System Based Conservation Agriculture

Vinod Kumar Singh
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Foreword

The challenge of ever increasing pressure on agricultural/arable lands for producing more with less has encouraged the adoption of conservation agriculture (CA) in India. The economization of resources through efficient use under CA not only reduces the cost of cultivation but also benefits the environment. The trend of depleting natural resources under conventional agricultural systems could be favourably reversed to the soil organic carbon build up, lesser fuel consumption and higher water productivity. A diversified cropping system under CA improves soil biodiversity, resists insect-pest-disease outbreaks, and prevents deterioration of natural resource base. The significance of wide-scale adoption of CA becomes more pertinent when we are at the verge of facing serious threats like declining partial factor productivity, climate change, and land degradation.

Globally 157 million hectare area, which constitutes 10.9% of the total arable area is currently under CA. There are enough research evidences which show this huge shift towards adopting conservation systems ensures soil health and production quality improvement brought through enhanced soil biological processes, indigenous nutrient supplying capacity and organic recycling. On the other hand, the emerging issues like nutrient stratification, misalliance of farm machinery and weed shift under CA need to be scientifically addressed. Further, CA technologies would also have to be standardized for specific crops under diverse ecologies in cropping system perspectives. Likewise, fabrication of appropriate machines can overcome the biasness of clean cultivation and constraints in adoption of CA technologies.

A remarkable success has been made in developing CA technologies for rice-wheat cropping system in Indo-Gangetic Plains of India, but the location-specific most critical intervention to break yield barrier through resource conservation technologies is still lacking. This book is a perfect compilation of consorted efforts of various researchers done in the direction of development, standardization and dissemination of the refined CA technologies. The emerging concerns of environmental unsustainability raised in the book necessitates the development of a policy framework promoting CA. I strongly believe that the book would be of great value to various stakeholders in addressing the goals of achieving sustainable agricultural systems through conservation agriculture.

Arvind Kumar

Preface

Conservation agriculture (CA) benefits agro-ecosystems by improving soil health and preserving biodiversity. Facilitation of good agricultural practices *viz.* land preparation, crop establishment, water management and stress management etc. through conservation agriculture ensures environmental safety and resource savings. Agricultural production intensification through diversified cropping systems and integration of various enterprises under CA could offer economically viable options for more than 86% small farm holders of the country. The minimum soil disturbance due to controlled traffic promotes biological tillage. An established CA system could address the emerging issues of nutrient imbalance and reliance upon the external organic inputs. The principles of CA are universally applicable, however its implementation through the set of practices has to be standardized in diversified situation and cropping system perspective. Since, CA in India is still in its nascent stage, through this book, the authors have made an attempt to suggest the possible package for wide scale adoption of CA.

The chapter 1, compares the scope and significance of adoption of CA in India with the global scenario. The chapter 2, 3, 4 and 5 discuss the nutrient dynamics, management alterations as per CA principles with both macro and micro nutrients perspectives. The chapter 6 and 7 carries a comprehensive assessment of water use, its efficiency and the possible ways to augment water productivity under CA. The chapter 8 has focused upon the differences to be considered at the time of weed management under CA as the weed expression, growing pattern and seed dispersal mechanism is altogether different than conventional systems. The chapter 9 discusses the role of mechanization and the need for suitable modifications in the existing machinery in terms of residue management and challenges offered in sowing with zero tillage. The chapters 10, 11 and 12 have focused that if CA technologies need to be up-scaled in wider domain, it has to be standardized for wider crops including pulses and oilseeds and also to the different soil types. The development of decision support system and soil quality indices for evaluation of CA based systems in long-term perspectives has been discussed in the chapter 13, 14 and 15. The higher on-farm resource use efficiency and by-product recycling through integrated farming system and organic farming for targeted crops and areas with CA principles for livelihood security on a sustainable basis has been discussed in chapter 16 and 17. The concluding chapters have shown the enhanced long-run profitability due to reduced inputs, higher resource use efficiency and higher economic returns due to stable yields.

We express our sincere gratitude to Dr. Trilochan Mohapatra, Secretary (DARE) & Director General, Indian Council of Agricultural Research (ICAR), New Delhi for his kind patronage and keen interest in conservation agriculture. During the process of compilation of this information, the continuous encouragement extended by Dr. A.K. Singh, (Director, Indian Agricultural Research Institute, New Delhi and Deputy Director General, Agril. Extension, ICAR) and Dr. Arvind Kumar, Vice-Chancellor, Rani Lakshmi Bai Central Agricultural University, Jhansi (Ex. Deputy Director General, Agril. Education, ICAR) was a great source of inspiration to us. In fact, this publication is the improved version of lectures delivered during the winter school "System based conservation agriculture" by selected resource persons/ subject matter specialists. We place our sincere thanks to all the contributors for their timely action for improving their write up as per requirement. The initial help extended in compilation of different chapters by Dr. K.K. Singh, Assistant Director General (Farm Machinery and Power), ICAR, New Delhi is duly acknowledged.

