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Adoption of new resource conservation technology for sustainable production

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Abstract
The concept of a sustainable farming system refers to the capacity of agriculture over time to contribute to overall welfare by providing sufficient food and other goods and services in ways that are economically efficient and profitable, socially responsible, while also improving environmental quality. It is a concept that can have different implications in terms of appropriate technologies whether it is viewed at the farm level, at the agri-food sector level, or in the context of the overall domestic or global economy. Farming methods are undergoing significant technological changes. New government regulations and the demand for more advanced and labour-saving technological solutions are among the driving forces behind the change.

Keywords: Sustainable farming, Conservation, Precision, Seed drill, Grain yield

Introduction
The Indian Agriculture has been improved through adoption of quality seeds, increased input use and higher investment and expansion in irrigated area. The higher production has been realised by putting stresses on natural resources mainly in soil and water. In recent years, stagnation in crop productivity, decline in soil health, lower water table and ecological imbalance has been observed in many areas. There are widespread problem of soil degradation in India by erosion (93.7 Mha by water and 9.5 Mha by wind), water-logging, salinization, soil acidity and other physical and chemical processes (Table 1)

Table 1: Extent and severity of soil degradation in India (Adopted from Rattan Lal, 2016)

Type of degradation	Land area affected ($x10^6$ ha) NBSS & LUP (2005)
Water erosion	93.7
Wind erosion	9.5
Water logging	14.3
Salinity/ Alkalinity	5.9 (6.7)
Soil acidity	16.0 (30.9)
Other	7.4 (120.7)
Total	146.8

Total land area = 297.3 Mha, The data in parenthesis are from Prasad (2015)

The water is another important source for life but its availability is decreasing day-day. The average annual rainfall is 1160 mm in the country, but its distribution over time and space in uneven and erratic. The variability is rainfall is so high that country is facing problem of drought and flood. The gradual decrease in water table is big threat is intensive agriculture. The per capita availability of renewable freshwater supply (m^3yr^1) was 2309 in 1991, 1902 in 2001 and is projected to be 1491 in 2050 (Kumar *et al*., 2005) [11]. The adequacy of water resources is considered “water-stressed” (for per capita annual availability of 1700 m^3) and “water-scare” (for per capita availability of 1000 m^3). Thus, India has been a water-stressed nation since 2006 (Table 2) and will be water-scarce country if the population exceeds 1953 million. However, these resources have to be utilized carefully for enhancing the productivity of crops in sustainable manners. Many research findings revealed that under proper use of resources, productivity may be improved without putting much stress on natural resources. These technologies are named as resource conserving technologies (RCT’s). To promote more rapid and extensive adoption of resource-conserving technologies, better understanding is needed not only of the factors that influence the adoption, but also of the impacts of resource-conserving technologies at various levels of aggregation (field, farm, and watercourse). Research has indicated the potential benefits of resource-conserving technologies, but experience suggests that successful adoption depends on a favorable confluence of technical, economic, institutional, and policy factors. Only by understanding these factors, researchers, extension specialists, machinery manufacturers, and policy makers be able to modify the technology, delivery mechanisms, and policy environment to stimulate successful adoption.

Table 2: Per capita availability of water in India (Adopted from Rattan Lal, 2016)

Year	Population ($x10^6$)	Per capita renewable water (m3 yr^1)	Utilizable water resources (m3 y^1)
1700	127	15,387	-
1750	155	12,600	-
1800	255	7,659	-
1850	283	6,901	-
1900	295	6,620	-
1950	350	5,580	-
1970	539	3,623	-
1990	834	2,342	-
2000	1054	1,853	-
2006	1162	1,680 Water stressed	-
2010	1231	1,587	-
2015	1311	1,490	774
2020	1389	1,406	731
2050	1705	1,145 Approaching	595
2070	1753	1,114 Water scarcity	579
2080	1737	1,124	584
2090	1704	1,146	596
2100	1660	1,176	611

The some of resource conserving technologies attracted to the farmers, scientists and policy makers are; Zero Tillage, Laser-aided land leveling, Precision Farming, Site – specific nutrient management (SSNM) Practices, Leaf color chart (LCC), Direct drill seeding rice, System of rice Intensification (SRI), Raised Bed Planting and Integrated Farming Systems (IFS).

