubtedly useful for increased agricultural production. Unfortunately, it is happening in areas where rainfall is ranging between 350 and 700 mm, and rice has emerged as principal crop. Ground water utilization is still at its infancy in many parts of middle-and lower-Gangetic plains, where rainfall is plenty. Underutilization of this crucial resource is causing problem of waterlogging and adversely affecting agricultural production. Ground water utilization in these regions would function as vertical drainage and contribute to raising agricultural production by pushing up yields and utilizing lands kept fallow due to excess moisture.

It is interesting to note that there was a gradual shift towards specialization in all the regions, except in lower-Gangetic plain, where diversification was expanding (see Annexure VI). The Simpson Index of Biodiversity has come down from 0.83 in 1967-77 to 0.75 in 1987-96 in IGP, with maximum decline in the plain sub-region of trans-Gangetic region from 0.79 to 0.64. Shifting to more specialization in trans- and upper-Gangetic plains has already witnessed a number of second generation problems, like increased incidence of insect pests, problem of weeds, etc., which induced indiscriminate use of pesticides and herbicides. The lower-Gangetic plain, which was earlier characterized as monocrop area due to extensive rice cultivation, was now allowing for crop diversification.

For a sustainable system, the requirement is that composite index of sustainability, which amalgamates both private and social objectives, should be greater than one. The results revealed that about 62 percent of rice area and 53 percent of wheat area in IGP during 1987-96 period were unsustainable, where the private and social needs were less than the threshold levels (Table 4). The corresponding area during 1967-76 period was 34 percent for rice and 9 percent for wheat. The sustainability indices of rice and wheat for all sub-zones during 1966-76 and 1987-96 periods were also plotted in the form of radar (Figures 1 and 2). It may be seen that during 1966-76 period, most of the sub-zones were placed in the sustainable boundary. The situation changed during the period 1987-96, when majority of the sub-zones were pushed to unsustainable zone. It may be mentioned that a large part of the trans-Gangetic and upper-Gangetic plains was non-traditional rice growing area. Indiscriminate ground water utilization and declining biodiversity severely affected the yield levels and production of rice in these regions. Ground water utilization is excessively increasing without any provision of recharge.

Overutilization of ground water has caused fall in the water table, which escalated production cost and adversely affected production. On the other hand, declining biodiversity has also erupted several insect pests and weeds in the region, which has adversely affected yield levels and production. Less utilization of ground water in the middle and lower-Gangetic plains, where rainfall is ranging from 1,500 to 2,000 mm, has caused waterlogging conditions, which suppressed rice and wheat production. This indicated that optimum utilization of natural resources and an ideal biodiversity mix were the necessary conditions for sustaining production and satisfying private needs.

Table 4 *Sustainability Indices with Respect to Rice and Wheat*

Sub-region	*Rice*			*Wheat*		
	1967	*1977*	*1996*	*1967*	*1977*	*1996*
		Trans-Gangetic Plain Region				
Foothills of Shivalik	1.44	1.23	1.02	1.23	1.15	1.00
Plains	1.95	1.48	0.98	1.36	1.37	1.13
Arid	3.13	1.95	1.61	2.06	1.52	1.27
		Upper-Gangetic Plain Region				
North-western plain	1.33	1.19	0.77	1.21	1.32	0.94
South-western plain	1.22	1.18	1.32	1.27	1.30	0.89
Central plain	1.70	1.37	1.11	1.78	1.35	1.09
		Middle-Gangetic Plain Region				
Eastern plain	1.27	1.48	1.07	1.76	1.40	1.04
Vindyan	1.95	1.51	1.41	2.13	1.94	1.65
South Bihar plain	1.42	0.94	0.41	2.34	1.07	0.95
North eastern plain	1.29	1.37	1.09	1.20	1.26	0.88
North Bihar plain	1.50	0.94	0.62	2.19	0.96	1.16
North-east plain	1.65	0.98	0.84	1.69	1.20	0.93
		Lower-Gangetic Plain Region				
Barind plain	1.98	1.17	1.16	3.95	1.96	1.20
Central alluvial plains	2.27	1.23	0.94	3.40	1.55	1.07
Rorh plain	6.50	2.84	1.97	7.48	2.86	1.72
Alluvial coastal saline	8.63	1.47	1.05	10.34	1.62	0.15
Unsustainable area in IGP (%)	34.00	43.00	62.00	9.00	6.00	53.00

Conclusion

The analysis suggested that a large part of rice wheat system in IGP was showing clear signs of unsustainability. It may be mentioned that the unsustainable sub-regions were contributing about 55 percent of both rice and wheat production to IGP. Their share in increased rice and wheat production during 1967-96 was nearly 50 percent. The production increase has now been constrained due to plateauing of rice and

