Conservation Agriculture, Livestock and Livelihood Strategies in Indian Punjab: Synergies and Trade Offs*

D.K. Grover
Professor and Director
Agro – Economic Research Centre, Punjab Agricultural University, Ludhiana – India
Email: dkg_59@rediffmail.com, dkgrover@pau.edu

Abstract

The rapid and significant intensification of rice-wheat cultivation in response to the availability of improved inputs and policy/institutional support has eventually resulted into stagnant or declining grain yields, falling underground water tables and soil degradation, making the present agriculture system as non sustainable in Indian Punjab. Applying conservation agriculture practices typically implies the need to retain crop residues on the soil surface to improve soil organic matter, which reduces the availability of crop residue for livestock production. Thus, to adopt conservation agriculture practices, farmers faced trade-offs between crop and livestock production. Under this context, the present study attempted to research the crop-livestock interactions in the rice-wheat-livestock systems of the Indo Gangetic Plains (IGP) to quantify the trade-offs faced by farmers who have adopted or are considering conservation agriculture practices. The research focused to assess: (i) the trade-offs affecting crop and livestock production and natural resource management (NRM); (ii) the impacts of the trade-offs on the livelihoods of poor households; and (iii) their implications for the design of research and extension programmes in support of improved livelihoods and NRM in the IGP. The study has been conducted in six villages of Patiala districts of Indian Punjab based on the sample of 120 farmers adopting Resource Conserving Technologies (RCT) and Non RCT. Study highlighted that RCT households were bigger land holders, larger family sized with better education of the household heads and even better equipped with farm machinery as compared to their counterpart i.e. Non RCT households. The grain wheat yield on RCT plot was found lower (4168 kg/ha) as compared to 4817 kg/ha on Non RCT plot. The total estimated input cost was also lower at Rs 12294/ha on RCT as compared to Rs 13403/ha on Non RCT plot. The net revenue has been estimated as Rs 30547/ha and Rs 36378/ha on RCT and Non RCT plot respectively. Similarly, Paddy grain yield on RCT plot was found to be lower (5568 kg/ha) as compared to 7286 kg/ha on Non RCT plot. The net revenue has been estimated as Rs 34171/ha and Rs 48086/ha on RCT and Non RCT plot respectively. RCT dynamics brought out that during the year 2003-04, 39 percent wheat area was sown with zero tillage and only 14 per cent with reduced tillage. At present, a great deal of emphasis is being laid on the modernization of agriculture, with a view to raise the production per unit area, the income of the farmers under sustainable environment. The goal can be achieved only, if the scientific agricultural technology is efficiently adopted at proper time and stage by large number of farmers at their farm. Though, the farmers in Indian Punjab have started picking up RCT, yet its adoption level /rate has been very slow rather disadoption process has also been started. The main reasons responsible for such reverse trend was that the farmers adopted conservation agriculture without following the full package of practices required for conservation agriculture. Conservation agriculture demands to leave more and more crop residues on the soil itself, the RCT farmers rather used the crop residue especially of wheat as feed for their own livestock and or sell in the market for earning of their livelihood. Almost whole of paddy crop residue was burnt in their fields terming it as the easiest method to vacate fields for sowing the next crop. Under such faulty crop residues management practices, the conservation agriculture rather reduced the soil fertility and hence the crop productivities and profitabilities, putting the adoption of RCT under the question mark. Farmers observed that due to inadequate exposure, non-availability of required machines and lower yield had been the major hindrances in the fast adoption of conservation agricultural practices in the state. Keeping in view the multifaceted merits of RCT, the farmers need to be encouraged for its fast adoption. RCT represents a major departure from the past way of doing things. This implies that the whole range of management practice will need to be evolved, evaluated & matched in the context of new systems and disseminated its practices to the farmers for achieving sustainable economic development in general and environment/ natural wealth friendly agricultural development in particular.

Key words: Conservation agriculture, Resource conserving technologies, Natural resource management, judicious use of nature's wealth, Sustainable agricultural development, Green economic development

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In the agriculturally advanced state of Punjab, the rice-wheat cropping system is widely practiced. The area under rice crop was just 0.39 million hectares in 1970-71, increased by about 7 times to 2.72 million hectares in 2008-09. At present, the rice crop has about one –third share in the gross cropped area and about sixty five per cent share in the net area sown in the state. Similarly, wheat crop in the state is being grown over 84 per cent of its cultivated land. Livestock population plays an important role in the rice-wheat system. These crop-livestock systems support the livelihoods of majority of the families in the state. Integrating crop and livestock production has a number of advantages, including complementarities in terms of resource use and income and risk reduction. These systems have seen rapid and significant intensification of rice-wheat cultivation in response to the availability of improved inputs and policy and institutional support. Lately though, the rice-wheat cropping system is experiencing stagnant or declining grain yields, falling water tables and soil degradation (Kumar et al., 1999; Pingali and Shah, 1999). These threats are being addressed by the Rice-Wheat Consortium (RWC, www.rwc.cgiar.org) through research on resource-conserving technologies (RCTs, including zero-tillage, permanent beds and mulching) within the context of conservation agriculture. The RCTs are having some success in improving resource use efficiency for crop production, but there is a lack of information about their impacts on overall farm productivity and its livestock components and the implications for the livelihood strategies of poor rural households.

