



## Adoption analysis of resource-conserving technologies in rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system of South Asia

RAM SINGH<sup>1</sup>, ERENSTEIN OLAF<sup>2</sup>, YASHPAL SINGH SAHARAWAT<sup>3</sup>, NEELAM CHAUDHARY<sup>4</sup> and M L JAT<sup>5</sup>

International Maize and Wheat Improvement Centre, NASC Complex, Dev Prakash Shastri Marg, Pusa, New Delhi 110 012

Received: 26 December 2010; Revised accepted: 13 February 2012

### ABSTRACT

The bread and rice baskets of South Asia feeding 20% of world population are showing stalled production due to fatigued natural resource bases. The present survey assesses the constraints in adoption of integrated crop and resource management practices in rice (*Oryza Sativa* L.) wheat (*Triticum aestivum* L. emend. Fiori & Paol.) systems of Indo-Gangetic plains. The research and developmental activities have a positive impact on resource-conserving technology (RCT) explain first then use RCT use rates. Further, study confirmed that RCTs generally are cost reducing without yield loss, thereby enhancing farmers' income. The village surveys do however, highlight that the better endowed farmers tend to be the first adopters of RCTs. Purposive efforts are therefore needed to ensure that access to and uptake of RCTs is more inclusive. The marked regional variation also emphasizes the need for local adaptation – giving further impetus to the need for on-farm R and D initiatives to help adapt promising technological innovations to the local and diverse circumstances faced by resource poor farmers.

**Key words:** Impact assessment, Rice-wheat system, South Asia, Technology adoption

Agriculture must feed, clothe and provide energy to a rapidly increasing world population while minimizing environmental and other unwanted impacts. Rice (*Oryza Sativa* L.)–wheat (*Triticum aestivum* L. emend. Fiori & Paol.) cropping (RW) system occupying 13.5 million ha in Indo-Gangetic plains (IGP) of South Asia and feeding 20% of world population is of immense importance for the food security and livelihood of region (Ladha *et al.* 2009). The widespread adoption of high-yielding cereals along with improved crop-management practices and availability of irrigation water and chemical inputs during the Green Revolution (GR) has led to tremendous impressive increase in system productivity. For over a decade, cereal production has stalled and annual growth rates in rice and wheat production have failed to increase reach even one per cent, trailing far behind population growth. The rice–wheat productivity is plateauing and total factor productivity is declining because of a fatigued natural resource base and

therefore, sustainability of this cropping system is at risk (Saharawat *et al.* 2010). In addition, environmental degradation, increasing water scarcity, labour shortage and socio-economic changes are seen as the other major contributors to the stagnation of rice-wheat productivity in the IGP (Erenstein *et al.* 2008). Thus, the region's food security is continuously threatened and the emerging challenges of post-Green Revolution (GR) agriculture pose additional hurdles. Additional gains in productivity, profitability, and product quality are becoming difficult to achieve by using the single-technology-centric approach. Therefore, a system approach is necessary to increase the productivity of both rice and wheat crops grown in sequence in the IGP (IRRI 2007). The contrasting edaphic soil and climatic requirement of both crops lead to deteriorated soil health, high input use and reduced wheat yields (8% on an average) due to adverse effect of puddling and delayed sowing (Saharawat *et al.* 2009; Kumar *et al.* 2008).

Traditional rice–wheat system is the most input-intensive process and therefore more efficient alternatives are urgently needed. As part of our comprehensive programme, we have been addressing these issues through designing and testing various alternative options (Jat *et al.* 2009). In the present preview, several new strategies and technologies have been evaluated that ensure higher returns, reduce drudgery, reduce input cost and offer greater environmental protection. Potential solutions include a shift from conventional

<sup>1</sup>Associate Professor (e mail: ramsingh.cau@gmail.com), College of Post Graduate Studies, Central Agricultural University, Barapani Meghalaya 793 103;

