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Integrating germplasm, crop management and policy for wheat farming systems development in the Indo-Gangetic Plains

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ABSTRACT

The Green Revolution markedly intensified the rice–wheat systems in the Indo Gangetic Plains (IGP), but these thereby became a victim of their own success, with the degradation of the natural resource base widely seen as the root cause for the recent stagnation in productivity growth and growing water scarcity. The agricultural development community faces the challenge of sustaining crop productivity gains, improving rural livelihoods and securing environmental sustainability in the IGP. This calls for a better understanding of farming systems and of rural livelihoods.

Key words: Wheat, India, Farming System, Germplasm, Crop Management, Policy

INTRODUCTION

Wheat production systems in South Asia have been transformed over the last 40 years starting with the Green Revolution in the 1960s. The technological packaging of improved wheat seed, chemical fertilizer and irrigation in an overall supportive infrastructural and policy environment for agricultural transformation led to rapid wheat productivity growth. For instance in India, average wheat yields have more than trebled over the last forty years and wheat yield growth thereby was the highest amongst all principal crops. Yield increase was the main source of wheat production growth during the 1980s, but it decelerated in the 1990s, and has been relatively stagnant since the turn of the century. The stagnation in wheat productivity, continued population growth and diversification incentives have put increasing pressure on India's self-sufficiency in wheat, leading to wheat imports during the last two years and putting wheat back on the political agenda (Chand 2007).

THE FARMING SYSTEM AND LIVELIHOODS BASE

Wheat production in South Asia is concentrated in the Indo-Gangetic Plains (IGP), where it is primarily grown under irrigated conditions in rice-wheat systems (Timsina and Connor 2001). The IGP can be divided broadly into eastern and western sub-regions (Erenstein *et al.* 2007d). The eastern sub-region (East (E) Uttar Pradesh [UP], Bihar, West (W) Bengal in India; Nepal terai; W Bangladesh) has problems of poor water control and flooding; rainfed (monsoon/kharif) lowland rice is the traditional cereal staple and the mainstay of food security. Only in recent decades have wheat and other cool season crops been introduced on a large scale in the East north of the tropic of Cancer. By contrast the western sub-region (Punjab, Haryana, W UP in India; Punjab in Pakistan), is mainly semi-arid and would be water scarce were it not for its irrigation infrastructure of canals and groundwater tube-wells. In the western plains winter/rabi wheat has traditionally been, and continues to be the mainstay of food security. In recent decades there has been a major increase in the area of rice grown in the monsoon/kharif season. Another important contrast is that whereas in the eastern IGP cattle are the predominant livestock, in the western IGP, buffalo dominate. In broad terms therefore the eastern IGP is characterized by rural livelihoods based on rice-cattle farming systems, while rural livelihoods in the western IGP are based on wheat-buffalo farming systems. Therefore, although the IGP is a contiguous plain area, there are significant gradients and variations between sub-regions. The sheer size of the IGP also implies that each sub-region assumes national/regional prominence: the North West (NW) IGP and the terai are the granary for Pakistan, India and Nepal; UP is India's most populous state; Bihar is one of India's poorest states; W Bengal and Bangladesh are respectively the most densely populated Indian state and country.

In the Indian IGP, the aggregate asset base is markedly more favorable in the NW IGP and declines proceeding to the E plains of Bihar. Particularly marked are the larger farm size, larger herd size, and more widespread mechanization and irrigation in the NW. In contrast, rainfall and population density increases proceeding to the E IGP, as does the incidence of poverty (Erenstein *et al.* 2007d; Erenstein *et al.* 2007c). Wealth is closely associated with access to land in the rural communities across the IGP, where smallholders and landless poor predominate and large farmers are markedly concentrated in the NW IGP (Erenstein *et al.* 2007d). The W – E asset gradient in the IGP also had pronounced effects on factor prices, such as the value of land and labor, both being markedly higher in the NW IGP. The institutional environment also tends to be more favorable in the NW IGP. Women's role in agriculture increases proceeding E. Gender inequity is still a major issue reflected inter alia by gendered wage rates and lower female literacy (Erenstein *et al.* 2007d).