Zero Tillage

The resource-conserving technologies that has received the most attention is zero-till (ZT) planting of wheat after rice. Successful adoption of ZT requires use of a tractor-drawn ZT seed drill, which allows wheat seed to be planted directly into unplowed fields with a single pass of the tractor. In contrast, conventional tillage practices for wheat involve multiple passes of the tractor to accomplish plowing, harrowing, raking, and seeding operations. Use of ZT significantly reduces energy costs, mainly by reducing tractor costs associated with conventional tillage methods, but also by reducing the amount of time that tube wells must be operated. Use of ZT also allows the wheat crop to be planted sooner than would be possible using conventional tillage methods, which significantly reduces turnaround time. This is an important consideration in many parts of the rice-wheat belt, where late planting of wheat is a major cause of reduced yields.

Table 3: Total productivity of rice-wheat-cowpea cropping system under conservation agriculture at Raipur (Mean of 3 years) (M.C. Bhambri, 2016)

Treatment	Yield, t/ha				NR (Rs in lakhs)	B:C ratio
	Rice	Wheat	Cowpea GFY	Rice equ.		
Tillage						
CT (Trans.) –CT-CT	3.54	2.14	13.9	6.72	2.78	1.32
CT (Trans.) –ZT-ZT	3.47	2.18	15.3	6.71	3.21	1.44
CT (DSR)-ZT- ZT	2.92	2.09	17.6	6.16	2.76	1.46
ZT (DSR)-ZT-R-ZT	2.54	2.15	18.1	6.00	2.91	1.52
ZT (DSR)-R-ZT +R-ZT	2.47	2.23	0.84	6.05	2.66	1.49
LSD (P= 0.05)	0.19			-	-	-
Weed Management						
Reco. herbicides	4.10	2.47	20.8	8.12	5.23	1.80
Integrated WM	3.89	2.63	24.0	8.28	5.87	1.88
Unweeded Control	0.99	1.36	2.23	2.58	-2.52	0.49
LSD (P= 0.05)	0.36	0.18	1.95	-	-	-

In rice-wheat-cowpea fodder at Raipur cropping system under conservation agriculture, the higher yields were obtained under CT (transplanted) –ZT (with or without residue) - ZT (with residue) with integrated weed management of oxadiargyl 80g ha^{-1} PE fb hand weeding at 25 DAT/S in rice, 1 HW at 20 DAS fb metsulfurn 4 g ha^{-1} at 35 DAS in wheat and PE application of pendimethaline 1.0 kg ha^{-1} fb 1 HW at 20 DAS in cowpea. Net return and B:C ratio was also higher in this system (Table 3). Similarly in Under the tillage practices, significantly higher seed yield (1227 kg/ha) with maximum net return (Rs. 35342/ha) and B:C ratio (2.40) were obtained under zero tillage. Among the crop residue management treatment, significantly maximum seed yield (1288 kg/ha) with maximum net return (Rs. 37067/ha) with highest Benefit: Cost Ratio (2.42) were obtained under maintaining the 30 cm rice stubbles height over no residues (Table 4). Similarly yield enhancement has been also observed in rice- chickpea system with residue management (Table 5).

The ZT reduces irrigation requirements in wheat by facilitating crop residue buildup and improving soil structure, which have been linked to increased retention, better infiltration, and reduced overall use of water. In addition, the faster turnaround time made possible by ZT allows wheat to be planted and harvested earlier, reducing the need for one or more late-season irrigations in some areas. The major constant for adoption in ZT are Lack of appropriate seeders especially for small farmers and medium scale farmers, The wide spread use of crop residues for livestock feed and fuel, Burning of crop residues, Lack of knowledge about the potential of ZT and Skilled and scientific manpower.

