Sustaining Rice-Wheat Cropping System Productivity in the Indo-Gangetic Plains

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Abstract

Rice-Wheat cropping system which involves the growing of rice and wheat crops on the same piece of land in different seasons in a year, has emerged as a major production system in the Indo-Gangetic Plains of South Asia over the past nearly three decades. Spread over four countries of the region, Bangladesh, India, Nepal and Pakistan, the rice-wheat cropping system is currently practiced over some 12 million ha of prime agricultural lands and accounts for nearly one-fourth of the region's foodgrain production. The productivity of rice and wheat crops and of the system rose rapidly following the introduction of Green Revolution Technologies,although the gains in productivity were not uniform across the region. Large-scale adoption of rice and wheat cultivars with a high yield potential, increased use of fertilizers and plant protection chemicals and spread of irrigation were the key elements of technology interventions. Of late, however, there is increasing evidence to suggest that the productivity growth has slowed and that the use of productivity-enhancing inputs appears to be approaching saturation. The reasons for yield stagnation and decline are not fully understood although these are not likely to be the same across the region. Declining soil fertility resulting from the depletion of nutrients, their unbalanced application and reduced recycling of organic matter, water-induced degradation of soil and water resources, leading to spread of salinity and water balance aberrations, increase in the incidence of diseases and pests and loss in biodiversity are some of the factors that adversely affect the sustainability of the production system. The presentation will highlight the need for a new research paradigm that emphasizes approaches that will result in increased productivity while ensuring the long-term quality of the resource base and environment in our efforts to achieve food security in the region.

Introduction

Over the past three decades Rice-Wheat Cropping System has emerged as a major production system in the South Asia's Indo-Gangetic Plains region spread over the four countries, Bangladesh, India, Nepal and Pakistan. The Indo-Gangetic Plains region constitutes one of the most productive agricultural regions in the world, feeding many million people more than its vast resident population. Despite expanding population, production of rice and wheat in the region has kept pace with the demand. Rice and wheat now account for a major proportion of food supplies in South Asia. In the early 1950s, rice and wheat accounted for only 50% of grain production in India. By 1990, this share rose to more than 70%. In Bangladesh

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and Pakistan, the share of rice and wheat accounts for more than 90% of the total cereal grains while in Nepal for nearly 70% of the grain production. Imported cereals have shrunk to a small fraction of total consumption. Despite these significant achievements, there are indications that the "Green Revolution" of the 1970s and the 1980s is receding into the past. Evidence is accumulating to suggest that the impressive rates of growth achieved earlier are no longer being sustained. In some intensively cultivated areas there are signs that the yields may indeed be on the decline. It is a formidable challenge for researchers and policy makers to devise ways to improve and sustain productivity to keep pace with ever increasing demand. It is the objective of this paper to highlight relevant issues that deserve attention.

Rice-wheat system in India

Rice and wheat are the major food crops accounting for some 85% of the cereals produced and nearly 60% of the caloric intake by the population. In 1995, the area occupied by rice and wheat covered 42 and 25 million ha, respectively. Nearly 25% of the area under rice and 40% of the area under wheat are cropped in rice-wheat sequence largely in the Indo-Gangetic Plains in the states of Haryana, Punjab, Uttar Pradesh, Bihar and West Bengal. In this system rice is grown in the *kharif* (rainy) season followed by wheat in the *rabi* (winter) season. Although by definition rice and wheat crops are two system components, in practice the system is highly variable and complex because the farmers commonly include a range of crops e.g. oilseeds, sugarcane, pulses, potatoes, jute, etc. in temporal and/or spatial sequences, leading to a high degree of complexity for the system. The area under rice-wheat cropping system has grown rapidly. During the period 1959-62, the area under rice-wheat was estimated at 3.97 million ha, which grew to 9.53 million ha, by 1986-89, i.e. at an annual growth rate of 3.2% (Hobbs and Morris, 1996). During this period, per ha, yields of rice and wheat also increased markedly resulting in significant overall gains in production (Table 1) and in per capita availability (Table 2).