The terms "conservation agriculture" and "resource conserving technologies" are quite different. "Conservation agriculture" refers to crop management practices that involve a minimum level of soil movement, soil cover (particularly through retention of crop residues) and the use of sensible, profitable crop rotations. "Resource conserving technologies" refer to those practices that enhance resource/input use efficiency. The RCTs are typically part of conservation agriculture practices, but may become unsustainable in the long run, if they do not meet all the components of conservation agriculture. Although the adoption of zero/minimum tillage in wheat is spreading fast, adopters often do so without retaining significant amounts of crop residues as mulch. In part, this seems to relate to practical difficulties with crop residue management, particularly in view of changes in harvesting practices (use of combiners) and the current zero-till drills in use. However, even without zero-tillage, the practice of burning crop residues is common in certain locations (Gupta et al., 2004; Sidhu et al., 1998). The crop residues are also removed for use in agro-based industries and as household fuel and building material. However, the most important factor appears to be that crop residues are an important source of fodder for both landed and landless livestock keepers. Applying

conservation agriculture practices typically implies the need to retain crop residues on the soil surface, which reduces the availability of crop residue for livestock production. Thus, to adopt conservation agriculture practices, farmers face trade-offs between crop and livestock production. Retention of crop residue in the field improves the soil organic matter content. In principle, using the crop residue as fodder and returning the manure to the soil should improve soil productivity and be environmentally sustainable. However, in the Indo-Gangetic Plains (IGP) the widespread use of dung as household fuel limits its availability for crop production. The advent of conservation agriculture further decreases the role of draft animals, which may lead to specialized dairy or meat enterprises. This will have varying implications for landed and landless households in terms of land allocation decisions for food and fodder production and dependence on markets for purchase of livestock inputs. Not much is documented about crop-livestock interactions in the IGP (Paris, 2002; Parthasarathy Rao et al., 2004; Parthasarathy Rao and Hall, 2003; Thomas et al., 2002). Indeed, research and technical interventions typically focus on crops or on livestock, often without a system perspective (Devendra et al., 2000; Thomas et al., 2002). Yet a better understanding of the system and the livelihood objectives of landed and landless families are essential for successful alleviation of poverty and improving rural livelihoods. Under this context, the present paper researches the crop-livestock interactions in the rice-wheat-livestock systems of the IGP to quantify the trade-offs faced by farmers who have adopted or are considering conservation agriculture practices.

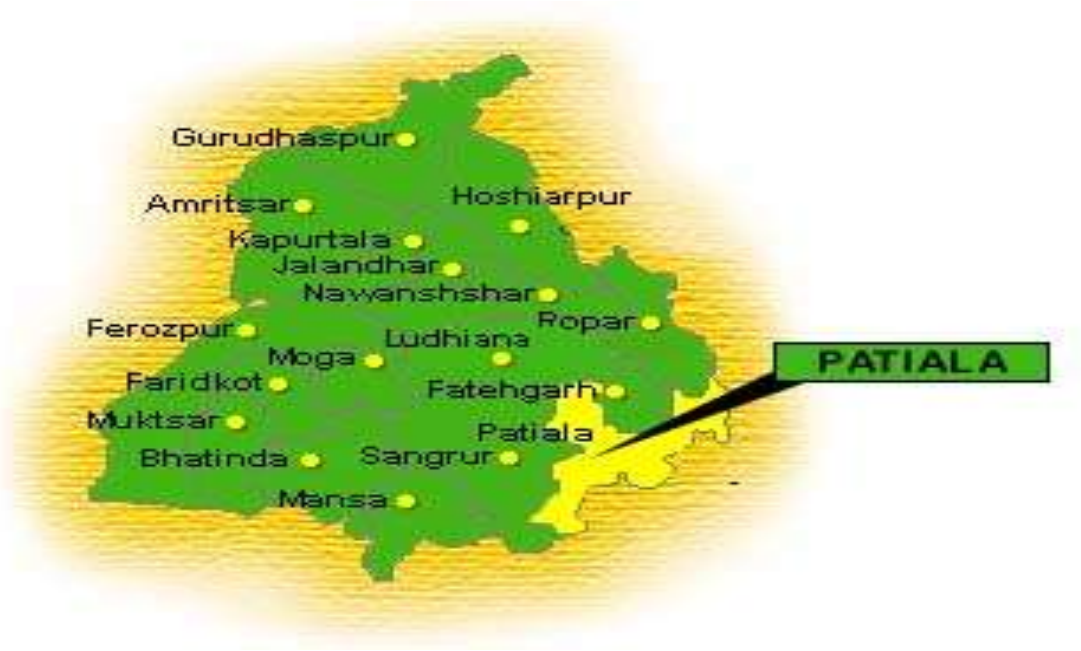
The specific objectives are:

1. To better understand crop-livestock interactions (CLI) and the trade-offs farmers face in applying conservation agriculture practices in rice-wheat-livestock systems;
2. To assess the implications of the CLI and the trade-offs for the development of conservation agriculture in particular and of rice-wheat-livestock systems in general;
3. To use this understanding to realign and focus current and future R&D efforts addressing conservation agriculture practices in rice-wheat-livestock systems so as to optimize their benefits for rural livelihoods, poverty alleviation and environmental sustainability.

Methodology

Description of the survey area: Patiala District

Patiala district is one of the famous princely states of erstwhile Punjab. Forming the southeastern part of the state, it lies between 29°49’ and 30°47’ north latitude, 75°58’ and 76°54' east longitude.



Village selection procedure: The villages were selected according to the expectation of the greatest differences in specific issues. Keeping in view the concentration of Resource Conservative Technology (RCT) activities, the study was focused in two blocks of Patiala districts i.e. Patiala and Rajpura. While selecting a sample of 6 villages, due care was accorded to various issues such as RCT and non-RCT activities, farness and nearness of the villages from market and population size of the village etc. The detail classification of the selected villages has been shown as under:

Classification of the selected villages

Village Type	**Village title**	**Household**{#}
RCT far	Devinagar H.S	**64**
RCT near	Jalalpur	**218**
Non-RCT near	Ramgarh	**154**
RCT far	Dhuman	**105**
RCT near	Jansla	**303**
Non-RCT far	Dhindsa	**126**

Village level information/data

In each village, the people were gathered with the help of village chief in a large group in school/ religious place or other premises and were sensitized about the research purpose and data collection process by the team leader. In order to get overall view of the survey area, soil, irrigation, RCT activities and livestock population etc, the key informants including Village chief were interviewed. Thereafter the people were divided into three groups viz: Large farmers, Small farmers and Landless of 8-10 persons each. The team members interviewed each group separately with key informants' information as a check. The survey was conducted during 28.11.2006 –1.12.2006

Household level information/data

In order to accomplish the objectives of the study, the main primary data sources for this study were targeted informal and formal surveys at four different systems levels: community, household, enterprise and market. This document presents the findings from household and enterprise surveys conducted in 6 villages of Patiala district of Punjab during 2007-08. The required enterprise data/information have been collected from 120 sample households using personal information method with the help of an especially designed schedule prepared for the purpose. The data have been collected in three separate survey rounds for kharif, rabi and summer seasons. The analysis has been based on a sample of 120 households selected for the purpose.