Table 4: Conservation agriculture practices for enhancing productivity of rice-lentil cropping system during 2015-16 (D. K. Chandrakar, 2016)

Treatment	Seed yield (kg/ha)	Cost of cultivation (Rs/ha)	Net Return (Rs/ha)	B:C Ratio
Main plot (Tillage)				
Conventional tillage	1121	16032	29668	1.85
Reduced tillage	1078	15332	28605	1.87
Zero tillage	1227	14732	35342	2.40
CD at 5 %	98.8			
Sub plot (Crop residue)				
Without R	996	15365	25343	1.66
With Residue	1288	15365	37067	2.42
CD at 5 %	222.1			

Table 5: Chickpea productivity after rice under residue – management practices Source: Kumar *et al*. (2012)

Crop rotation	Residue management	Yield (kg/ha)
Rice-chickpea	With residue	2,020
	Without residue	
Rice-chickpea-mungbean	With residue	1,972
	Without residue	2,486

Laser land leveling

Laser controlled precision land leveling helps in uniform soil moisture distribution, better water application and distribution, good germination, enhanced input use efficiency, reduces weed, pest and disease problems, reduced consumption of seeds, fertilizers, chemicals and fuel and improved yields. It may have cost and expertise constraints. Laser leveling is a process of smoothening the land surface (± 2 cm) from its average elevation using laser equipped drag buckets to achieve precision in land leveling. Precision land leveling involves altering the fields in such a way as to create a constant slope of 0 to 0.2%. This practice makes use of large horsepower tractors and soil movers that are equipped with global postioning systems (GPS) and/or laser-guided instrumentation so that the soil can be moved either by cutting or filling to create the desired slope/level.

A review of various studies suggested that laser land leveling in Pakistan resulted in about 25% reduction in irrigation water application and an increase of about 30% in wheat yield as compared to conventional practices (non-laser leveled fields (Humphreys *et al*., 2005) [6]. Similar increased yield and reduced irrigation water application in the case of zero tillage wheat and laser land leveling were reported in India and China (Jat *et al*., 2009; Humphreys *et al*., 2010) [8, 5]. For instance, Kahlown *et al*. (2006) [9] showed that the use of RCTs, including zero tillage, laser leveling and bed and furrow planting, reduced irrigation water applications between 23 and 45% while increasing yield.

Precision Farming

It is a farming management concept based on observing and responding to intra-field variations with the goal of optimizing returns on inputs while preserving resources. It relies on new technologies like satellite imagery, information technology, and geospatial tools. GPS, GIS and Remote sensing satellites can track the soil variability, can assess the nutritional status of the soil, disease prevalence and can predict the yields. These technologies can reduce the input rates decrease cost of production increase yields and can reduce the environmental concerns. Precision agriculture refers to the application of precise and correct amounts of inputs like water, fertilizers, pesticides etc. at the correct time to the crop for increasing its productivity and maximizing its yields. The benefits of so doing are twofold i) the cost of producing the crop in that area can be reduced; ii) the risk of environmental pollution from agrochemicals applied at levels greater than those required by the crop can be reduced (Earl *et al*. 1996) [2]. Thus, it helps to improve input use efficiencies, economy, and sustainable use of natural resources, because it minimizes wastage of inputs. In other words, it may also be referred to 'Site-Specific Farming'. The practice of precision farming is viewed as comprising of four stages, information acquisition related to variability in environmental and biophysical parameters, their interpretation for input application, evaluation and control. To support precision farming, the important information technology tools are Global Positioning System (GPS), Geographical Information System (GIS) and Simulation Modeling for Decision Support System (DSS), remote sensing, yield monitor and variable rate technology. The experiment conducted Raipur, Bilaspur and Ambikapur indicated that the seed yield of mustard may be obtained from 19.91 – 25.14 q/ha when nutrient was applied through drip (Table 6).

Table 6: Effect of drip fertigation and spacing on seed yield and net return of mustard (A.K. Verma, Geet Sharma and R. Tigga, 2016-17)

Treatment	Seed yield (q/ha)			Net return (Rs./ha)		
	Raipur	Bilaspur	Ambikapur	Raipur	Bilaspur	Ambikapur
Drip Fertigation						
75% RDF	18.05	16.33	19.81	43078	36224	50135
100% RDF	20.20	18.28	22.35	48169	40502	56791
125% RDF	22.19	19.91	25.14	52622	43519	64430
Control	10.16	9.56	11.36	21004	18596	25783
CD(0.05)	1.74	0.97	1.30	-	-	-
Spacing (cm)						
45 x 20	18.57	16.94	21.09	44858	38352	53315
60 x 20	18.31	16.24	20.42	43876	35579	50313
75 x 20	16.06	14.88	18.98	34920	30200	44227
CD (0.05)	1.44	1.40	2.51	-	-	-