Increased production and productivity that characterized the "Green Revolution Period" have resulted from a combination of factors, the key ones being the expansion of irrigated area, the introduction of high-yielding dwarf rice and wheat varieties and the increased use of inputs including fertilizers and crop protection chemicals. Other supporting elements included expansion and strengthening of research and extension services and overall agricultural support policies. The net irrigated area increased from 2,466 million ha, in 1960-61 to 47.78 million ha, in 1990-91. During the same period, the irrigated wheat area rose from 4.23 to 19.55 and irrigated rice area from 12.56 to 19.13 million ha, respectively. From 1960-61 to 1990-91, the consumption of inorganic fertilizers increased from 0.29 to 12.55 million tons and a large part of these were consumed in the rice-wheat cropping system. As a result many, rice-wheat farmers use high doses of fertilizers, up to 4-500 kg nutrients/ha/annum.

Gains not uniform across the Indo-Gangetic Plains

The impact of Green Revolution Technologies has not been uniform across the region. The Indo-Gangetic Plains region represents a great diversity of biophysical and socio-

Table 1 Yield and production of rice and wheat in India

Year	Rice		Wheat		% of wheat to rice
	Yield (kg/ha)	Production (million ton)	Yield (kg/ha)	Production (million ton)	
1960-61	1,013	34.58	851	11.00	31.8
1970-71	1,123	42.22	1,307	23.83	56.4
1980-81	1,336	53.63	1,630	36.31	67.7
1990-91	1,740	74.29	2,281	55.14	74.2
1995-96	1,855	79.62	2,493	62.62	78.6

Table 2 Per capita availability of rice and wheat (kg/annum) in India

Year	Rice	Wheat	Pulses
1960-61	78.7	25.0	25.2
1970-71	77.0	43.5	18.7
1980-81	78.3	53.0	13.7
1990-91	87.8	65.1	12.8

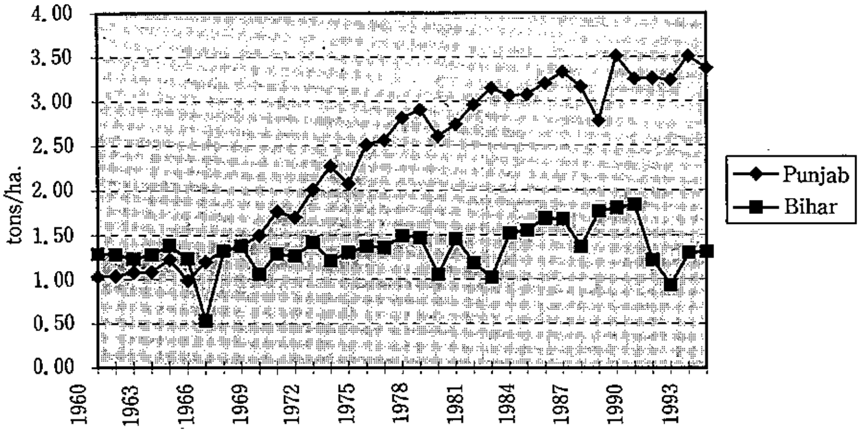
economic elements. In the northwestern states of Punjab, Haryana and western Uttar Pradesh farming is characterized by intensive use of farm inputs, fertilizers, pesticides, good irrigation facilities, mechanization, good infrastructure and extension services. The gap between average field productivity levels and the yield potential of available germplasm is nearly closing. Productivity growth of the system and particularly of rice has been declining or leveling off since the late eighties. Enhancing productivity and sustainability of rice-wheat production system in the region has assumed a major challenge.

In contrast ,the eastern region of the Indo-Gangetic Plains represented by the eastern Uttar Pradesh, Bihar and West Bengal states has not benefited from the gains of "Green Revolution" technologies to the same extent as the northwestern region due to a variety of reasons that include poor infrastructure and extension services, relatively lower level of development of irrigation facilities, greater dependence on animal power for the range of farm operations, etc. As a result, the technologies that worked so well in transforming the agriculture in the northwestern region failed to have the same impact, resulting in slow and delayed growth in the rice and wheat productivity (Fig 1 A and B). The productivity levels in the east remained nearly one-third of the levels achieved in the northwest. The region reflects a situation where there is yet enough potential to raise productivity by exploiting existing germplasm and available technology options.