The actual versus intended sample composition by household type for the present analysis has been presented below in table format. Due to certain practical compulsion, some intended sample households were required to be replaced. The category wise intended sample household composition was 48 RCT, 47 Non – RCT and 24 landless while actual sample composition included 45 RCT, 49 Non – RCT and 24 landless households after the replacement as shown below:

Actual versus intended sample composition by household type (no. of households)

		Intended			Replacements	Total Actual
		RCT	Non-RCT	Landless		
Actual	RCT	45	0	0	0	45
	Non-RCT	3	45	0	1	49
	Landless	0	0	22	2	24
Not included		0	2	2		
Total intended		48	47	24		

Results and Discussion

Results have been discussed under the following sub heads:

I Conservation agriculture based Resource Conserving Technologies

II System characteristics

III Crop management and conservation agriculture based RCT's

IV Crop residue use and livestock feeding

V Constraints to RCT adoption and suggestions for its rapid adoption:

I Conservation agriculture based Resource Conserving Technologies:

RCT Dynamics:

The RCT dynamics in terms of zero tillage, zero till seed drill and reduced tillage in all the six sample villages have been shown in Table 1. Of the total households in these villages, 32, 42 and 53 were practicing zero tillage, Zero till seed drill, and reduced tillage respectively, constituting 34, 45 and 56 percent of the total RCT households. It is further noticed that all these forms of RCT were in use in these village for the last about 5 years (4.9 years – zero tillage, 5.3 years – zero till seed drill and 4.5 years – reduced tillage). RCT dynamics brought out that during the year 2003-04, 39 percent wheat area was sown with zero tillage and only 14 per cent with reduced tillage. Though zero till seed drill was used on 32 percent of the wheat area. Over the years, the zero tillage practice reduced and disappeared completely till the year 2006-07 and thereafter while the percent wheat area sown with reduced tillage has gone up to the level of 48 in 2006-07 and stabilized thereafter till 2008-09. The use of zero till seed drill has also become more popular among the farmers as its use has been expanded over 51 percent wheat area in the sample villages during 2008-09. Hence, over the years (2003-04 to 2008-09), farmers shifted from zero tillage to reduced tillage in the state.

II System characteristics:

The land of these villages was upland and irrigated. The major source of irrigation was electric tube wells followed by canal irrigation. It is worthwhile to point out that in *rabi* season, wheat crop alone occupied about 80 percent of the total cropped area and paddy was the major *kharif* crop, it occupied about 70 percent of the area. The fodder crops were the next important on the cropping

map of the villages. The other crops, though grown over minor areas were vegetables, pulses, oilseeds and maize etc. Most of the household kept animals like buffalo and cow. All the villages were well electrified and enjoyed telephonic and transport connectivity. The farming operations were well mechanized. Though the main occupation of the people was farming, yet they have some subsidiary occupations like dairy, bee keeping, poultry, custom hiring, private/government service, trading etc. The income of the farmers, primarily, depends on the size of operational holding.

Household and farm assets:

The total land owned by RCT & Non RCT and landless households was 4.3, 2.4 and 0.1 hectare respectively. The cultivated land was found to be 4.4 and 2.3 hectares for RCT and Non RCT households in 3.2 and 2.2 numbers of plots with an average plot size of 1.4 and 1 hectare. The family size of RCT households was comparatively larger with 7 members than Non RCT households (6.5) and landless (5.9). The education of household head in terms of years in school was 6.8, 5.7 and 4.3 for RCT, Non RCT, and landless households respectively. On the whole RCT households were found to be bigger land holders, larger family sized with better education of the household heads as compare to Non RCT and landless sample households. Regarding livestock, 96, 86 and 96 percent of RCT, Non RCT and landless households were keeping livestock assets with an average herd size of 8.5, 9.and 4.4 tlu. The household asset indicators by households brought out that 91 percent RCT, 96 percent Non RCT and 96 percent landless sample households had pakka house with respective value of Rs 679268, Rs 677872 and Rs 350000. All the households irrespective of their type were electrified. Land line telephone connections were found with 84 percent RCT, 51 percent Non RCT and only 4 percent landless households. The mobile phones were even more common in these households as 91 percent RCT, 76 percent Non RCT and 33 landless households enjoyed this source of telecommunication. Further, television sets were found with 96, 92 and 75 percent RCT, Non RCT and landless households respectively. The 87 percent RCT, 63 percent Non RCT and 13 percent landless households possessed motor bike as local source of transportation while 20 percent RCT and 8 percent and Non RCT households even had four wheeled vehicles for the purpose.

Farm machinery:

The farm machinery owned by household types has brought out that four wheel tractors were owned by 80 percent RCT and 41 percent Non RCT households. Around 33 percent RCT and 4 percent Non RCT households had zero till seed drill with them. Electric pump was also found very common with the sample households as 80 percent RCT and 63 percent Non RCT households possessed this source of irrigation. On the whole, the total value of owned machines per household was estimated as Rs

196467 and Rs 103347 on RCT and Non RCT households respectively. Hence it was found that the RCT households were better equipped with the farm machinery as compared to their counterpart i.e. Non RCT households.