Site-specific nutrient management (SSNM)

Nutrient Management and recommendation process in India is still based on response data arranged over large domains. The SSNM provides an approach for need based feeding of crops with nutrients while recognizing the inherent spatial variability. It involves monitoring of all pathways of plant nutrient flows/supply, and calls for judicious combination of fertilizers, bio fertilizers, organic manures, crop residues and nutrient efficient genotypes to sustain agricultural productivity. It avoids indiscriminate use of fertilizers and enables the farmer to dynamically adjust the fertilizer use to fill the deficit optimally between nutrient needs of the variety and nutrient supply from natural resources, organic sources, irrigation water etc. It aims at nutrient supply at optimal rates and times to achieve high yield and efficiency of nutrient use by the crop. Many studies in the country, show that by adoption of SSNM, across the locations, grain yields of more than 13 t/ha in rice-wheat system (with a contribution of 58% rice and 42% wheat) and 12-15 t/ha in rice-rice system (with a contribution of 48% *kharif* rice and 52% *rabi* rice), are achievable (PDFSR 2011). It also helped in increase of organic carbon by 55.9%. It is, therefore, pertinent to further disseminate this technology, which has potential to enhance the productivity in the range of 3-4 t/ha. At RMDCAR, Ambikapur, hybrid Maize cv. Bio 9637 with 60x20cm spacing along with SSNM was suitable for higher seed yield, net return and B:C ratio for Northern hill region (Table 7).

Table 7: Effect of planting density and nutrient management on hybrids maize in *Kharif* at RMDCARS, Ambikapur (Mean of 2 yrs) A. K.Sinha 2016-17

Treatment	Seed Yield (kg/ha)	Net return (Rs/ha)	B : C Ratio
Hybrid			
Bio 9637	6496	60786	2.19
Bio 9682	5606	48599	1.75
CD at 5%	646	8806	0.30
Spacing			
60x20 cm	6483	60580	2.19
50x20 cm	5619	48805	1.76
CD at 5%	809	10992	0.39
Nutrient			
100% RDF	5589	49715	1.89
SSNM	6437	58853	2.04
CD at 5%	510	6929	NS

Leaf colour chart (LCC)

A LCC developed in Japan, is used to measure green color intensity of rice leaves to assess the nitrogen requirements by non destructive method (Nachimuthu *et al.*, 2007) [12], and is being standardized with chlorophyll meter. In hybrid as well as inbred rice, N management through LCC proved superior to locally recommended N application in three splits. It was found possible to curtail 20-30 kg of fertilizer N/ha without sacrificing rice yield, when N is applied as per LCC values. N application at LCC<3 in Basmati and at LCC<4 in coarse and hybrid rice was found optimum. Moreover LCC-based N management amy be adopted without any disadvantage in terms of grain yield, and agronomic, physiological or recovery efficiency of fertilizer N (Table 8).

Table 8: Grain yield (q/ha) of different HYV rice varieties as influenced by different Nutrient management practices during 2016

Treatment	Raipur	Bilaspur	Ambikapur	Jagdalpur	Mean
Management practices					
RDF (100: 60: 40)	59.02	57.73	58.60	49.08	56.11
150% RDF	62.35	61.52	64.20	56.10	61.04
RDF (30% N and full P + K as basal and remaining as LCC based)	57.75	64.08	59.40	52.21	58.36
STCR reco. dose for 7 t/ha	60.52	66.83	65.20	62.32	63.72
CD (P=0.05)	2.44	5.35	1.90	1.44	-
Varieties					
IGKV R1	68.46	62.29	59.60	53.74	61.02
IGKV R2	53.76	52.35	58.10	61.78	56.50
IGKV 1244	51.84	61.75	68.40	57.02	59.75
Karma Masuri	61.58	60.18	65.30	53.51	60.14
Indira Aerobic-1	63.90	66.19	59.60	48.48	59.54
CD (P=0.05)	1.54	4.23	2.80	1.72	-

Direct drill seeding rice

The shortages of labor and water, and soil fertility issues are causing increasing interest in shifting from puddling and transplanting to DSR. According to Pandey and Velasco (2005) [13], low wages and adequate availability of water favour transplanting, whereas, high wages and low water availability favour DSR. The recent shift from transplanting to DSR in Southeast Asian countries has been caused by labor shortages and rising wages. DSR can reduce the labor requirement by 50% compared with transplanting (Santhi *et al*., 1998) [16]. The DSR system provides incentives for saving water (Humphreys *et al*., 2005) [6]. In Northwest India, about 35– 57% water savings have been reported in research experiments in DSR sown into unpuddled soils (Singh *et al*., 2002) [18].