Livelihood strategies predominantly revolve around crop-livestock systems and agricultural labor throughout the IGP, but with significant W – E gradients (Erenstein *et al.* 2007d). Wheat is the dominant food/feed crop in the NW IGP whereas rice is dominant in the E plains. Rice-wheat thereby prevails as the dominant cropping pattern in the NW, whereas proceeding E cropping systems become more diversified (Erenstein *et al.* 2007d). For instance, in the rice-wheat belts of India and Pakistan in the NW IGP, rice and wheat crops occupied three-fourth of the cultivated area (Erenstein *et al.* 2007d; Farooq *et al.* 2007). Cereal production in the NW plains is also more market oriented, reflecting larger surplus (Erenstein *et al.* 2007d).

Livestock ownership is widespread and complements the rice and wheat based cropping systems as the basis of rural livelihoods. In the Indian IGP, the herd size shows a striking inverse relationship with the prevailing poverty levels (Erenstein *et al.* 2007d). Livestock are generally stall-fed throughout the year. Wheat straw is the preferred basal ruminant feed in the NW IGP and rice straw in the E, linked to tradition and availability of mechanical threshers for wheat. The preferred cereal straws have scarcity value and are intensively collected, stored and used as the basal animal feed and eventual surpluses traded. However, despite the importance of straw as feed, grain yield remains the main consideration in farmers' varietal choice. Stubble grazing shows a marked W-E gradient in the IGP, from low levels in the NW to high levels in the Eastern plains (Erenstein *et al.* 2007d). In the NW the seasonal cultivation of fodder crops is common, but fodder cultivation declines proceeding to the E plains (Erenstein *et al.* 2007d; Farooq *et al.* 2007).

Throughout the Indian IGP, crop production appeared as the main livelihood source for landed households, with livestock typically complementary and to a large extent dependent on the crop enterprise (Erenstein *et al.* 2007d). In the rice-wheat belts of India and Pakistan in the NW IGP, rice and wheat provide the lion share of household income which is supplemented by livestock farming (Erenstein *et al.* 2007a). Landless households depend primarily on their labor asset, with livestock providing an important contribution (Erenstein *et al.* 2007d). In the Indian IGP there is also a marked gradient in the reliance on casual labor: contracting casual labor for crop operations is the rule in the NW but decreases as one proceeds Eastwards to the Bihar sub-region, where small farms and family labor predominate.

The diverging agricultural history of the IGP sub-regions has led to significant variations in terms of poverty alleviation and agricultural productivity. Rural development indicators in the Indian states of Punjab and Haryana in the NW IGP now compare well with those of middle income countries (World Bank 2006). Yet large tracts of the IGP remain marred in dire poverty despite their agricultural potential. The main exponent of this is the poverty pocket of the E IGP, an area with 500 million people, typically characterized by smallholders and widespread poverty (>30% below official poverty line, and more than two-thirds surviving on less than US$ 2/day).

WHEAT – POVERTY LINKAGES

The foregoing situation analysis has important implications for wheat – poverty linkages. First, there is an inverse relationship between the relative extent of wheat cultivation in the farming system and rural poverty in the IGP. Second, within any wheat producing locality, there is a marked gradient in terms of wheat being a major contributor to household income on large farms to wheat being a major household expense for the landless. This implies that the poverty alleviation potential of general wheat cultivation enhancement is primarily indirect, through lower wheat prices for poor wheat consumers. Third, there has been a tendency for wheat R&D efforts to focus on the larger farmers and the NW IGP. Direct poverty alleviation would imply targeting wheat cultivation enhancement efforts to the specific wheat production constraints of smallholders in general and the poverty pocket of the eastern IGP in particular.

A techno-centric approach and the inherent diversity amongst stakeholders has often resulted in only partial stakeholder analysis, if any. Agricultural scientists have increasingly started to recognize the need to acknowledge the differential resource base of our target group – yet boundaries between what is considered a large farmer and smallholder are often blurred. And more worryingly, the implications for landless often forgotten. The larger farmer clientele typically demands labor-saving technologies, but these inherently shift income from laborers to producers. Both large and small farmers may ostensibly benefit from labor-saving technologies, and may actually need it to remain competitive, enhance productivity and make a decent living from farming. But the landless laborers typically lose out in the absence of alternative employment at the local level whereas they lack the skills to gain remunerative employment elsewhere. The gender segmentation in the labor market imposes further social costs. The implications also cut across IGP sub-regions, with the intensive NW systems still relying on migrant labor from the eastern plains to alleviate their labor peaks. This calls for a better understanding of livelihood implications and a broader stakeholder dialogue/participation in technology development. In the end it also calls for remedial action outside the immediate agricultural development sphere, both in terms of making non-agricultural economic growth more labor-intensive and enhancing primary rural education to provide the rural poor with the minimum human capital needed to escape poverty (Erenstein 2006).