Household income and expenditure:

The total annual income per person has been estimated at Rs 55766, Rs 36627 and Rs 16972 for RCT, Non RCT and landless households respectively. In case of RCT households, 98 percent income was contributed by crops and livestock, and only 1 percent each from services and other sources. Income composition of Non RCT households brings out that crops and livestock accounted for 90 percent of their total income. Services were the next best contributor (4%) to their income, followed by business (3%), non agricultural labour (2%) and agricultural labour (1%). Agricultural labour was found to be the second major source of income for the landless household constituting 28 percent towards their income with 29 percent from farm and livestock. The other important sources of their income were non agricultural labour (22%), services (19%) and business (3%). Total expenses per person for RCT, Non RCT and landless households were estimated at Rs 8567, Rs 9985 and Rs 6920 respectively. In case of RCT households, food constituted 53 percent of the total expenses followed by clothing and electricity with 11 and 9 percent of the expenses. The respective figures were 55, 13 and 8 percent for Non RCT households and 59, 13 and 10 percent for the landless households. The per capita annual consumption of major food items like wheat, rice and milk was kg 69, kg 42 and litre 238 for RCT households. These figures were found to be kg 73, kg 60 and litre 267 for Non RCT households and kg 88, kg 44 and litre 274 for the landless households.

Credit and savings:

It was found that about 69 percent RCT households, 94 percent Non RCT households and 92 percent landless households had bank account. No landless household took loan from the formal as well as other sources as revealed. In case of RCT households and Non RCT households, around 64 and 76 percent took loans with an average amount of Rs 28089 and Rs 26878 respectively. Around 99 percent RCT households and 83 percent Non RCT households took loans from formal sources.

Household work time allocation and objectives:

The average time share working in own crops was 9.84, 10.23 and 0.36 percent in RCT, Non RCT and landless households. In case of RCT households, the percent time allocated to various activities was found to be 8.31 percent for own livestock activities, 5.50 percent for market activities, 14.26 percent for household work, 13.09 percent for schooling/ non farm activities and 16.98 percent for leisure. The Non RCT households devoted 8.83, 7.17, 15.71, 15.68 and 19.54 percent of their total work time for

own livestock activities, market activities, household work, schooling/non farm activities and leisure respectively. The percent work time spent by the landless households for own livestock activities, market activities, household work, schooling/non farm activities and leisure was noted as 8.79, 5.89,18.02,18.14, and 17.74 respectively. These households also spent around 1 percent of their work time on agricultural as well as non agricultural labour activities. The value of average rank calculated for RCT households were 4.53(tradition), 3.38 (risk), 3.11 (profit), 2.80 (consumption) and 1.07 (liquidity) for pursuing farm activities. In case of Non RCT households, the major objectives of farm activities were found more or less similar as that of RCT households. The major objectives of farm activities in Non RCT households have been reported as tradition (4.29), profit (4.27), risk (2.96), consumption (2.43) and liquidity (1.06). The livestock activities were being carried out by the RCT households with prime objectives of crop support (4.00), risk (3.74), profits (3.30), consumption (2.67) and liquidity (1.28). The Non RCT households' major objectives of livestock activities were profits (4.48), crop support (3.50), risk (3.43), consumption (2.37) and liquidity (1.12).The landless households adopted the livestock activities mainly to cover the risk and make profits along with consumption and liquidity purposes.

Crops:

Wheat in the rabi and paddy in the kharif season were the principal crops both on RCT and Non RCT households. In case of RCT households, wheat was grown over 85 percent area followed by 6 and 9 percent under vegetables and fodder during rabi season. The Non RCT households grew wheat on 83 percent area followed by fodder and vegetables on 14 and 3 percent area respectively. In kharif season, the whole wheat acreage was put under paddy cultivation and area under vegetables and fodder remained the same both in RCT and Non RCT households. Hence, a kind of paddy – wheat monoculture was followed by the sample households irrespective to the household type.

Irrigation sources:

The major agricultural water source was found to be the electric submersible pump on RCT and Non RCT households sharing 78 and 82 percent cultivated area. The canal irrigation covered 19 and 12 percent cultivated area of these households' types respectively. The market share of crops by household type brought out both wheat and paddy were the commercial crops of all the households irrespective to their type. Almost 84 percent of wheat and 80 percent paddy grain were sold in the post harvest season by the RCT households and these percentages were around 78 and 76 for the Non RCT households.

Livestock:

Of the total, 96 percent RCT, 82 percent Non RCT and 88 percent landless households were keeping buffaloes with the respective buffalo herd size of 4.6, 5.3 and 2.7. Further about 29 percent RCT, 24 percent Non RCT and 17 percent landless households kept cattle and the respective cattle herd size was found to be 2.8, 2.3 and 2.3. Goats and sheep were not found with any sample household. Total daily milk production on RCT households was 18 liters, of which 13.1 liters were sold at an average price of Rs 10.9/liter of cattle milk and Rs 16.1/liter of buffalo milk. Similarly, of the total 19.7 liters of milk produced, 14.3 liters was sold by Non RCT households at an average price of Rs10.6/liter cattle milk and Rs 15.9/liter buffalo milk. The landless household produced 7.7 liters daily milk and sold 5.3 liters of milk at Rs 10.0/liter of cattle milk and Rs 15.9/liter for buffalo milk.

III Crop management and conservation agriculture based RCT's

This section deals with the crop management and conservation agriculture based resource conserving technologies both for wheat and rice crops.