It is a cost effective technology for the seeding of rice crop. This technology saves water by 10-30%, avoids soil degradation and plow-pan formation, saves labor, energy, fuel, seeds, and gives 10% higher yields with 10-15 days early maturation of crop. The dry seed is drilled into the non-puddled soils with proper land leveling and weed control measures. Sowing of seeds at a depth of 2-3 cm with zero till, minimum till machine seed then covered with the thin layer of soil to aid in proper germination and to avoid the birds damage. Soil moisture should be sufficient for better germination. The problem of weeds is tackled by application of pre-emergence herbicides or by stale seedbed method (Table 9). Next weeding can be done manually. The seed yield was recorded under 40, 60 and 80kg/ha seed rate was found to be comparable with each other (Table 9).

Table 9: Grain yield of direct line seeded rice as influenced by weed management and seed rate at Raipur (S. K. Jha, 2016)

Treatment	Seed yield (q ha^{-1})		
	2013	2014	Mean
Weed management			
W_1:- Two hand weeding	51.57	53.65	52.61
W_2:- Bispyribac-Na @ 25 g ha^{-1} at 20DAS	45.41	49.50	47.45
W_3:-PE Oxadiargyl 70 g ha^{-1} fb Bispyribac Na @ 20 g ha^{-1} at	50.31	52.93	51.62
W_4:- PE Pretilachlor + Bensulfuron 660 g ha^{-1} fb Bispyribac Na @ 20 g ha^{-1} at	47.85	50.91	49.38
W_5:- Azimsulfuron 35 g ha^{-1} fb Bispyribac Na 20 g ha^{-1} 15,35	49.40	51.64	50.52
W_6:- Weedy check	15.59	13.78	14.69
CD (P = 0.05)	3.09	4.07	2.31
Seed rate (kg ha^{-1})			
S_1 :- 80	42.62	44.67	43.84
S_2 :- 60	42.05	45.24	43.64
S_3 :- 40	45.40	46.43	45.92
CD (P = 0.05)	NS	NS	NS

Bed planting of crops

It is sowing of crops on the raised leveled surface. Crop is sown on beds in lines Size of bed and furrow depth depends on the type of crop and soil. Bed planter is used for making beds and/or sowing seeds. Using either Dry or Wet sowing method crop can be sown. Irrigation is applied in the furrows. For the sowing of wheat, University of Agriculture Faisalabad has developed a university bed planter machine. It makes two beds and three furrows in the same operation; bed width is 2 feet with four rows of wheat sowing on it, and furrow width is 1 foot. The first row of wheat on bed is sown 3 inches away from either side of furrow, and 2nd row is sown 5 inches away from first line from either side; between these two lines there is a buffer zone with width of 8 inches for the accumulation of any salt. In this planting geometry of crop, plant population is not reduced in any way. This technology saves 40-50% water, reduces the seed rate upto 10%, better weed control and 20% increase in the yield of the crop has been achieved. Similarly other crops can also be grown successfully on beds such as cotton etc. Direct-seeded and transplanted rice grown on raised beds decreased water use by 12–60% when compared with flooded, transplanted rice in the IGP (Gupta *et al*., 2003) [3]. At farmers field of Raipur, large scale demonstration on soybean seeded in bed increased the yield by 22.46% to 35.13% during 2015 and 2016, respectively (Table 10 and Table 11). Similarly pigeonpea yield have been also increase when seeded on raised bed (Table 12 and Table 13)

Table 10: District wise average, maximum and minimum yield of soybean under demonstration and farmers practice (R. Lakpale, 2015) at IGKV, Raipur

