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Sustaining rice–wheat system productivity in the Indo-Gangetic plains: water management-related issues

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Abstract

The Indo-Gangetic plains constitute the most important agricultural region in south Asia. From early 1960s to late 1980s, the area under rice–wheat cropping systems in the Indian portion of the plains has grown rapidly and the crop yields have increased resulting in large production gains. The gains were particularly significant in the north-western region covered by the states of Punjab, Haryana, and western Uttar Pradesh although, of late, growth rates have slowed. In comparison productivity levels and growth rates in the eastern region represented by eastern Uttar Pradesh, Bihar and West Bengal have remained low. Water management-related issues pose a major concern to the sustainability of production systems across the region. In the eastern region flooding is widespread, groundwater resources have not been adequately developed and water availability to crops from surface irrigation systems is unreliable and poorly distributed. Over exploitation of groundwater resources and quality degradation are major concerns in sustaining high productivity in the north-western region. Suggestions are made on areas which call for enhanced research efforts.

Keywords: Indo-Gangetic plains; Rice–wheat systems; Irrigation

1. Introduction

South Asia's Indo-Gangetic plains spread over the region's four countries, Pakistan, India, Nepal and Bangladesh, are agriculturally the most important region of the sub-continent. The Indian portion of the plains accounts for 27% of the net cultivated area and nearly 52% of the food grains production in the country.

The plains experience a gradual transition in rainfall from east to west. The alluvial plains constitute one of the richest groundwater resources with the greatest potential for

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development. The aquifer systems are extensive, thick, hydraulically inter-connected and moderate-to-high yielding. The salinity of groundwater increases in the south-west direction with the decrease in rainfall, suggesting that groundwater picks up salt as it passes from the recharge to transition–discharge zones.

2. Rice–wheat cropping system

Rice and wheat account for nearly 75% of the total food grains and nearly 60% of the caloric intake by the Indian populace. In 1995, the areas planted with rice and wheat crops in India were 43 and 25 million ha, respectively. Nearly 25% of the area under rice and 40% of the area under wheat are currently cropped in a rice–wheat sequence. In this system rice is grown in the *kharif* (rainy) season and followed by wheat in the *rabi* (winter) season. Although by definition rice and wheat crops constitute the system components, in practice farmers include a range of other crops in varying spatial and temporal sequences imparting a high degree of complexity to the system.

In the period 1959–1962 the area under rice–wheat cropping system was estimated at 4 million ha which grew to over 9 million ha by 1986–1989 (Hobbs and Morris, 1996). During this period the yields of rice and wheat increased significantly resulting in large gains in production and productivity of the two crops. These improvements were due to a combination of factors, the most important being the expansion of the irrigated area by harnessing surface and groundwater; the introduction and spread of dwarf photoperiod-insensitive high yielding varieties of rice and wheat; the increased use of inputs including fertilisers and plant protection chemicals; the greatly expanded and strengthened research and extension services; and the overall agricultural support policies.

3. Sustainability concerns

The annual growth in wheat and rice production between 1980–1981 and 1990–1991 was 3.2% considerably greater than the annual population growth rate of 2.1% during the same period. However, during the first 8 years of this decade (1990–1997) the annual increase in food grain production has been only 1.7%, slightly below the current population growth rate, and thus is a matter of concern. The reasons for slowed growth are, however, not the same across the region.

In the higher productivity north-western region, covering the states of Punjab, Haryana and western Uttar Pradesh, the gap between the average farm productivity levels and the yield potential of available germplasm is narrowing. In contrast, productivity levels in the eastern region, represented by eastern Uttar Pradesh, Bihar and West Bengal, are only one-half to one-third the levels achieved in the north-west. By far the most serious threats to the sustainability of production systems are related to issues of water management across the region. A good understanding of the issues is important for developing sound future strategies.

4. Eastern region – Causes of low productivity

4.1. Yield potential

In the wetter easter region, the winter season is shorter than in the north-west. Due to this and greater cloud cover during the later parts of the rainy season, the yield potential of rice and wheat crops is likely to be 15–20% lower than in the north-west. However, most field observations and experiments support the view that the current yields are far below their potential in the region.

4.2. Water availability and management

An important factor for continued low productivity of the rice–wheat system (Table 1) has been the non-timely availability of irrigation and the problems arising from inadequate drainage in the region.