Wheat crop:

The wheat crop management practices by RCT and Non RCT plots, wheat residue use by harvest mode and wheat performance indicators have been presented in Tables 2 through 4. The various crop management practices followed on RCT and Non RCT plots by the RCT households have been contrasted in Table 2. There were 45 RCT plot and 85 Non RCT plot. The preceding crop was rice almost on all the plots. The residue measurement brought out the coverage of soil as 18 percent on RCT plot and 12 percent on Non RCT plot. The land was tilled with tractors with the average 2 passes on RCT plot and 4.60 passes on Non RCT plot. The most common practice of straw management was found to be mixing with soil on both kinds of plots i.e. 93 percent RCT plot and 95 percent Non RCT plot. Drill/Zero tillage machines were used for wheat planting on 98 percent RCT plots and only 2 percent Non RCT plot. The seed quantity used was almost the same i.e. kg 112-113/ha on RCT and Non RCT plots. The turn-around time was also noticed as 25.09 and 25.53 days on RCT and Non RCT plots. The chemical fertilizers N, P and K was found to be 194, 66 and 5 kg/ha respectively on RCT plot as against 189, 60 and 3kg/ha on Non RCT plots. The use of manure was more on Non RCT plot (14251kg/ha) as compared to RCT plot (12333kg/ha). Weed management practices and irrigation were more or less similar on both types of plot. The crop was harvested with combine on 67 percent RCT plots and 59 percent Non RCT plots while power thresher was used on 29 percent and 38 percent on

these plots for the purpose. Wheat residue use by harvest mode i.e. manual or combine on RCT plot and Non RCT plot has been depicted in Table 3. Under manual harvest mode, 82 percent wheat residue was taken home from the RCT plot and 86 percent from Non RCT plot. Further 14 and 12percent was sold from these plots respectively. Wheat residue left in the fields was just 4 percent on RCT plot and 2 percent on Non RCT plots. Under combine harvest mode 27percent and 23 percent wheat residue was left in the field on RCT and Non RCT plots respectively. The wheat residue sold under this mode was found to be 45 percent and 38 percent on RCT and Non RCT plots respectively. Only 28 percent and 39 percent wheat residue was taken home on these plots under combine harvest mode. On the whole, manually harvested wheat residue was considered of better quality and preferred to take home for consumption of their own animal whereas major component of combined harvested wheat straw was either sold or left in the field. Wheat performance indicators on RCT and Non RCT plots have been contrasted in Table 4. The grain yield on RCT plot was found to be lower (4168 kg/ha) as compared to 4817 kg/ha on Non RCT plot. As part of the wheat residue is left on the field on RCT plot, the yield straw realized was lower on the RCT plot as compared to Non RCT plot. The product value has been estimated at Rs 42841/ha and Rs 49781/ha on RCT and Non RCT plot. The total estimated input cost was Rs 12294/ha on RCT and Rs 13403/ha on Non RCT plot. The net revenue has been estimated as Rs 30547/ha and Rs 36378/ha on RCT and Non RCT plot respectively.

Rice crop:

The rice crop management practices by RCT and Non RCT plots, rice residue use by harvest mode and rice performance indicators have been presented in Tables 5 through 7.

The various crop management practices followed on RCT and Non RCT plots by the RCT households have been contrasted in Table 5. There were 44 RCT plot and 85 Non RCT plot. The preceding crop was wheat on all the plots. The residue measurement brought out the coverage of soil as 9 percent on RCT plot and 7 percent on Non RCT plot. The land was tilled with tractors with the average 4.14 passes on RCT plot and 4.26 passes on Non RCT plot. Drill/Zero tillage machines were not at all used for rice planting both on RCT plots and Non RCT plot. The seed quantity used was almost the same i.e. kg 14 /ha on RCT and Non RCT plots. The turn-around time was also noticed as 59 and 54 days on RCT and Non RCT plots. The chemical fertilizers N, P and K was found to be 113, 42 and 3 kg/ha respectively on RCT plot as against 119, 40 and 0kg/ha on Non RCT plots. The use of manure was more on RCT plot (49034kg/ha) as compared to Non RCT plot (48724kg/ha). Weed management practices and irrigation were more or less similar on both types of plot. The crop was harvested with combine on 93 percent RCT plots and 94 percent Non RCT plots while power thresher was used only

on 2 percent Non RCT plots for the purpose. Rice residue use by harvest mode i.e. manual or combine on RCT plot and Non RCT plot has been depicted in Table 6. Under manual harvest mode, 90 percent rice residue was burnt in the field on the RCT plot and 96 percent on the Non RCT plot. Further 10 and 4 percent was left in the fields on these plots respectively. Under combine harvest mode 91percent and 94 percent rice residue was burnt in the field on RCT and Non RCT plots respectively. The rice residue left in the field under this mode was found to be 9 percent and 6 percent on RCT and Non RCT plots respectively. Rice performance indicators on RCT and Non RCT plots have been contrasted in Table 7.The Paddy grain yield on RCT plot was found to be lower (5568 kg/ha) as compared to 7286 kg/ha on Non RCT plot. The product value has been estimated at Rs44542/ha and Rs 58287/ha on RCT and Non RCT plot. The total estimated input cost was Rs 10371/ha on RCT and Rs 10201/ha on Non RCT plot. The net revenue has been estimated as Rs 34171/ha and Rs 48086/ha on RCT and Non RCT plot respectively.

Perceived effects on soil fertility and crop management:

Effects of leaving more wheat /paddy straw on the fields as reported by various holding size groups have been discussed here. The large farmers were of the view that leaving more wheat straw on the field would affect the subsequent crop in the form of poor germination and hence lower yield whereas, leaving more paddy straw in the fields would require more ploughings for land preparation for the subsequent crop. This would of course, lead to fertilizers cost saving and yield improvement. As per their perception, there would be no effect on water requirements for the subsequent crop. Small farmer on the other hand perceived no effect of leaving more wheat straw in the fields on the subsequent crop except increasing the tillage cost and labour requirement for land preparation. Leaving paddy straw in the fields would lead to lower fertilizer requirements and yield enhancement of the following crops.