S. No.	District	Demonstration (q/ha)			Farmers Practices (q/ha)			Yield increase in %
		Avg.	Max.	Min.	Avg.	Max.	Min.	
1.	Kawardha	7.99	11.88	5.13	6.95	10.94	3.75	14.93
2.	Bemetara	8.18	11.85	5.74	6.70	9.52	4.32	22.23
3.	Durg	8.33	13.33	4.85	6.76	11.85	3.78	22.69
4.	Rajnandgaon	5.57	14.81	2.03	3.36	8.50	1.44	64.68
Overall Average		7.52	12.96	4.43	5.94	10.20	3.32	22.46

Table 11: District wise average, maximum and minimum yield of soybean under demonstration and farmers practice (R. Lakpale, 2016) at IGKV, Raipur

S. No	District	Demonstration (q/ha)			Farmers Practices (q/ha)			Yield increase in %
		Avg.	Max.	Min.	Avg.	Max.	Min.	
1.	Kawardha	21.90	22.36	21.36	16.04	17.03	15.20	36.53
2.	Bemetara	22.15	23.96	20.44	15.19	16.88	13.75	45.82
3.	Rajnandgaon	24.18	26.54	22.56	17.71	19.52	16.60	23.87
4.	Mungeli	25.07	26.41	24.18	17.78	18.67	17.05	34.28
Overall Average		23.44	24.67	22.41	16.53	17.65	15.54	35.13

Table 12: Effect of pigeonpea varieties and methods of planting on yield, nitrogen (N) content and N recycling through litter (based on 45 farmers' field data)

Planting methods	Seed yield (t/ha)		N-content in litter (%)		N-recycling through litter (kg/ha)	
	'ICPL 88039*	UPAS 120*	'ICPL 88039*	UPAS 120*	'ICPL 88039*	UPAS 120*
Raised bed	2.6	2.2	1.57	1.55	26.53	24.41
Flat bed	2.2	1.8	1.56	1.55	25.43	21.82
Mean	**2.4**	**2.0**	**1.57**	**1.55**	**25.98**	**23.12**

Source: Pandey *et al.* (2006)

Table 13: Performance of pigeonpea with different crop establishment techniques for water productivity in the pigeonpea-wheat cropping system in western Uttar Pradesh, 2004-2005

Establishment technique	Seed yield (t/ha)	Total irrigation (cm/ha)	Water productivity (litre water/kg grain)
Fresh raised bed (14)*	1.75	7.75	443
Permanent raised beds (2)	1.73	7.45	431
Farmers practice (55)	1.42	9.12	642
Mean	**1.63**	**8.11**	**498**

(**Source:** Pandey *et* al. 2006)
*Figures in parentheses indicate the number of trials

System of Rice Intensification (SRI)

The basic principle of SRI are planting of early aged seedlings at wider spacing adopting alternate irrigation and mechanical weeding. It is also mentioned that most of the organic/manuring should be done to meet the nutrient requirement of the plant. At present, SRI methods have been adopted in almost 50 countries, including major rice-producing nations such as India, China, Vietnam and the Philippines (Uphoff, 2012) [21]. The principles of SRI originate from experiments conducted by farmers in Madagascar to improve rice productivity for resource-poor producers. Today, SRI is usually understood as a package of possible practices, which have to be adapted to local conditions (Stoop, 2011) [19]. SRI produce higher yields with less water and seeds (Barah, 2009; Zhao *et al*., 2009) [1, 22]. Moreover, studies found rice under SRI to be more robust against extreme weather events, pests, and diseases due to improved plant vigor and root strength (Stoop *et al*., 2002). Alternating irrigation aims to tackle various challenges such as the loss of soil quality and water scarcity, whereas early transplanting and wide spacing are both meant to boost tillering (Thakur *et al*., 2010) [20]. However, a few studies identified higher labor requirements of SRI as a constraint to adoption (Senthilkumar *et al*., 2008) [17]. Other studies showed that higher labour inputs occurred only in the early phase of adoption; labour requirements seem to decrease with growing SRI experience (Barrett *et al*., 2004; Uphoff, 2012) [21]. The study conducted at Raipur indicated that system of rice intensification produced the highest grain yield (Table 14).