Concerns of sustainability

Several indicators highlight sustainability concerns. Per hectare yields of rice and wheat rose significantly during the seventies and eighties. Consequently both food grains registered

A. Rice



B. Wheat

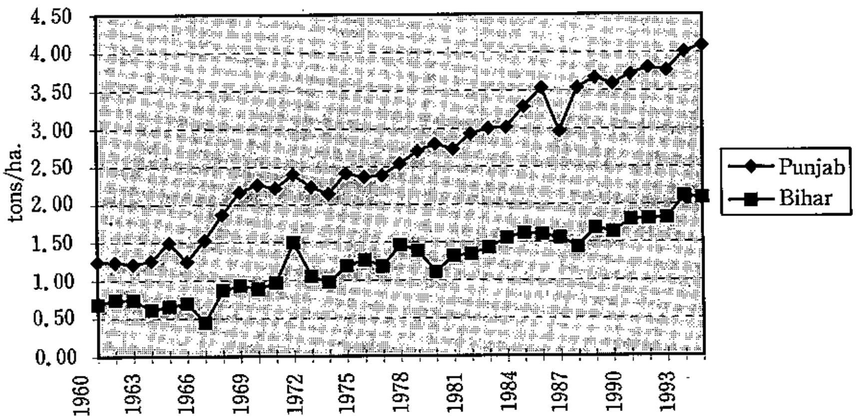


Fig. 1 Trends in rice and wheat yields in India

over 3% annual growth in production between 1980-81 and 1995-96 which was significantly higher than the annual population growth of 2.14% during the eighties. However, in the first seven years of this decade (1990-91 to 1996-97) the annual rate of growth of food grains was only 1.7% which is lower than the current level of population growth.

Slower growth in yields (Table 3) is a matter of concern. The use of productivity-enhancing inputs appears to be approaching saturation levels. In the higher production north-western region adoption of high-yielding cultivars is virtually complete. Fertilizer use for rice and wheat is now close to optimal level and application of additional doses of fertilizers is often unprofitable. Almost entire wheat and rice crops in the states of Haryana and Punjab and western Uttar Pradesh are already irrigated. Thus since with most traditional sources of productivity, growth has been exhausted, future gains will need to come from else-

Table 3 Annual growth in production (%)

Period	Rice	Wheat	Pulses
1967-68 to 1995-96	2.90	4.72	2.67
1980-81 to 1995-96	3.35	3.62	2.86
1990-91 to 1996-97	1.52	3.62	1.70

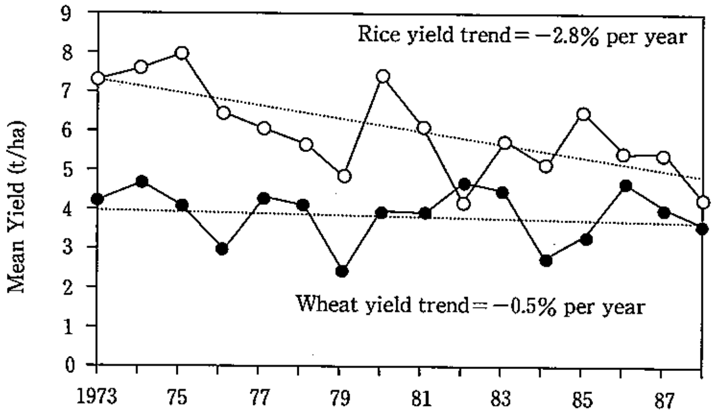


Fig. 2 Rice and wheat yields, long-term trials, Pantnagar, U. P., India, 1973-88
Source: Nambiar (1994).

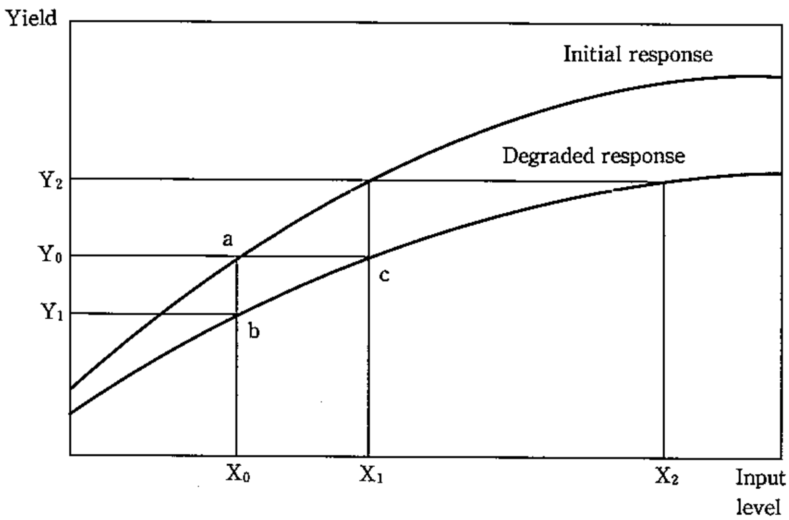


Fig. 3 Shift in fertilizer response function resulting from resource degradation
Source: Byerlee (1994).

where.