Figure 1 *Sustainability Status of Rice in Indo-Gangetic Plain in 1966 and 1996*

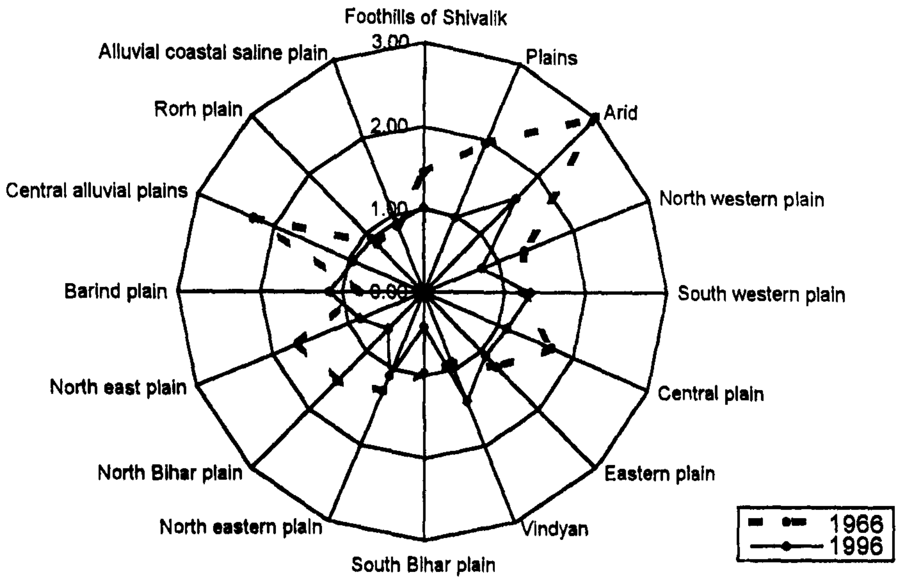
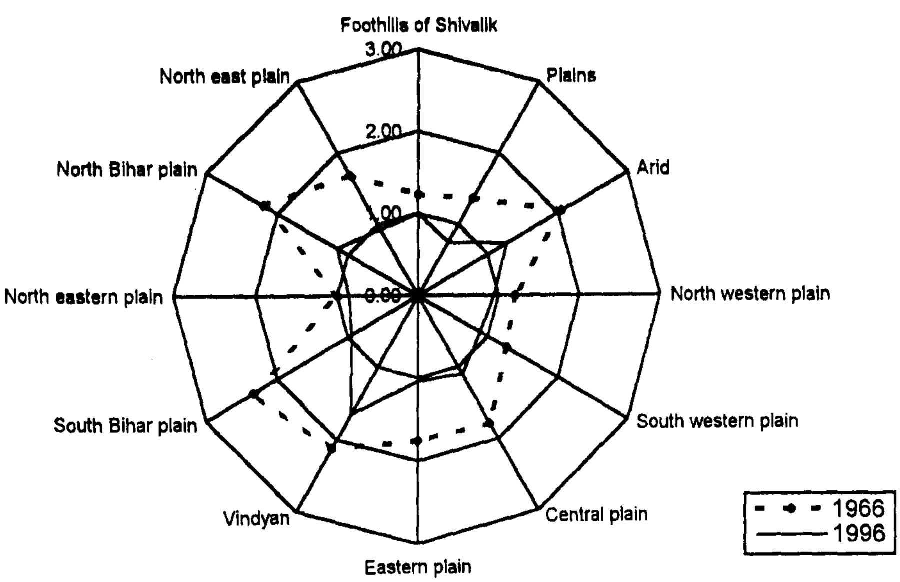


Figure 2 *Sustainability Status of Wheat in Indo-Gangetic Plain in 1966 and 1996 (excluding lower-gangetic plain)*



wheat yields and limited scope of area expansion. In both trans- and upper-Gangetic plains, overexploitation of ground water and declining biodiversity were responsible for unsustainability. More concerning issue in it middle- and lower-Gangetic plains was that yield levels of both rice and wheat have reached to plateau even at a very low level than the potential. A large yield gap lasted between what farmers were achieving and what the potential existed with the available technologies. The need is to better understand the constraints in production of rice and wheat in these regions.