Table 14: Grain yield of rice as influenced by planting techniques and water management practices at Raipur during 2005

Treatments	Grain yield (kg/ha)
Planting technique	
Standard Transplanting	63.78
System of Rice Intensification	66.18
Integrated Crop Management	64.37
Random Transplanting	59.31
CD at 5%	2.91
Water management practices	
Continuous submergence of 5±2 cm water throughout crop period	64.33
Irrigation of 7 cm water at 3 days after disappearance (DAD) of ponded water throughout crop period	64.24
Irrigation of 3 cm water at 3 DAD (Days after disappearance) up to PI and there after saturation	64.89
Farmers practice of storing rain water up to 10 cm depth, i.e. rainfed	60.19
CD at 5%	2.71

Diversification

A shift from sole cropping to a diversified/ intensified farming system is highly warranted. The increased cropping intensity/diversification is intended to minimize risk, improve biodiversity and diversify income sources and enhance resource sustainability. It will be a key strategy for future gains in crop production. Short duration pulses, oilseeds and other high value crops will find their definite niche as sequential or intercrops, rather than replacing the major cereal crops having higher yield stability (IIFSR 2015) [7]. Hence, an increased cropping intensity will contribute substantially to additional demands of food and cash crops. Pigeonpea, the most important wet season grain legume crop in south Asia has shown potential for rice crop diversification in Indo-Gangetic Plain (IGP). The introduction of extra short duration (ESD) pigeonpea (ICPL-88039) and Furrow Irrigated Raised Bed (FIRB) planting technique in the region has shown tremendous potential for increasing the water productivity and economic growth of the farmers with the limited resources. Development of new crop varieties with more efficient photosynthetic apparatus and shorter duration would be of massive help in increasing cropping intensity (IIFSR 2015) [7]. Similarly, bio-intensive diversified cropping systems would enable small and marginal farmers to utilize limited land and water resources in more efficient manner. At Raipur in order to diversification of rainfed upland rice with pulses (Table 15), the maximum urdbean equivalent yield (1773 kg/ha) was recorded in Urdbean + pigeonpea (1:1) with the highest net return of Rs. 64282/ha, B:C ratio (3.3) and land equivalent ratio (1.60).

Table 15: Yield and economics of intercropping system in upland (Mean of 2 years) at Raipur (D. K. Chandrakar, 2016)

Treatments	Seed Yield (kg/ha)	Urd Eq. Yield (kg/ha)	Net Return (Rs/ha)	B: C Ratio
Rainfed upland rice (control)	1777	570	13412	0.99
Urdbean (30 cm)	888	904	29006	2.12
Pigeonpea (60 cm)	1305	1305	44154	2.52
Urd + Pigeonpea 1:1 (30/60 cm)	652 + 1033	1773	64282	3.30
Urd + Pigeonpea 2:1 (30/90cm)	423 + 827	1388	45576	2.28
CD (P=0.05)	-	182	8607	0.50

Integrated Farming Systems

Integrated Farming Systems hold a special position in conservational agriculture as in this system nothing is wasted, the by product of one system becomes the input for other. For example, crop residues from the field can be used for animal feed, while manure from livestock can enhance agricultural productivity by improving soil fertility as well as reducing the use of chemical fertilizers (Gupta *et al*., 2012) [4]. Moreover, the system helps poor small farmers, who have very small land holding and a few heads of livestock to diversify farm production, increase cash income, improve quality and quantity of food produced and exploit unutilized resources. Animals play key and multiple roles in the functioning of the farm. These not only provide meat, milk, eggs, wool, and hides; but can be converted into prompt cash in times of need. Animals transform plant energy into useful work: animal power is used for ploughing, transport, marketing and water lifting for irrigation.

In order to sustain the productivity of different crops, region-specific interventions on sustainable soil and water conservation measures along with crop-diversification through substitution/ intensification and matching production technologies need to be adopted without putting stress on the natural resources especially on soil and water.