<sup>2</sup>Senior Research Scientist (e mail: O.Erenstein@cgiar.org), CIMMYT C/O ILRI, PO Box 5689, Addis Ababa, Ethiopia, Africa;

<sup>3</sup>Senior Scientist (ysshaharawat@gmail.com), Indian Grassland and Fodder Research Institute, Jhansi, Uttar Pradesh;

<sup>4</sup>Research Scientist (e mail: n.chaudhary@cgiar.org), <sup>5</sup>Senior Scientist (e mail: m.jat@cgiar.org)

production systems to resource-conserving technologies (RCTs) including laser leveling, reduced or no tillage, direct seeding instead of transplanting. The RCTs include several other modifications as discussed elsewhere (Ladha *et al.* 2009). A new farmer participatory model involving farmers, researchers, input and machinery suppliers and extension workers as teams were adopted in the present study for development, testing, refining and dissemination of RCTs. The introduction of RCTs in the region was mainly driven by economic considerations, reduced tillage and no-tillage practices reduces the crop production costs and allow greater timeliness in crop sowing. Despite this early interest, there still are few synthetic reviews of the research findings (Holland 2004, Deumlich *et al.* 2006). The adoption of conserving technologies in IGP are still very weak compared to other regions of the world (Derpsch 2005). Although farmers may choose to adopt RCTs owing to lower production costs and sustained long-term productivity, it is not clear whether these benefits alone will lead to widespread adoption of RCTs. The present study provided an interface platform for sharing ideas in identifying, defining and rectifying the site- and technology-specific constraints. The present study elaborates the important factors that influence the adoption decision of farmers including socio-econometric analysis emphasizing on impact and adoption indicators across IGP sites with contrast integrating crop and resource-management technologies in the rice–wheat system.

#### MATERIALS AND METHODS

In socio-economic terms, IGP is the most important region of South Asia. The present study was conducted across IGP including parts of Bangladesh, India, Nepal and Pakistan to analyze the adoption constraints of resource- conservation technologies (RCTs) in the rice–wheat cropping system. The study comprised 10 clusters across South Asia representing the domain areas of RCTs dissemination through Asian Developmental Bank (ADB) sponsored project. Each cluster is a research site that comprised on-farm research and developmental activities in several peripheral villages. For practical purposes, the study zone was grouped into three

main regions of IGP, namely North-west IGP (NW IGP), Central IGP (C IGP) and Eastern IGP (E IGP). Notwithstanding, even within each region there can still be considerable divergences between sites (Saharawat *et al.* 2010). Out of the total project listed villages, 37 technology intervention/adopted villages were randomly selected to assess the socio-economic aspects of integrated crop and resource management typically 2–4 villages representing each domain area. Additionally, 19 control villages were selected in same domain area through Geo-positioning System (GPS). Control villages represent the non-project intervention villages. For comparative study, typically one control village was selected for each of the two technology intervention villages. In case two control villages were needed, we had a ‘near’ village (within 8.5 km) and a ‘far’ village (between 8.5 and 15 km). In case of one control village, only a near village was selected. Up to two randomly generated replacement points were used in case the earlier random location was logistically unsuitable (e.g. when not falling within a rural agricultural setting). A total of 56 survey villages (19 control and 37 project villages) were selected for the socio-economic study. A two-phase approach involving village survey and village census survey was conducted in spring 2008 for a three-year (2005–08) sponsored project. All farm households in selected villages were subsequently enlisted for village census involving demographic information, education level. The census primarily served as sampling framework on socio-economic indicators of the adopters. On an average, 153 farm households were enlisted per village. Furthermore, in each selected village a detailed survey was conducted within focused farmer group (comprising 10–15 farmers) to record the village and technology-specific characteristics. On an average, 61% of group participants were small (limit between large and small farm size 0.8 ha cultivated land except Haryana 2.4 ha and Pakistan Punjab 2.8 ha) farmers, with their share in the groups also increasing proceeding eastwards (Table 1). The study thereby uses two types of control, viz. Control villages (non-project) and Control farmers (non-RCT farmers). These controls allow for ‘with – without’ comparisons to be made. In addition, the study uses ‘before – after’ comparisons and