Table 5 *Status of Sustainability of Rice and Wheat in Different Sub-regions of IGP*

Sub-region	*Rice*			*Wheat*		
	1967	*1977*	*1996*	*1967*	*1977*	*1996*
		Trans-Gangetic Plain Region				
Foothills of Shivalik	S	S	S	S	S	S
Plains	S	S	US	S	S	US
Arid	S	S	S	S	S	S
		Upper-Gangetic Plain Region				
North-western plain	S	S	US	S	S	US
South-western plain	S	S	S	S	S	US
Central plain	S	S	S	S	S	S
		Middle-Gangetic Plain Region				
Eastern plain	S	S	S	S	S	S
Vindyan	US	S	S	S	S	S
South Bihar plain	US	US	US	S	S	US
North-eastern plain	S	S	S	US	S	US
North Bihar plain	S	US	US	S	US	S
North-east plain	S	US	US	S	S	US
		Lower-Gangetic Plain Region				
Barind plain	US	US	S	S	S	S
Central alluvial plains	S	S	US	S	S	S
Rorh plain	US	S	US	S	S	US
Alluvial coastal saline	US	US	US	S	S	US

Note: S indicates sustainable system; and US indicates unsustainable system.

IGP has contributed to a great extent in achieving the food security and self-sufficiency in the country. The system, however, is now showing saturation with respect to production increase. Ignoring the problems arising in IGP would threat the food security of the country, and more particularly of the region. Nonetheless, there is huge potential exists in raising yield levels in middle- and lower Gangetic plains. It has to be exploited by appropriate technology intervention to raise yield levels and judicious use of natural resources.

Annexure I *Annual Compound Growth Rates in Production of Rice and Wheat in Different Sub-regions of IGP (%)*

Sub-region	*Rice*			*Wheat*		
	1967-76	*1977-86*	*1987-96*	*1967-76*	*1977-86*	*1987-96*
			Trans-Gangetic Plain Region			
Foothills of Shivalik	9.34	5.67	2.99	6.45	5.25	2.78
Plains	14.06	7.12	1.51	4.35	4.94	0.37
Arid	20.83	12.25	8.66	4.79	6.01	3.38
			Upper-Gangetic Plain Region			
North-western plain	5.91	5.07	0.09	3.26	6.29	1.39
South-western plain	3.35	3.82	7.10	3.63	5.48	0.89
Central plain	5.38	6.12	3.79	5.99	6.83	3.23
			Middle-Gangetic Plain Region			
Eastern plain	3.96	8.28	4.21	9.83	8.65	3.34
Vindyan	3.05	5.17	5.41	0.46	8.77	7.51
South Bihar plain	0.45	1.04	-5.29	13.06	2.84	1.98
North-eastern plain	3.30	6.76	1.90	2.69	6.89	2.68
North Bihar plain	2.67	2.52	-3.34	13.13	3.79	5.06
North-east plain	5.64	1.36	-1.06	8.64	3.73	1.84
			Lower-Gangetic Plain Region			
Barind plain	1.86	3.36	4.31	28.94	10.75	3.37
Central alluvial plains	3.49	4.12	3.35	18.19	6.72	3.37
Rorh plain	1.05	2.66	2.59	13.94	3.29	-1.07
Alluvial coastal saline plain	2.27	3.34	2.69	25.17	3.33	-9.2
Threshold value	2.30	2.26	2.21	2.30	2.26	2.21

Annexure II *Average Yield of Rice and Wheat in Different Sub-regions of IGP*

Sub-region	*Rice*			*Wheat*		
	1967	*1977*	*1996*	*1967*	*1977*	*1996*
			Trans-Gangetic Plain Region			
Foothills of Shivalik	1132	2188	2820	1290	2002	3496
Plains	1318	2841	2963	1949	2454	3963
Arid	1308	2881	3999	1749	2479	3873
			Upper-Gangetic Plain Region			
North-western plain	820	820	2351	1208	1655	2702
South-western plain	816	1257	2125	1340	1794	2899
Central plain	670	1112	1851	967	1298	2164
			Middle-Gangetic Plain Region			
Eastern plain	496	937	1890	1064	1447	2216
Vindyan	563	912	1556	1124	1029	1693
South Bihar plain	874	1028	1085	799	1371	1906
North-eastern plain	668	816	1559	940	1108	2009
North Bihar plain	589	826	980	772	1290	2102
North-east plain	616	959	1344	753	1454	1812
			Lower-Gangetic Plain Region			
Barind plain	881	1002	1937	851	1418	2221
Central alluvial plains	1086	1331	2335	1036	1807	2477
Rorh plain	1300	1428	2341	1021	1494	2436
Alluvial coastal saline plain	1096	1177	1979	1069	1889	1909
Threshold value	1000	1337	2116	1131	1632	2559

Annexure III *Coefficient of Variation in Yield of Rice and Wheat in Different Sub-regions of IGP (%)*