References

1. Barah B. Economic and Ecological Benefits of System of Rice Intensification (SRI) in Tamil Nadu. Agric. Econ. Res. Rev. 2009; 22:209-214.
2. Earl R, Wheeler PN, Blackmore BS, Godwin RJ. Precision farming- the management of variability, 1996.
3. Gupta R. Agenda notes 12th Regional Co-ordination Committee Meeting of Rice–wheat Consortium for Indo-Gangetic Plains. February 7-9, Islamabad, Pakistan, 2003, 39-50.
4. Gupta V, Rai PK, Risam KS. Integrated Crop-Livestock Farming Systems: A Strategy for Resource Conservation and Environmental Sustainability. Indian Res. J. Ext. Edu. 2012; 2:49-54.
5. Humphreys E, Kukal SS, Christen EW, Hira GS, Singh B, Yadav S *et al.* Halting the groundwater decline in North West India-which crop technologies will be winners? *Adv. Agron.* 2010; 109:155-217.
6. Humphreys E, Meisner C, Gupta R, Timsina J, Beecher HG, Lu TY *et al*. Water savings in rice–wheat systems. Plant Prod. Sci. 2005; 8:242-258.
7. IIFSR. Vision 2050. Indian Institute of Farming Systems Research, 2015. www.iifsr.res.in
8. Jat ML, Gathala MK, Ladha JK, Saharawat YS, Jat AS, Kumar V *et al*. Evaluation of precision land levelling and double zero tillage systems in the rice–wheat rotation: water use, productivity, proûtability and soil physical properties. Soil Till. Res. 2009; 105:112-121.
9. Kahlown MA, Azam M, Kemper WD. Soil management strategies for rice-wheat rotations in Pakistan’s Punjab. J Soil water Cons. 2006; 61:40-44.
10. Kumar N, Singh MK, Ghosh PK, Venkatesh MS, Hazra KK, Nadarajan N. Resource conservation technology in pulse based cropping system. Indian Institute of Pulses Research, Kanpur, Uttar Pradesh, India, 2012, 1-32.
11. Kumar R, Singh RD, Sharma KD. Water resources of India, Current Science, 2005; 89:794-811.
12. Nchimuthu G, Velu V, Malarvizhi P, Ramasamy S, Gurusamy L. Standardisation of leaf colour chart based nitrogen management in direct wet seededrice(*Oryza sativa* L.). J Agron. 2007; 6:338-343.
13. Pandey S, Velasco L. Trends in crop establishment methods in Asia and research issues. In “Rice Is Life: Scientific Perspectives for the 21st Century” (K. Toriyama, K. L. Heong, and B. Hardy, Eds.). International Rice Research Institute, Los Banos, Philippines and Japan International Research Center for Agricultural Sciences, Tsukuba, Japan. 2005, 178-181.
14. PDFSR. Project Directorate for Farming Systems Research. Annual Report, 2011-12.
15. Rattan Lal. Indian Journal of Fertilizers. 2016; 12(11):18-29.
16. Santhi PK, Ponnuswamy K, Kempuchetty N. A labour saving technique in direct-sown and transplanted rice. Int. Rice Res. Notes 1998; 23:35-36.
17. Senthilkumar K, Bindraban P, Thiyagarajan T, De Ridder N, Giller K. Modified rice cultivation in Tamil Nadu, India: Yield gains and farmers’ (lack of) acceptance. Agric. Syst. 2008; 98:82-94.
18. Singh AK, Choudhury BU, Bouman BAM. Effects of rice establishment methods on crop performance, water use, and mineral nitrogen. In: [Bouman, B.A.M., Hengsdijk, H., Hardy, B., Bindraban, B., Toung, T.P., Ladha, J.K. (Eds.)], Proceedings of the International Workshop on Water-wise Rice Production, Los Banos, Philippines. IRRI, Los Banos, Philippines, 2002, 237-246.
19. Stoop W. The scientific case of the system of rice intensification and its relevance for sustainable crop intensification. Int. J. Agric. Sust. 2011; 9:443-445.
20. Thakur A, Rath S, Roychowdhury S, Uphoff N. Comparative performance of rice with System of Rice Intensification (SRI) and conventional management using different plant spacings. J. Agron. Crop Sci. 2010; 196:146-159.
21. Uphoff N. The System of Rice Intensification (SRI) as a System of Agricultural Innovation, 2012. (available at http:// www.future-agricultures.org/farmerfirst/files/T1c_Uphoff. pdf).
22. Zhao L, Wu L, Li Y, Lu X, Zhu D, Uphoff N. Influence of the system of rice intensification on rice yield and nitrogen and water use efficiency with different N application rates. Exp. Agric. 2009; 45:275-286.