IV Crop residue use and livestock feeding

Crop residue use:

Crop residue use has been given in Tables 8 through 10. Wheat and rice residue use by harvest mode and household type has been set out in Table 8. A big chunk of manually harvested wheat straw was fed to animals as it is considered of a better quality. As high as 77 percent and 78 percent of such wheat straw was fed to owned animals on RCT and Non RCT households and 19 percent was sold on both type of households. In case of manually harvested rice straw, whole of it was burnt in the field by

RCT and Non RCT households. The combined harvested wheat straw was either sold or fed or left in the field. About 29 and 28 percent of such wheat straw was left in the field by RCT and Non RCT households respectively and 45 percent and 25 percent of it was sold on these households. About 26 percent and 46 percent of combined harvested wheat straw was fed to animals by RCT and Non RCT households. The whole of combined harvested rice straw was burnt in the fields by RCT and Non RCT households. On the whole, 100 percent rice straw both manually as well as combined harvested was burnt in the fields whereas more of the manually harvested wheat straw was fed to animals and the remaining either is sold or left in the fields. Similarly, the combined harvested wheat straw was sold, left in the field and fed to the animals. The wheat and rice straw management practices used by harvest mode and household type have been presented in Table 9. The manually harvested wheat straw has got multiple uses unlike the manually harvested rice straw that was simply burnt in the fields by almost 100 per cent households both RCT as well as Non RCT households. In case manually harvested wheat straw, 100 percent RCT and 89 percent Non RCT households used to feed to the animals, about 47 percent and 31 Percent RCT and Non RCT households sold the straw in the market for its consumption to the animals while 87 percent and 56 percent RCT and on RCT households left some of this straw in the fields too. The uses of combined harvested wheat straw were also similar to manually harvested wheat straw. Around 93 percent RCT and 92 percent Non RCT households left such straw in the fields while 93 percent and 69 percent households sold the wheat straw in the market. On the whole it is observed that rice straw either manually harvested or combined harvested was burnt in the fields of RCT and Non RCT households while wheat straw either manually or combined harvested was subject to multiple management practices in RCT and Non RCT households. The importance of fuel sources by household type has been explained in Table 10. The various sources used as fuel were found to be wood, dung cakes/sticks and LPG by the sample households. The major source of fuel was LPG that covered 69.11 percent, 56.43 percent and 61 46 percent of the total fuel used by RCT households, Non RCT households and landless households respectively. The other important source of fuel was dung cakes/sticks covering 16.67, 24.53 and 20.0 percent of total fuel consumption by these households respectively. Wood covered 14.22 percent of fuel consumption on RCT households, 19.04 percent on Non RCT households and 18.54 percent on the landless households.

Livestock feeding:

Feeding practices, feeding composition, quantity of wheat and rice straw fed by season and households, wheat and rice straw contribution to feeding ration and straw contribution to feeding ration by ruminant etc have been presented in Tables 11 through Tables 13.Feeding practices in terms of

straw, green fodder and concentrates by household type has been shown in Table 11. The wheat straw was being fed to animals by 96 percent RCT, 90 percent Non RCT and 96 percent landless households whereas only 2 percent, 10 percent and 8 percent RCT, Non RCT and landless households were feeding rice straw to the animals. About 90-96 percent households were feeding green fodder and concentrates to their animals across these household types.

Feeding composition by household types as shown in Table 12 highlights that of the total dry matter fed to animals, wheat straw constituted 32.11, 32.01 and 30.98 percent on RCT, Non RCT and landless households respectively. The share of paddy straw varied from as low as 0.06 percent to 1.67 percent across the household types. The green fodder covered 50 -51 percent and bough concentrates 16-18 percent on these households.

Table 13 shows the amount of wheat and rice straw fed by season and household type. The amount of wheat straw fed to the TLU daily by RCT households varied from 3.31 kg during May – June to 1.33 kg during September – October. Similar range has been found on Non RCT households i.e. 3.63 kg wheat straw was fed in the months of March – June and only 1.28 kg wheat straw was fed during September – October. The landless households fed daily wheat straw to TLU as 3.30 kg during the months March April and 1.33- 1.34 kg during July – October. The rice straw has not been fed to the animals by all the households irrespective to their type.

V Constraints to RCT adoption and suggestions for its rapid adoption:

Excessive tillage is energy, time and cost consuming and is considered harmful to the soil health. During the past few years, scientists have suggested that physical properties favorable for plant growth are destroyed by too much tillage. The cost of hydrocarbon fuels is rising day by day and is a well-known fact that they are bound to be exhausted sooner or later. Keeping these factors in view and with a motive of timely sowing and reducing cost of production, researchers world over have studied tillage operations more closely. In general, zero tillage/ minimum tillage is defined as reducing field trips by machinery for seedbed preparation to a minimum numbers. By adopting the minimum/zero tillage concept, the farmers are not only able to reduce the cost of cultivation/enhance their profit margins save a significant quantity of much needed fuel, energy and time but also it enables the farmers to sow the crop at right time. At present, a great deal of emphasis is being laid on the modernization of agriculture, with a view to raise the production per unit area, the income of the farmers under sustainable environment. The goal can be achieved only, if the scientific agricultural technology is efficiently adopted at proper time and stage by large number of farmers at their farm. Though, the

farmers in Indian Punjab have started picking up RCT yet its adoption level /rate has been very slow rather disadoption process has even been started. The main reasons responsible for such reverse trend was that the farmers adopted zero tillage technology under conservation agriculture without following the full package of conservation agriculture. Conservation agriculture demands to leave more and more crop residues on the soil itself to reap the advantage of conservation agriculture, the RCT farmers rather used the crop residue especially of wheat as feed for their own livestock and or sell in the market for earning their livelihood. Almost whole of paddy residue was burnt in their fields. Under such faulty crop residues management, the conservation agriculture reduced the soil fertility and hence the crop productivities and profitabilities. Consequently, over the years, zero tillage practice reduced and disappeared completely till the year 2006-07 and thereafter while the percent wheat area sown with reduced tillage has gone up to the level of 48 in 2006-07 and stabilized thereafter till 2008-09. Farmers observed that due to inadequate exposure, non-availability of required machines and lower yield had been the major hindrances in the fast adoption of zero tillage. Landless group though apprehended the adverse effect of RCTs on employment opportunities in the sample areas. It is important to diagnose various constraints associated with its adoption and suggest policy measures for rapid adoption of RCT in Punjab.