Unlike in the north-west, groundwater resources in the eastern region have been poorly developed (Table 2). Surface irrigation systems in this region have been, typically, designed as a 'protective irrigation measure' for supplementing water during the *kharif* season and are based on run of the river diversion schemes with little or no storage. This implies that water availability from these is monsoon-dependent. Even during the monsoon water availability is unreliable and poorly distributed, often having a negative impact on yield. Indeed, examination of data on water deliveries (Meinzen-Dick, 1994)

Table 1
Area under rice–wheat cropping system and productivity of rice and wheat in the Indo-Gangetic plains (3-years average ending 1994)

State	Area under rice–wheat (million ha)	Productivity (kg ha^{-1})			Nutrient use (kg ha^{-1})
		Rice	Wheat	Rice–wheat	
Punjab	1.8	3370	3956	7326	162
Haryana	0.6	2730	3639	6369	108
Uttar Pradesh	5.6	1830	2345	4175	86
Bihar	1.7	1176	2003	3179	57
West Bengal	0.3	2011	2109	4120	88

Table 2
Extent of groundwater development in Indian states within the Indo-Gangetic plain (1992–1993)

State	No. of administrative units (blocks)	Average groundwater development (%)	Range of development (%)	No. of blocks over-exploited
Punjab	118	93.8	43–260	53
Haryana	108	92.6	32–203	42
Uttar Pradesh	895	37.1	3–63	21
Bihar	585	18.6	1–41	–
West Bengal	–	24.4	1–56	–

showed that inadequacy of water delivery was less of a problem than the timeliness of irrigation availability. While timely supplies had a significantly positive impact on yield, surplus supplies tended to reduce yield. Water scarcity had greatest adverse impact on production in the middle of the season while surpluses were most damaging at the beginning and towards the end of the season.

Efforts to improve productivity will call for significant improvements in the management of surface irrigation schemes and of drainage to reduce the adverse impact of widespread flooding. In the context of crop requirements efforts are needed to find ways to provide water for the early establishment of rice nurseries and subsequent early growth and tillering before the onset of major monsoon rains. Towards this, development of shallow tubewells together with land consolidation are required urgently. Groundwater development in the eastern region, however, is threatened by unpredicted consequences as exemplified by serious contamination of groundwater with arsenic in the West Bengal and Bangladesh region (Mandal et al., 1996).

4.3. North-west – sustaining high productivity

In contrast to the slow growth of rice–wheat productivity in the eastern region, productivity growth has been very significant in the north-west, e.g. in the states of Punjab and Haryana (Table 1), and the average rice and wheat yields compare well with those obtained in other countries. Factors that have contributed to enhanced productivity include the irrigation of almost the whole cropped area and the large-scale exploitation of groundwater in rice–wheat areas. This has ensured farmer control of irrigation which in turn has catalysed the spread of high yielding varieties and the greater use of inputs.

A major concern in the region is the sustainability of groundwater resources in the face of over-exploitation (Table 2). Continued expansion of groundwater use in the rice–wheat areas has led to:

- considerable lowering of water table such that the farmers now need to expend more on pumping;
- increased probability of water quality deterioration due to influence of high salt/alkali waters from the adjacent/deeper regions; and
- consequences for other components of the hydrological cycle e.g. reduced river flows.

Other sustainability concerns in the region related to accession and the adverse impact of agrochemicals, e.g. fertilisers and pesticides, on the quality of surface and ground water resources.

5. Researchable issues

A recent meeting of some 20 members of the Rice–Wheat Consortium identified several research issues in the area of water resource management for the rice–wheat cropping system. It was emphasised that water management-related issues had to be analysed in an integrated way at all the levels e.g. farm, irrigation system and policy level. The group stressed that water management research must address both the field-

and irrigation-system level problems. Similarly, there is need to emphasise the complete range of research issues – these will include efforts aimed at diagnosing the problem (diagnostic research); those aimed at testing and adapting known technologies and options (adaptive research) to those aimed at generating new technologies or new research approaches (strategic research).

It was considered necessary to identify and evaluate options using appropriate simulation/optimisation models for:

- augmenting groundwater recharge by increasing the supply to groundwater or decreasing groundwater withdrawals;
- predicting salt and water balances;
- evaluating salinity impacts on productivity;
- conjunctive management of ground and surface water resources;
- movement and impacts of agrochemicals on ground/surface water and on the soil profile;
- develop crop growth and water-use models to identify the areas of intervention for improving water-use efficiency in different water supply situations;
- enhancing 'on-farm' water-use efficiency by developing practical water application methods, schedules and appropriate management techniques for rice and wheat for specific water supply situations in given areas; and
- analysis of policy options in relation to pricing of input/output irrigation rates, electricity rates, regulation of groundwater, and impact analysis.

6. Conclusions

Water management-related issues are a major threat to the sustainability of rice–wheat cropping-based production systems in the Indian part of the Indo-Gangetic plains. Suggestions are made on the areas for enhanced research efforts to address emerging problems.

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