Concerns of sustainability arise from other sources as well. Several long-term experiments involving rice-wheat cropping system are underway to study the behavior of rice-wheat yields in relation to input levels. Although in many cases results are inconclusive, many long-term experiments show declining yields in intensive rice-wheat system when the input levels were kept constant (Fig.2). In one case it was shown (Byerlee ,1994) that yield decline had occurred across a wide range of fertilizer application rates suggesting a downward shift in the entire fertilizer response functions (Fig. 3). As a result of resource degradation the yield level achieved at fertilizer application rate X_0 has declined from Y_0 to Y_1. Only by increasing fertilizer application rate to X_1 can the original yield level be maintained.

At the farmer level, sustainability concern is being expressed in several ways. Many farmers feel that they have to keep on increasing the input levels in order to maintain previous yields. In the sixties and seventies most farmers used only nitrogenous and phosphate fertilizers to achieve high yields. Due to increasing deficiencies of several secondary and micronutrients most farmers now apply phosphorus, potassium, sulfur, zinc, boron, iron and manganese to mitigate emerging deficiencies of these nutrients (Fig.4).

Lowering of groundwater levels due to intensive rice-wheat system is forcing many farmers to lower their pumping sets with consequent increased cost of lifting water.

Yet another concern arising out of intensive rice-wheat cropping with corresponding decline in pulses and coarse grains has been nutritional imbalance especially micronutrient malnutrition among the people. This situation has developed because the production of micronutrient-rich crops (vegetables, pulses, fruits) has not matched the increasing output of staple grains (FAO, 1993).

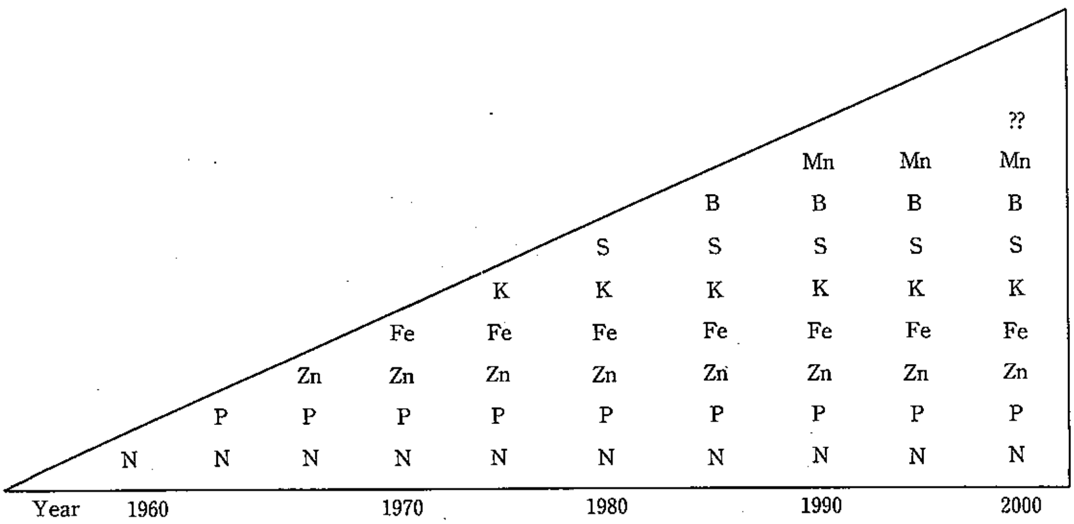


Fig. 4 Progressive expression in the occurrence of nutrient deficiencies in rice-wheat system in northwestern states

Some emerging problems

Rice-wheat cropping system which has emerged as a major production system in the Indo-Gangetic Plains over the past three decades has been the center point of the "Green Revolution" of the seventies and eighties. Major gains in production and productivity have been confined to areas which had no serious limitations to production (had good supply of irrigation water, deep production soils, climatic conditions favoring multiple cropping, etc.). By contrast productivity and output growth have been only modest in the eastern region. Even in the region that has contributed to the green revolution, productivity gains have not taken place without a cost. The "Green Revolution" technologies have also resulted in weakening of the resource base and brought about a series of second generation problems affecting the sustainability of the system. Important amongst these are:

1 Biodiversity

Many advances in modern plant breeding have been possible because of the wide range of genetic resources provided by the land races. This very success now threatens the source of genetic diversity on which further progress depends. Farmers find it less rewarding to maintain land races developed by their ancestors. The widespread use of modern varieties raises question about the stability of production and threatens the endemic breakout of diseases or pest attacks. The principal threat to yield stability from modern varieties is their increasing area coverage and their continuous use in a cropping system. Large areas planted to a single variety are a potential cause of concern, regardless of the source of variety. Biodiversity has intrinsic values and confers a natural balance within an ecosystem. As the diversity is reduced, natural processes that control and affect habitat quality and genetic expression decline. Simplified ecosystems are more difficult and inefficient to maintain. As biodiversity is reduced, internal and natural controls must be replaced by more externally applied artificial controls in the form of management and other inputs.

2 Disease and pest problems

Disease and pest problems are now more serious than ever before. These problems are a result of continuous cropping of selected crops, e.g. rice and wheat: the carry-over of some pest and disease complexes between the two cereals poses both short and long-term problems. *Phlaris minor* a grassy weed which has reached a serious proportion in the high productivity area is promoted by the rice-wheat system. It was reported that this weed has developed resistance to the commonly used herbicide, isoproturon. This implies that the farmers are applying more and more of the herbicide incurring increasing costs without the benefit of effective control. Carry-over of stem borer (pink borer) and build-up of soil-borne pathogens in continuous cereal system are other examples. Pesticide residues entering the food chain are associated with serious health hazards. Overall safety in the use of pesticides is still a widespread problem.

3 Water management related problems

Inadequacies in water management have led to serious resource degradation problems.

All these years major emphasis was placed on the expansion of irrigation with little attention paid to issues of efficient use of resources. In the eastern region where canal irrigation has spread in the absence of significant groundwater use, serious problems of salinity, alkalinity and high water table together with restricted drainage are a serious constraint on enhancing the productivity. Inadequate attention to rectify the problem may result in an irreversible loss in the ability of resources to support high productivity agriculture. There are other areas, e.g., the northwest, where unrestricted installation of tubewells has resulted in continuous lowering of the groundwater table so that the farmers have to incur increasing costs in lifting water for irrigation.

Groundwater resources in large parts of Punjab and Haryana states have been showing clear signs of over-development. Of the 118 development blocks in Punjab and 108 in Haryana, 53% of the blocks in Punjab and 42% in Haryana are classified as over-exploited implying that the net yearly draft exceeds utilizable resources (Table 4). Groundwater table depth

Table 4 Status of groundwater development in some rice-wheat cropping system states

State	No. of blocks	Level of ground water development	% of blocks overexploited
Haryana	108	84	42
Punjab	118	94	53
Uttar Pradesh	895	38	21
Bihar	585	19	-
West Bengal	-	24	-

Source: Central Ground Water Board 1995.

in a significant fraction of the region has already reached levels of more than 15 to 20 m and is further declining at a rate of half to one meter per year. Declining groundwater balance is a serious threat to the sustainability of the production system.

According to a recent report (Chakraborti, 1996) arsenic is present in the groundwater in large areas spread over seven districts of West Bengal affecting nearly 800 villages and more than one million people drinking the contaminated water. More than 200,000 people are reported to be suffering from arsenic-related diseases of varying intensity. The situation is also serious in the adjoining areas in Bangladesh. While the exact causes of build-up of arsenic in the groundwater are not clear, most evidences indicate that the source is geological. Table 5 gives the level of groundwater development in the 15 districts of West Bengal. It is obvious that groundwater extraction for irrigation through shallow and deep tubewells, primarily, is leading to conditions whereby the air enters the aquifer resulting in the oxidation of arsenic-rich pyrite and its release into the groundwater through the action of acid released upon oxidation. Most of the degradation problems related to water resources are system-related and defy simple solutions.