To make the adoption of RCT faster, there is a need to identify the constraints inhibiting the adoption of this technology and solutions thereof. The various constraints of this technology as identified in earlier studies were the non-availability of the drill and unawareness of the RCT resulting in slow technology adoption process. Farmers further reported that there was a problem of sowing with the zero till drill in the standing stubbles. The standing stubbles lead to the wear and tear and also the breakage of the drill, thus, they were burning the stubbles before sowing. Another problem reported was the depth of sowing. The zero till drill sows the seed to a depth of about four inches, which according to them leads to non-emergence of the seed. Farmers were also afraid of the low grain yield. They were of the opinion that the tillage practice was necessary in the process of cultivation as their ancestors have been doing it for last so many years. Moreover, The sowing operation consumed more time on zero till farms as against the conventional farms, the reason being the formation of hardpan on the farm, thus, causing a problem while sowing operation.

Suggestions/recommendations for the rapid adoption of RCTs in Punjab:

To encourage the rapid adoption of this technology the following suggestions can help to a great extent:

* Keeping in view the multifaceted merits of RCT, the farmers needs to be encouraged through easy availability of zero till drill at subsidized rates in the beginning or making the drill available at cheap rates through the help of agricultural department or the co-operative societies.
* Zero tillage technology represents a major departure from the past way of doing things. This implies that the whole range of management practice will need to be evolved, evaluated & matched in the context of new systems. The guidelines for the different farm operations may be published and provided to the farmers for proper crop management.
* The field trials may be conducted by the agricultural scientists on the farm conditions to demonstrate the various practices needed to be evolved in the technology adoption.
* The demonstrations or some exhibitions may be arranged to make the people familiar to the technology and remove any doubts and mis-perceptions like lower grain yield and the fear of even non-emergence of the seeds from their minds. The case studies may also be undertaken to find out the reasons responsible for the lower grain yields of paddy as well as wheat on RCT plots as compare to Non RCT plots of the RCT households.
* Although significant successful efforts have been made in developing and promoting machinery for seeding wheat in no till system, the successful management of standing stubbles and deep sowing of the seed require further improvement in machinery.
* Managing zero tillage will be highly demanding in terms of knowledge base and thus, there will be a great need of extension services.

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Table 1: RCT dynamics in sample villages (average of 6 villages)

	Zero tillage (ZT)	ZT seed drill	Reduced tillage (RT)
Households used [no]	32	42	53
Share [% farms]	34	45	56
Since first use [years]	4.9	5.3	4.5
2003/4 [% wheat area]	39	32	14
2004/5 [% wheat area]	12	31	22
2005/6 [% wheat area]	4	50	43
2006/7 [% wheat area]	0	51	48
2007/8 [% wheat area]	0	51	48
2008/9 [% wheat area]	0	51	48

Table 2: Wheat crop management practices by RCT use (plot level)

		RCT plot	Non-RCT plot
Plots	[no]	45	85
P receding crop	non-rice crop [% plots]	0.00	1
Residue measurement	soil coverage [%]	18	12
Tillage (wheat)	Passes [no.]	2.00	4.60
	Tractor [% plots]	100	100
	first tillage [date	10/23/2007	10/20/2007
Straw management	most common practice	mix	mix
	[% plots]	93	95
Planting	drill/ZT mach [% plots]	98	2
	Date	11/5/2007	11/5/2007
	turn-around time [days]	25.09	25.53
	seed quantity [kg/ha]	112	113
Fertilization	Manure [kg/ha]	12333.33	14251.19
	N [kg/ha]	194	189
	P_2O_5 [kg/ha]	66	60
	K_2O [kg/ha]	5.00	3
Weed management	herbicide applications [no.]	1	1
	Manual weeding [no].	0.00	0.00
	pesticides applied [% plots]	2	1
Irrigation	Irrigations [no.]	3.4	3.4
Harvest	combine [% plots]	67	59
	power thresher [% plots]	29	38

Table 3: Wheat residue use by harvest mode and RCT use (plot level)

% Straw from field	Manual		Combine	
	RCT plot	non-RCT plot	RCT plot	non-RCT plot
Plots [no]	15	35	30	50
Left in field [%]	4	2	27	23
Burnt in field [%]	0.00	0.00	0.00	0.00
Sold [%]	14	12	45	38
Taken home [%]	82	86	28	39
Other [%]	0.00	0.00	0.00	0.00
	100	100	100	100

Table 4: Wheat performance indicators by RCT use (plot level)

		RCT plot	Non-RCT plot
Plots	[no]	45	85
Yield	Grain [kg/ha]	4168	4817
	Straw [kg/ha]	3553	4287
Product values	Grain [Rs/ha]	37512	43351
	Straw [Rs/ha]	5329	6430
	gross revenue [Rs/ha]	42841	49781
Input costs Incl labour expenses	Tillage [Rs/ha]	1222	2728
	planting & seed [Rs/ha]	3523	3566
	Fertilizer [Rs/ha]	3534	3127
	herb. & pesticide [Rs/ha]	1691	1677
	Harvest [Rs/ha]	2324	2305
	Total [Rs/ha]	12294	13403
Net revenue	[Rs/ha]	30547	36378

Table 5: Rice crop management practices by RCT use for previous crop (plot level)

		Rice in RCT plot	Rice in non-RCT plot
Plots	[no]	44	85
Preceding crop	non-wheat/rice [% plots]	0.00	0.00
Residue measurement	soil coverage [%]	9	7
Tillage (wheat)	Passes [no.]	4.14	4.26
	Tractor [% plots]	100	100
	first tillage [date]	5/19/2007	5/23/2007
Straw management	most common practice	lab	lab
	[% plots]	75	71
Planting	drill/ZT mach [%]	0	0.00
	Date	6/2/2007	6/6/2007
	turn-around time [days]	7759.14	54.11
	seed quantity [kg/ha]	14	14
Fertilization	Manure [kg/ha]	49034	48724
	N [kg/ha]	113	119
	P_2O_5 [kg/ha]	42	40
	K_2O [kg/ha]	3	0
Weed management	herbicide applications [no.]	1.9	1.9
	Manual weeding [no].	0.00	0.00
	pesticides applied [% plots]	98	100.00
Irrigation	Irrigations [no.]	23.2	23.4
Harvest	combine [% plots]	93	94
	power thresher [% plots]	0.00	2