Table 1 Selected sample indicators

	NW IGP (n=27)	Central IGP (n=17)	E IGP (n=12)	Overall mean	SD	n	p
<i>Focus group indicators</i>							
Number of group participants	7.0	9.4	13.6	9.2	5.8	55	0.00
Number of Small farmers in group (%) <sup>a</sup>	55	64	71	61	21	55	0.08
Farm household listing (Number of farm households per village)	174	129	140	153	116	56	0.43

NW-IGP, North-west Indo-gangetic plains; E-GP, eastern Indo-gangetic plains; C IGP, central Indo-gangetic plains

Note: overall mean is overall average (n=56); SD, standard deviation; n, number of observations (villages) with reported valid data; p: significance of group effect (Anova). <sup>a</sup> Small farms have less cultivated area than the state average farm size. This is 0.8 ha cultivated land for most sites except Haryana (2.4 ha) and Pakistan Punjab (2.8 ha)

regional/site contrasts as appropriate. The present paper reports on the findings from the village survey and village census in the selected villages. Each table typically includes the average for each of the 3 regions (NW IGP, n=27; Central IGP, n=17; E IGP, n=12), the overall average (n=56), the standard deviation (SD), the number of villages with reported valid data (n) and the significance of the group effect (ANOVA, p). Due to rounding of there may be slight discrepancies between reported values and variable totals and/or means.

## RESULTS AND DISCUSSION

### *Adoption indicators*

There were a number of adoption indicators for RCT's in the assessment domain area/region. In the current study, we distinguished two types of contrast, viz. Between regions; and Between project and control villages. For practical purposes the present study specifically focused on selected RCTs and grouped these into four broad groups.

*Zero tillage (ZT) and reduced tillage (RT) wheat:* Wheat tillage and establishment options that typically rely on a seed drill and eliminate/reduce tillage prior to wheat establishment and thereby reduces production cost, reduces turn around and enhances timeliness of wheat establishment ( Erenstein and Laxmi 2008, Laxmi and Erenstein 2007). More recently other tillage (OT) options for wheat have emerged, primarily using a tractor, drawn rotavator with subsequent broadcasting.

*Reduced tillage drill seeded rice (RT-DSR) and conventional tillage drum-seeded rice (CT-DrumR):* Rice tillage and establishment options that eliminate the need for nursery establishment and transplanting and thereby reduce production cost. CT-DrumR typically still implies puddling. More recently-a rotavator-based option has emerged for rice, with reduced tillage followed by broadcasting (RT-BCR).

*Laser land leveling (LLL):* Precision land leveling that enhances water-use efficiency and crop productivity in surface

irrigated systems and reduces irrigation cost (Jat *et al.* 2009);

*Leaf colour chart (LCC):* Increases N-use efficiency, reduces N fertilizer use and cost (Islam *et al.* 2007).

### *RCT exposure*

As a first proxy of RCT adoption we compiled the exposure of group participants to RCTs, distinguishing between having heard of, having seen and actually using RCTs. The group participants are a self selected group and these proxies can thus be considerably biased. Still, they provided a first indicator in terms of the diffusion of RCT and associated knowledge and particularly their relative values (across sites and technologies) were of interest here. They also allowed seeing whether the group participants were familiar with the RCTs. Of all RCTs, zero tillage wheat was widely known and the most widely used in the NW IGP and the central zone, but had failed to make any inroads in the E GP. Similarly, laser leveling was largely confined to the NW IGP. In contrast, proceeding eastwards farmers were more familiar with alternative rice seeding methods (wet and/or dry) and the leaf colour chart (Table 2).