SYSTEM DYNAMICS AND TECHNOLOGICAL CHANGE

The current farm systems in the IGP are predominantly small-scale integrated crop-livestock systems and likely to remain so in the medium term to 2020. Continuing fragmentation of land holdings implies an increasing reliance on off-farm income sources. Marginal farmers will likely continue to move out of agriculture only where sufficient and appropriate alternative income generating opportunities exist, as has been the case in the NW IGP in India – thereby allowing for some consolidation of farm size. The few large land holdings seem to move towards crop specialization having the means to invest in mechanization and thereby circumvent labor bottle necks. Further specialization into commercial dairy is likely for those that have a potentially big enough milk enterprise and secured market access. Such specialization is more likely in the peri-urban interface. Such specialized dairy would also imply an increasing spatial separation between livestock production and feed production and further reliance on and development of crop residue and fodder markets (Erenstein *et al.* 2007d).

A striking feature of a recent village survey was the apparent current stagnation of the rural communities across the Indian IGP in this post-Green Revolution period (Erenstein *et al.* 2007d). Many communities thereby gave a sense that they were waiting to be helped, exhibiting a strong dependence on hoped-for government intervention and demonstrating a lack of personal initiative. Another striking feature of the communities surveyed across the IGP was the lack of shocks having widespread impact on the rural population (Erenstein *et al.* 2007d).

In terms of technological change, zero and reduced tillage wheat have spread rapidly in the rice–wheat systems in the IGP since the turn of the century to an estimated 1.6 million ha in 2004/05 in India (Laxmi *et al.* 2007). Central to the new technology is the zero tillage drill (ZTD): a mechanical tractor-mounted seed drill that can sow wheat into an untilled rice field. Recent studies confirmed widespread adoption of zero tillage (ZT) wheat in the rice–wheat belt of the NW IGP (Erenstein *et al.* 2007b). More recently ZT has also started to pick up in the eastern plains.

Developing adequate input value chains for ZTDs, from factory to farmer fields, proved crucial to the success of reducing tillage in the NW IGP (Seth *et al.* 2003). The private sector recognized that zero tillage offered a substantial market opportunity and local manufacturing capacity was developed to produce, adapt and deliver ZTD to farmers at a competitive cost. Close linkages of scientists and farmers with the private manufacturers, including the provision of machines to villages for farmer experimentation, allowed rapid feedback on, and refinement of, the implements. Strong support from State and local government officials in India helped with dissemination, including the provision of a subsidy to lower the investment cost. The Rice–Wheat Consortium (RWC) for the IGP (www.rwc.cgiar.org) played a catalytic role in promoting the public– private partnership, nurtured it through its formative stages and facilitated technology transfer from international and national sources. Accessibility to the ZTD was greatly enhanced by ZTD service providers (Erenstein *et al.* 2007b), with the added advantage of having hands-on experience and having a clear incentive for promoting the technology. The concerted efforts from a range of stakeholders, thus, proved crucial in developing the input value chains of ZTD to the farmer.

The main driver behind the rapid spread and widespread acceptance of ZTD is the combination of a significant continuing 'yield effect' and a substantial 'cost saving effect' which ensure the immediate profitability of adoption, particularly in Haryana-India (Erenstein *et al.* 2007b; Erenstein *et al.* 2008). The resource base and livelihood strategy of the farm household also prove particularly influential: ZTD adoption is closely associated with farm size, asset base and with specialization in the rice–wheat system (Erenstein *et al.* 2007b). The significant wheat area of ZTD adopters implies larger annual benefits, lower relative learning costs and earlier payback to ZTD investment.