Table 6: Rice residue use by harvest mode and RCT use for previous crop (plot level)

% Straw from field	Manual		Combine	
	Rice in RCT plot	Rice in non-RCT plot	Rice in RCT plot	Rice in non-RCT plot
Plots [no]	2	5	41	80
Left in field [%]	10.00	4.00	9.02	6.13
Burnt in field [%]	90.00	96.00	90.98	93.88
Sold [%]	0.00	0.00	0.00	0.00
Taken home [%]	0.00	0.00	0.00	0.00
Other [%]	0.00	0.00	0.00	0.00
	100.00	100.00	100.00	100.00

Table 7: Rice performance indicators by RCT use for previous crop (plot level)

		Rice in RCT plot	Rice in Non-RCT plot
Plots	[no]	44	85
Yield	Grain (paddy) [kg/ha]	5567.75	7285.88
	Straw [kg/ha]		
Product values	Grain [Rs/ha]	44541.97	58287.04
	Straw [Rs/ha]		
	Gross revenue [Rs/ha]	44541.97	58287.04
Input costs	Tillage [Rs/ha]	3039.44	3107.99
incl labour expenses	Planting & seed [Rs/ha]	1703.50	1753.71
	Fertilizer [Rs/ha]	2351.12	2183.17
	herb & pest [Rs/ha]	2002.27	1831.23
	Harvest [Rs/ha]	1274.56	1324.91
	Total [Rs/ha]	10370.89	10201.02
Net revenue	[Rs/ha]	34171	48086

Table 8: Wheat and rice residue use by harvest mode and household type (household level)

% Straw used	Wheat		Rice	
	RCT	non-RCT	RCT	Non-RCT
Manually harvested				
Households [no]	15	36	19	13
Left in field [%]	4	2	0	0
Burnt in field [%]	0	0	100	100
Sold [%]	19	19	0	0
Fed [%]	77	78	0	0
Fuel [%]	0	1	0	0
Other [%]	0	0	0	0
	100	100	100	100
Combine harvested				
Households [no]	30	13	27	37
left in field [%]	29	28	0	0
Burnt in field [%]	0	0	100	100
Sold [%]	45	25	0	0
Fed [%]	26	46	0	0
Fuel [%]	0	1	0	0
Other [%]	0	0	0	0
	100	**100**	**100**	**100**

Table 9: Wheat and rice straw management practices use by harvest mode and household type

% Households practicing	Wheat		Rice	
	RCT	non-RCT	RCT	Non-RCT
Manually harvested				
Households [no]	15	36	19	13
Left in field [%]	86.67	55.56	0.00	0.00
Burnt in field [%]	0.00	0.00	100.00	100
Sold [%]	46.67	30.56	0.00	0.00
Fed [%]	100.00	88.89	0.00	0.00
Fuel [%]	0.00	2.78	0.00	0.00
Collected/grazed [%]	0.00	0.00	0.00	0.00
Roof/constr. [%]	0.00	0.00	0.00	0.00
Other [%]	0.00	0.00	0.00	0.00
Combine harvested				
Households [no]	30	13	27	37
Left in field [%]	93.33	92.31	0.00	2.70
Burnt in field [%]	0.00	0.00	100.00	97.30
Sold [%]	93.33	69.23	0.00	2.70
Fed [%]	90.00	100.00	0.00	0.00
Fuel [%]	0.00	7.69	0.00	0.00
Collected/grazed [%]	0.00	0.00	0.00	0.00
Roof/constr. [%]	0.00	0.00	0.00	0.00
Other [%]	0.00	0.00	0.00	0.00

Table 10: Importance of fuel sources by household type

[% Fuel used]	RCT	Non-RCT	Landless
Households [no]	45	49	24
Straw [%]	0.00	0.00	0.00
Wood [%]	14.22	19.04	18.54
Dung-cakes/sticks [%]	16.67	24.53	20.00
LPG [%]	69.11	56.43	61.46
Bio-gas [%]	0.00	0.00	0.00
Leaves/bamboo [%]	0.00	0.00	0.00
Kerosene [%]	0.00	0.00	0.00
Jute sticks [%]	0.00	0.00	0.00
Maize stover [%]	0.00	0.00	0.00
Other [%]	0.00	0.00	0.00
	100	100	100

Table 11: Feeding practices by household type

[% Households using as feed]		RCT	Non-RCT	Landless
Household	[no]	45	49	24
Straw	wheat [%]	96	90	96
	paddy [%]	2	10	8
Green	fodder [%]	96	90	96
	collected [%]	0	0	0
Concentrates	own [%]	96	90	96
	bought [%]	0	0	0

Table12: Feeding composition by household type

[% of dry matter fed]		RCT	non-RCT	landless
Household	[no]	43	44	23
Straw	wheat [%]	32.11	32.01	30.98
	paddy [%]	0.06	1.67	1.56
Green	fodder crop [%]	51.51	49.86	49.63
	by-product [%]	0.00	0.00	0.00
	collected [%]			
Concentrates	own [%]	0.00	0.00	0.00
	bought [%]	16.32	16.46	17.83

Table13: Amount of wheat and rice straw fed by season and household type

kg DM/(tlu*d)	Wheat			Rice		
	RCT	Non-RCT	Landless	RCT	Non-RCT	Landless
Households[no]	43	44	23			
Jan-Feb [kg]	2.68	2.63	2.72			
Mar-Apr [kg]	3.15	3.63	3.30			
May-Jun [kg]	3.31	3.63	3.25			
Jul-Aug [kg]	1.47	1.50	1.33			
Sep-Oct [kg]	1.33	1.28	1.34			
Nov-Dec [kg]	2.07	1.93	2.00			