### *RCT adoption*

Our farm census data indicate that on average more than one-third of farm households have adopted at least one RCT (Table 3). There was however significant variation between regions and RCTs, associated with the regional contrasts reviewed earlier. RCT adoption has made most inroads in the NW IGP, where nearly half the farm households (including project and control sites) reported the use of some RCT. In the two other zones, this approximated a quarter of farm households. The high RCT use in the NW IGP primarily revolves around three RCTs: zero tillage , reduced tillage and laser leveling. ZT/RT wheat adoption declines proceeding to the central zone and has yet to make any inroads in E IGP.

Table 2 Exposure to resource-conserving technologies in survey villages (% of village survey group participants, village averages)

Technology	Parameter	NW IGP (n=27)	Central IGP (n=17)	E IGP (n=12)	Overall mean (n=56)	SD	p
ZT-W	Heard	83	82	8	66	45	0.00
	Seen	75	72	8	60	46	0.00
	Use	52	47	6	40	40	0.00
RT-DSR/ CT-DrumR	Heard	38	59	63	50	45	0.17
	Seen	30	57	61	45	45	0.06
LLL	Use	9	17	18	13	24	0.44
	Heard	68	15	2	37	44	0.00
	Seen	48	6	0	25	39	0.00
LCC	Use	29	0	0	14	27	0.00
	Heard	20	33	46	29	40	0.20
	Seen	16	32	46	27	39	0.11
	Use	10	32	23	20	37	0.14

ZT-W, Zero tillage wheat; RT-DSR/CT-Drum R, reduce tillage drill-seeded rice/conventional drum-seeded rice; LLL, laser land leveling; LCC, leaf colour chart; NW-IGP, north-west Indo-gangetic plains; E-IGP, eastern Indo-gangetic plains; C IGP, central Indo-gangetic plains

Table 3 Resource-conserving technology adoption in survey villages (% of farm households reporting by village)

Technology	NW IGP (n=27)	Central GP (n=17)	E IGP (n=12)	Overall mean (n=56)	SD	p (ANOVA)	p (t-test project-control)
ZT-W use	25	17	2	18	24	0.01	0.11
RT-W use	20	18	3	16	23	0.11	0.55
CT-drumR use	0	3	1	1	3	0.01	0.03
RT-DSR use	1	10	0	3	11	0.01	0.10
LLL use	14	0	0	7	18	0.01	0.07
Any use of above mechanical RCTs (ZT-W, RT-W, CT-DrumR, RT-DSR or LLL)	48	24	6	32	33	0.00	0.09
LCC use	3	13	18	9	18	0.04	0.00
Any mechanical RCT or LCC use	48	25	23	36	32	0.01	0.02

ZT-W, Zero tillage wheat; RT-W, reduced tillage wheat; CT-Drum R, conventional tillage drum seeded rice; RT-DSR, reduce tillage direct seeded rice; LLL, laser land leveling; LCC, leaf colour chart; NW-IGP, north-west Indo-gangetic plains; C IGP, central Indo-gangetic plains, E-IGP, eastern Indo-gangetic plains.

Note: village averages from farm household listing.

Table 4 Resource-conserving technology adoption in project and control survey villages (% of farm households reporting by village)

GP region	NW IGP (n=27)		Central (n=17)		E IGP (n=12)	
	control	project	control	project	Control	project
ZT-W use	22 <sup>b</sup>	27 <sup>b</sup>	1 <sup>a</sup>	26 <sup>b</sup>	0 <sup>a</sup>	2 <sup>a</sup>
RT-W use	24 <sup>b</sup>	18 <sup>ab</sup>	5 <sup>ab</sup>	24 <sup>b</sup>	0 <sup>a</sup>	5 <sup>ab</sup>
CT-drumR use	0 <sup>a</sup>	0 <sup>a</sup>	1 <sup>a</sup>	3 <sup>b</sup>	0 <sup>a</sup>	1 <sup>a</sup>
RT-DSR use	0 <sup>a</sup>	1 <sup>a</sup>	3 <sup>a</sup>	14 <sup>b</sup>	0 <sup>a</sup>	0 <sup>a</sup>
LLL use	4 <sup>a</sup>	19 <sup>b</sup>	0 <sup>a</sup>	1 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>
Any use of above mechanical RCTs (ZT-W, RT-W, CT-DrumR, RT-DSR or LLL)	41 <sup>b</sup>	52 <sup>b</sup>	6 <sup>a</sup>	34 <sup>b</sup>	0 <sup>a</sup>	9 <sup>a</sup>
LCC use	0 <sup>a</sup>	5 <sup>a</sup>	0 <sup>a</sup>	20 <sup>b</sup>	5 <sup>a</sup>	24 <sup>b</sup>
Any mechanical RCT or LCC use	41 <sup>b</sup>	52 <sup>b</sup>	6 <sup>a</sup>	36 <sup>b</sup>	5 <sup>a</sup>	31 <sup>ab</sup>