So far, ZTD has primarily been adopted for the wheat crop in rice–wheat systems. For the full potential environmental impact of ZT to materialize, the R&D community faces the challenge of extending reduced tillage to the rice crop and retaining crop residues as mulch on the soil surface (Gupta and Sayre 2007; Hobbs 2007). Reducing tillage for the subsequent rice crop is still problematic and presents additional challenges, although such an initiative could benefit from the existing machinery and information value chains (Erenstein 2006). Prevailing crop residue management practices are still largely incompatible with residue retention, not least due to the widespread use of wheat residues for feed purposes and burning of rice residues in the NW IGP (Erenstein *et al.* 2007d).

IMPLICATIONS FOR RESEARCH

Water is a major concern for the sustainability of cropping systems throughout the IGP and for the S Asian economy as a whole. Water management concerns vary from over-exploitation of groundwater in some areas to poor unreliable irrigation and the negative effects on productivity from flooding and waterlogging in others (Erenstein *et al.* 2007d). With the continuing spread of private diesel-powered tube and shallow wells, declining water tables are likely to become more widespread and require urgent study to inform policy making and short- and medium term action planning. In fact this is one area where policy adjustments are essential to complement water use efficient (WUE) varieties and production practices. Resource conservation technologies like ZT can be successful in improving field scale irrigation efficiency but these savings do not necessarily translate into 'real' water savings (Ahmad *et al.* 2007; Humphreys *et al.* 2005). In any event, the irrigation water savings with ZT in wheat are still modest, particularly when compared to potential savings for rice. To address the impending water crisis the R & D community urgently needs to enhance the water productivity of the rice component of the rice-wheat system and tackle some of the more thorny policy issues such as the subsidy and support schemes that currently undermine the sustainability of rice-wheat systems (Erenstein *et al.* 2007b).

Soil fertility and organic matter mining pose another threat to the current livelihood strategies in the IGP. Organic matter management is particularly problematic, with the largely one-way extractive flows from the field leading to depletion of soil organic matter stocks throughout the IGP, and particularly in the E plains. The prevailing crop residue management practices, intensive use of cereal residues and limited application of FYM imply few organic residues remain in the field at the time of land preparation. Soil fertility is further undermined by unbalanced fertilizer use (Erenstein *et al.* 2007d). R&D efforts are needed to address this challenge, including research to establish the minimum amounts of crop residues that should be retained and developing appropriate alternative feeding and crop residue management practices, along with appropriate policy measures.

The prevalence of single wheat varieties over large contiguous areas (e.g. PBW 343 in India and Inqalab-91 in Pakistan, Erenstein *et al.* 2007b) is another worrying threat in view of the underlying risk from any resistance breakdown. Cool and moist weather spells can trigger yellow rust and leaf rust epidemics in the IGP (Nagarajan 2004). The risks have become even more pressing in view of the general susceptibility of prevailing varieties to and advent of the virulent new stem rust for wheat (Ug99, Mackenzie, 2007; Raloff 2005) – which poses a major threat to wheat production throughout the IGP in the immediate future. The recent Global Rust Initiative (www.globalrust.org) merits further urgent support to mitigate the impending impact of Ug99 in S Asia.

Wheat is a temperate crop grown during the cool winter season in the IGP. Proceeding to the E plains, the winter season gets progressively shorter thereby inherently limiting the potential productivity of wheat. Limited water control also often implies delays in the rice crop, further retarding wheat establishment. In the Indian IGP this contributes to actual wheat productivity being highest in the NW IGP and decreasing by some 100 kg per ha for every 100 km eastwards (Nagarajan 2004). In West Bengal and Bangladesh current wheat productivity levels increasingly undermine its competitiveness against alternative winter crops like winter maize. Global warming will exacerbate the heat stress for wheat and thereby have far-reaching consequences for its cultivation across the IGP. R & D efforts are urgently needed to develop appropriate coping strategies.

Despite the above threats and the overall stagnation in wheat productivity growth in the IGP, there is still scope for enhancing wheat productivity (e.g. Reynolds *et al.* 2007). The main opportunities for reinvigorating wheat yield growth in the IGP thereby lie in the traditional sources of productivity growth: improved varieties and crop management to push out the wheat yield frontier and narrow the yield gap. Improved varieties will also play a major role in tackling the above threats – particularly through higher irrigation water productivity, drought tolerance, durable stem rust resistance and heat tolerance. In the eastern plains, there is also an increased need for appropriate short duration germplasm.