Sub-region	*Rice*			*Wheat*		
	1967-76	*1977-86*	*1987-96*	*1967-76*	*1977-86*	*1987-96*
			Trans-Gangetic Plain Region			
Foothills of Shivalik	11.04	10.84	9.39	10.8	8.53	7.44
Plains	14.09	13.9	14.14	10.58	7.22	6.73
Arid	15.22	13.33	10.67	8.53	7.16	6.33
			Upper-Gangetic Plain Region			
North-western plain	12.43	21.17	12.58	14.41	9.96	9.11
South-western plain	17.65	27.59	17.51	12.37	11.13	7.66
Central plain	13.45	23.76	18.55	12.19	10.74	10.26
			Middle-Gangetic Plain Region			
Eastern plain	13.4	27.53	15.27	14.38	9.07	10.85
Vindyan	11.18	13.72	15.29	41.9	27.99	19.68
South Bihar plain	26.29	28.41	23.96	32.99	23.42	16.44
North-eastern plain	17.74	29.33	41.11	15.1	13.89	11.29
North-Bihar plain	20.18	16.57	24.68	19.6	10.06	13.54
North-east plain	22.27	20.26	24.32	11.18	23.94	18.22
			Lower-Gangetic Plain Region			
Barind plain	9.49	7.07	12.73	6.6	23.44	16.79
Central alluvial plains	8.3	12.72	9.49	14.74	20.72	18.07
Rorh plain	9.55	19.27	6.92	13.23	19.35	12.26
Alluvial coastal saline plain	6.96	10.76	8.98	10.37	20.25	11.51
Threshold value	14.00	19.00	17.00	16.00	15.00	12.00

Annexure IV *Share of Tubewell Irrigation in Net Irrigated Area in Different Sub-regions of IGP (%)*

Sub-region	*1967*	*1977*	*1996*
	Trans-Gangetic Plain Region		
Foothills of Shivalik	61.21	67.98	81.72
Plains	39.28	62.85	72.85
Arid	6.92	28.83	36.86
	Upper-Gangetic Plain Region		
North-western plain	32.81	52.83	71.17
South-western plain	23.47	49.67	70.84
Central plain	9.16	34.13	57.36
	Middle-Gangetic Plain Region		
Eastern plain	16.49	50.06	69.52
Vindyan	4.75	9.76	13.52
South Bihar plain	8.65	24.89	36.17
North-eastern plain	14.37	31.35	51.27
North Bihar plain	10.10	47.84	65.95
North-east plain	10.19	21.07	43.44
	Lower-Gangetic Plain Region		
Barind plain	4.71	14.27	23.59
Central alluvial plains	4.13	18.98	43.64
Rorh plain	1.01	3.00	4.84
Alluvial coastal saline plain	0.73	8.71	17.52
Threshold value	65.00	65.00	65.00

Annexure V *Extent of Land Degradation in Different Sub-regions of IGP ('000 ha)*

Sub-region	*1967*	*1977*	*1996*
	Trans-Gangetic Plain Region		
Foothills of Shivalik	1349	1126	766
Plains	3666	2976	1906
Arid	3803	3789	3168
	Upper-Gangetic Plain Region		
North-western plain	3212	3123	3027
South-western plain	3960	3492	3263
Central plain	4058	4021	3119
	Middle-Gangetic Plain Region		
Eastern plain	3159	2948	2220
Vindyan	1044	967	750
South Bihar plain	12213	12315	4721
North-eastern plain	7889	7530	7073
North-Bihar plain	3260	3150	1735
North-east plain	3354	3285	1455
	Lower-Gangetic Plain Region		
Barind plain	857	978	873
Central alluvial plains	2773	2854	4230
Rorh plain	561	674	634
Alluvial coastal saline plain	849	785	815
Threshold value (kharif) %	80	74	64
Threshold value (Rabi) %	71	66	52

Annexure VI *Simpsion Index of Crop Diversification in Different Sub-regions of IGP (%)*

Sub-region	*Crop diversification*		
	1967	*1977*	*1996*
	Trans-Gangetic Plain Region		
Foothills of Shivalik	79	74	67
Plains	83	74	64
Arid	79	77	75
	Upper-Gangetic Plain Region		
North-western plain	83	79	77
South-western plain	88	85	80
Central-plain	86	83	78
	MiddleGangetic Plain Region		
Eastern plain	78	79	70
Vindyan	80	77	73
South Bihar plain	70	66	66
North-eastern plain	75	71	68
North Bihar plain	75	72	68
North-east plain	61	57	61
	Lower-Gangetic Plain Region		
Barind plain	60	62	58
Central alluvial plains	51	56	66
Rorh plain	29	38	31
Alluvial coastal saline plain	38	43	39
Threshold value	70	69	66

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