ZT-W, Zero tillage wheat; RT-W, reduced tillage wheat; CT drum R, conventional tillage drum-seeded rice; RT-DSR, reduce tillage direct-seeded rice; LLL, laser land leveling; LCC, leaf colour chart; NW-IGP, north-west Indo-gangetic plains; C IGP, central Indo-gangetic plains, E-IGP, eastern Indo-gangetic plains.

Note: Village averages from farm household listing. Data followed by different superscripts differ significantly–Duncan (0.10), within row comparison

Laser land leveling in survey sites was found to be confined to the NW IGP. In contrast, LCC use increased proceeding eastwards. Dry seeded rice was largely confined to the central zone.

In line with expectations, RCT adoption typically was more widespread in project villages than control villages (Table 4). However, the difference was not always significant in view of the limited number of villages considered and the significant variation in terms of RCT use between regions (Table 3). The extent of the divergence between the two types of villages seems closely associated with the time of introduction of the RCTs. In the central and E IGP, RCTs have only been recently introduced and their use was largely confined to the project villages (Erenstein *et al.* 2008). In contrast, in the NW IGP ZT/RT wheat was introduced earlier and now has comparable adoption levels in project and

control villages; whereas the laser land leveler (LL) was largely confined to project villages (Table 4). The recent evolution of wheat area under different tillage and establishment systems in survey villages reiterates the regional variation in terms of RCT diffusion (Fig 1). In the NW IGP conventional tillage continues its downward trend, with farmers increasing their area of ZT and particularly other (rotavator) tillage, whereas reduced tillage is relatively constant. The trends in tillage and establishment systems in the 2 other areas were less clear, albeit with a little over a third of the wheat area under ZT/RT in the central zone and more than 90% under conventional tillage in the E IGP.

The present study shows the positive impact of RCTs adoption in the South Asia. The village surveys do however highlight that the better endowed farmers tend to be the first adopters of RCTs. Purposive efforts are therefore needed to

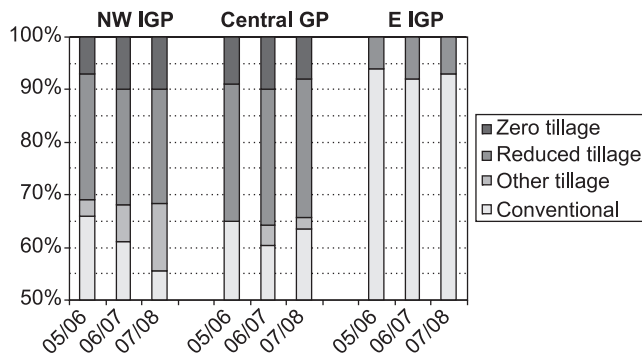


Fig 2 Recent evolutions of wheat tillage and establishment systems NW-IGP, North-west Indo-gangetic plains; C IGP, central Indo-gangetic plains, E-IGP, eastern Indo-gangetic plains.

ensure that access to and uptake of RCTs is more inclusive. Despite the apparent similarity of rice–wheat systems, the paper shows that there is significant regional variation of these systems across northern South Asia. Particularly striking was the RCT adoption. This reiterates the need to take care with making sweeping generalizations and extrapolations across northern South Asia or the IGP. The marked regional variation however also emphasizes the need for local adaptation – giving further impetus to the need for such initiatives as the underlying different research project to help adapt promising technological innovations to the local and diverse circumstances faced by resource-poor farmers.