4 Decrease of soil fertility

With increasing harvests, the level of application of fertilizers in some areas has in-

Table 5 Level of groundwater development in the 15 districts of West Bengal

District	Level of groundwater development (%)
Bankura	14.5
Burdwam*	24.5
Birbhum	14.0
Guchbehar	4.4
Howra	13.7
Hooghly*	31.2
Jalpaiguri	1.1
Malda*	29.7
Medinapur	27.9
Murshidabad	49.2
Nadia*	55.9
Purulia	8.4
24-Pargana (South & North)*	55.8
N and S Dinajpur	22.9
State average	24.0 (Range)
Average of 6 affected districts	41.0 (24.5-55.9)
Average of other districts	12.0 (1.1-27.9)

creased several fold while there are areas where the level of application of nutrients continues to be low. In general more nutrients are extracted (mined) from the soil than are restored through application of fertilizers. Use of organic materials does not reach the desired level. There is a demand for manure as fuel and the overall supply is decreasing as the tractors displace animals. In many areas crop residues are not being left in the fields to replenish soil nutrients because they are increasingly being fed to animals. In many cases plant residues are being burnt to save time for timely planting, at the same time exacerbating the pollution problem. Imbalance in the use of nutrients resulting in low use efficiency is a rule rather than exception. Sometimes fertilizer pricing and/or subsidy policies have encouraged imbalances in nutrients applied through fertilizers. Decline in the quantity and quality of organic matter in many soils is adversely affecting soil biodiversity and in turn biological regulation of soil processes. Strategies to reverse the processes of soil fertility decline or for the enhancement of soil quality require a long-term perspective. Issue of enhanced efficiency of nutrients is complex and has a strong interaction with water supply, physical conditions and disease and pest domains.

Meeting the challenges

A question that should be raised at this point of time is - what are the factors that have led to a situation where "sustainability" has suddenly become an issue. This, then should also offer some clues on how to proceed differently from the past. The answer lies largely in the manner in which we have considered research issues, organized research and attempted to translate research results into practice. Sustainability questions have arisen over a period of time. The aim of research all these years was to enhance productivity at the farm level in the shortest possible time. As a result, little attention was devoted to monitor the consequences of adopted technologies on the quality of the resource base or environment. Most of our research activities are organized in a disciplinary mode. Unfortunately they are not conducive to "problem-solving" since lasting solutions to most field problems require a multidisciplinary approach. Similarly in our anxiety to develop technologies that will enhance productivity in a short span we often failed to consider and tackle problems in totality. Our piecemeal approach to research has led us to serious resource management problems. Again there has been a definite gap in addressing socio-economic and policy-related issues in our past efforts.

For technology generation and adoption in agriculture, a wide range of partners and institutions are involved. Developing strong input-output-based linkages is therefore fundamental. Unfortunately these linkages are often loose and ill-defined. Strong linkages are also needed at the grassroots level to build a farmer and farming system perspective in research.

In conclusion, we have now a new dimension to our research agenda: productivity increase and enhancement of natural resource base quality. For addressing the new research agenda effectively, agricultural research system needs to acquire a new vision which is based upon emerging paradigm of agricultural development which will be driven by principles of efficiency, equitable economic growth and sustainability. As forcefully argued in Agenda 21, there is a need to re-examine the structure of national agricultural research systems, to reduce duplication, to merge separate bodies if necessary and to enforce coordinated priorities. This is the only feasible way to make available resources for research and to produce the required thrust to natural resource management research without reducing the priorities given to more traditional agricultural research.

References

Byerlee, D. (1994): Modern varieties, Productivity and sustainability, Recent Experience and Emerging Challenges, Mexico D. F.: CIMMYT.

Central Ground Water Board (1995): Groundwater Resources, India, Central Ground Water Board, Ministry of Water Resources,Government of India, Faridabad, 147 pp.

Chakraborti, D. (1996): Arsenic in Groundwater in seven districts of West Bengal. Paper presented at National Meet on Science and Technology Inputs for Water Resource Management, April 8-10, 1997 pp. 145-153 Pre-Proceeding Volume, Department of Science and Technology, New Delhi.

Food and Agriculture Organization of United Nations, (1993): Agriculture Towards 2010, FAO, Rome, 320 pp.

Hobbs, P. and Morris, M. (1996): Meeting South Asia's future food requirements from rice-wheat cropping systems, Priority issues facing researchers in the Post Green Revolution Era. NRG Paper 96-01, Mexico, D. F.: CIMMYT.

Nambiar, K. K. M. (1994) : Yield sustainability of rice-rice and rice-wheat systems under long term fertilizer use, In Resource Management for Sustained Crop Productivity, Indian Society of Agronomy, New Delhi.