Enhanced crop management practices offer particular scope to enhance the expression of genetic potential, save resources and costs and enhance wheat competitiveness. In the previous section, mention was already made of resource conserving technologies like ZT and the corresponding uptake by farmers. Late planting of wheat still is a major cause of reduced wheat yields in rice-wheat systems. Terminal heat implies that wheat yield potential reduces by 1-1.5% per day if planting occurs after mid November (Ortiz-Monasterio *et al.* 1994; Hobbs and Gupta 2003). ZT has the potential to alleviate late planting of wheat as it substantially reduces turn-around time between the rice and wheat crop. However, a recent survey in NW IGP found no significant difference in terms of time of wheat establishment between ZT and conventional plots (Erenstein *et al.* 2007b). This suggests farmers have generally been reluctant to significantly advance their wheat planting date despite apparently increased opportunities to do so with ZT. Still, wheat productivity will receive a boost in rice-wheat systems when conservation agriculture principles of reduced tillage and mulch are extended to the whole cropping system. ZT can also be seen as stepping stone towards permanent bed planting systems with further advantages for wheat yields and water and cost savings (Gupta and Sayre 2007).

There is an important role for R & D to generate the appropriate improved varieties and crop management practices. In doing so, there is a need to increasingly select improved varieties under conservation agriculture conditions so as to exploit GxE interactions. Conservation agriculture also has important risk reducing implications through its potential to conserve water and reduce soil temperature oscillations–aspects particularly important in view of the water scarcity and climate change implications.

Diversification poses both an opportunity and a threat to the wheat farming systems of the IGP. In the case of India, the output value chains in the NW IGP are characterized by widespread public intervention, particularly assured produce prices and marketing channels for rice and wheat grain. Although these fostered intensification, they now represent a major obstacle to the diversification of rice-wheat systems. Minimum support prices for "fair average quality" also provided no incentive for better grain quality (Nagarajan 2004). The combination of secure produce markets and irrigation means that rice and wheat production is a low risk activity that had proven difficult to displace until recently. However, forces are transforming the playing field in the Indian IGP. Liberalization has opened up wheat and rice markets to new private players and have put upward pressure on wheat prices (Chand 2007). The public sector thereby had to resort to imports for the last two years in order to procure enough wheat for its public distribution system that covers those under the poverty line. The rapidly evolving domestic market in India implies promising new opportunities for diversification of rice–wheat systems with selected vegetables, legumes, feed/fodder crops and livestock products (Gulati *et al.* 2007). Still, rice and wheat continue to provide the dominant share of calories, especially for the rural poor, notwithstanding the sharp decline in their expenditure share during the 1990s (Ray 2007). Diversification options tend to have a positive poverty reduction bias, being labor intensive and small scale. Finally, wheat productivity will receive a boost when rice-wheat systems become more diversified and include alternative monsoon crops. Targeted R & D efforts are needed to facilitate this diversification and address the immediate challenges and opportunities for wheat producers and wheat consumers, both within and beyond the IGP.

In conclusion, the rice-wheat systems in the IGP have long exemplified South Asia's agricultural transformation through the Green Revolution through a combination of improved varieties better crop management and enabling policies. The same systems now also exemplify the post-Green Revolution stagnation and challenges, despite receiving considerable attention from the R & D and policy community. The apparent homogeneity of vast irrigated plains masks significant diversity and underlying gradients in assets, livelihood strategies and livelihood outcomes. Zero tillage wheat is one of the few recent examples of widespread positive technological change in the IGP. However, further targeted R & D and policy efforts are needed in the IGP. First, to address threats such as the impending water crisis, soil fertility mining, the new virulent stem rust and global warming. Second, to realize opportunities for reinvigorating wheat yield growth, wheat competitiveness and diversification to high value crops and livestock. There is also scope to extend some of the rice-wheat R & D achievements like ZT to and/or initiate targeted R & D activities in other wheat systems, particularly cotton-wheat, maize-wheat and rainfed wheat systems in South Asia.

In the end, though, wheat R & D in the IGP would benefit from a paradigm shift. The change will involve a shift from a reductionist, plot-level research to people-centered, participatory and holistic methods and to inter-disciplinary, multi-institutional approaches which link farmers, technology and policy. Only by integrating technology (both varieties and crop management) and policy/institutions will we be able to sustain crop productivity gains, improve rural livelihoods and secure the environmental sustainability of the wheat farming systems of the IGP.

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