#### ACKNOWLEDGEMENT

We are grateful to Asian Development Bank (ADB), Philippines, for providing financial support for carrying out the present investigation

#### REFERENCES

- Deumlich D, Funk R, Frielinghaus M, Schmidt W and Nitzsche O. 2006. Basics of effective erosion control in German agriculture: A review. *Journal of Plant Nutrition and Soil Science* **170** (3): 70–81.
- Derpsch R. 2005. The extent of conservation agriculture adoption worldwide: implications and impact. *Proceedings of 3rd World Congress on Conservation Agriculture*. Nairobi. CD rom. 15.
- Erenstein O, Farooq U, Malik R K and Sharif M. 2008. On-farm impacts of zero tillage wheat in South Asia's rice–wheat systems. *Field Crop Research*. **105**: 240–52.

- Erenstein O and Laxmi V. 2008. Zero tillage impacts in India's rice–wheat systems: A review. *Soil and Tillage Research* **100**: 1–14.
- Holland J M. 2004. The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence. *Agriculture, Ecosystem and Environment* **103**: 1–25.
- IRRI. 2007. Socioeconomic and environmental impact assessment. Supplementary project proposal to *Enhancing farmers' income and livelihoods through integrated crop and resource management in the rice–wheat system in South Asia* (ADB Reta 6208). International Rice Research Institute, Los Banos.
- Islam Z, Bagchi B and Hossain M. 2007. Adoption of leaf colour chart for nitrogen use efficiency in rice: Impact assessment of a farmer-participatory experiment in West Bengal, India. *Field Crop Research* **103**: 70–5.
- Jat M L, Gathala M K, Ladha J K, Saharawat Y S, Jat A S, Kumar Vipin, Sharma S K, Kumar V and Gupta, Raj. 2009. Evaluation of precision land leveling and double zero-till systems in the rice–wheat rotation: water use, productivity, profitability and soil physical properties. *Soil and Tillage Research* **105**: 112–21.
- Kumar V, Bellinder R R, Gupta R K, Malik R K and Brainard D C. 2008. Role of herbicide-resistant rice in promoting resource conservation technologies in rice–wheat cropping systems of India: A review. *Crop Protection* **27**: 290–301.
- Laxmi V and Erenstein O. 2007. Assessing the Impact of NRMR: The Case of Zero Tillage in India's Rice-Wheat Systems. (in) *International Research on Natural Resource Management: Advances in Impact Assessment*, pp 68–90. Waibel H and Zilberman D (Eds), FAO and CAB International, Wallingford, UK.
- Ladha J K, Kumar V, Alam M M, Sharma S, Gathala M, Chandana P, Saharawat Y S and Balasubramanian V. 2009. Integrating crop and resource management technologies for enhanced productivity, profitability, and sustainability of the rice–wheat system in South Asia. (in) *Integrated Crop and Resource Management in Rice-wheat System of South Asia*. Ladha JK et al. (Eds). Los Banos, Philippines, pp 69–108.
- Saharawat Y S, Gathala M, Ladha J K, Malik R K, Singh Samar, Jat M L, Gupta, Raj, Pathak H and Singh Kuldeep. 2009. Evaluation and promotion of integrated crop and resource management in Rice-Wheat system in North West India. (in) *Integrated Crop and Resource Management in Rice-Wheat System of South Asia*, pp 133–50. Ladha J K et al. (Eds), Los Banos, Philippines.
- Saharawat Y S, Singh, Bhagat, Malik R K, Ladha J K, Gathala M K, Jat M L and Kumar V. 2010. Evaluation of alternative tillage and crop establishment methods in a rice-wheat rotation in North Western IGP. *Field Crop Research* **116**: 260–7.