The help extended by Dr. Anil K. Choudhary, Drs. Kapila Shekhawat (Senior Scientist, Agronomy), Pravin Kumar Upadhyay, Rishi Raj (Scientist, Agronomy) in proof reading is thankfully acknowledged. We assume that our efforts in the form of this publication will be useful to all the stake holders involved in agricultural production in general and conservation agriculture in particular.

Vinod Kumar Singh
B. Gangwar

Contents

About the Editors

Dr. V.K. Singh, is Head, Division of Agronomy at ICAR-Indian Agricultural Research Institute, New Delhi. Prior to this he was ICAR National Fellow and Principal Scientist at Indian Institute of Farming Systems Research, Modipuram. Dr. Singh has made significant contribution towards improving soil organic matters content and nutrient use efficiency in different cropping systems. Dr. Singh developed nutrient and water management protocols under conservation agriculture based system. In collaboration with international research organizations like IRRI, CIMMYT, ICRISAT, IPNI, TSI-FAI-IFA, Dr.V.K. Singh has generated findings of practical significance to restore the soil organic carbon and sustained productivity under different cropping systems. As ICAR-National Fellow, he explored the possibility of use of GIS in precision nutrient management under different cropping systems in Indo-Gangetic Plain. He has published more than 100 research papers in journals of repute, besides a number of review papers, popular article, bulletins and book chapters. Dr. Singh has excellent academic record, and is a recipient Fellow of Indian Society of Agronomy, NAAS Fellow/Associate, Fellow International Society for Noni Science, NAAS Young Scientist Award – National Resource Managment (2005-06), Young Agricultural Scientist (Natural Resource Management) Award (2003-04) by UPCAR, PPIC-FAI Award-2004, IPNI- FAI award 2014, ISSS-Dr. J.S.P. Yadav Memorial Award for Excellence in Soil Science (2011), P.S. Deshmukh Young Agronomist Award-2001 by Indian Society of Agronomy and the Sriram Award and Dhiru Morarji Memorial Award by the Fertilizer Association of India.

Dr. B. Gangwar, Ex-Director of Indian Institute of Farming System Research, Meerut has served as Project Coordinator (Agronomy/Diaraland) for five years (1994-1999) and Principal Scientist (Agronomy)/programme Facilitator (Cropping System Management) for 10 years 2000-2009. He has served in various positions in Andaman-Nicobar Islands for 18 years. Dr. Gangwar is a recipient of Fakhruddin Ali Ahmad Award (1986-87) for outstanding agronomic contributions in remote area of Andaman & Nicobar Islands, Rajendra Prasad Award (2015), Bharat Excellence Award for outstanding contributions in Agricultural Research and Management (2009) and Shriram Award (2002, 2010 & 2012). He has series of recognitions to his credit such as Fellow NAAS, Fellow International Society of Noni Science, Fellow of Indian Society of Agronomy, Fellow, Indian Society of Coastal Agricultural Research, Fellow of Society for Recent Developments in agriculture and Honorary Fellow of Hi-tech Horticultural Society. Scientific contributions in his credit involving 142 research papers, 186 popular articles, 28 book chapters, 24 books/ manuals, 15 research/extension bulletins and 36 edited publications.

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15

Resource Conservation through Enhancing Input use Efficiency

N. Ravisankar

Agricultural inputs are what go into the farm. There are two types of input. The natural or physical inputs include weather, climate, relief (height, shape and aspect), soil, geology and latitude. Farmers have little or no control over these. Changing the natural inputs can sometimes be done but it usually involves a lot of expense. For example areas with not enough rainfall get water from irrigation schemes, steep slopes can be cut into terraces and the climate can be greatly altered by using green houses. The intensive cropping system pushing up the agricultural output level parallel with the present demographic transition imparts a cruel attack on the scarce and precious soil resources. With rising cost of inputs, ever increasing demand for food with mounting pressure of human and animal population, limited available area for cultivation, scarce fresh water resources for agricultural use make it imperative to lay emphasis for increasing the input use efficiency (IUE). Proper assessment of available inputs and their use in a synergistic manner, preventing losses, judicial allocation of inputs among the competing demands to achieve maximum return and development of site-specific technologies are the means of achieving input use efficiencies (Acharya and Bandyopadhyay, 2002). Among the inputs, water and nutrient plays important role in final output of the crop and any measures which are taken to increase its use efficiency will lead to saving of resources.

Physical inputs include land, labour, capital, seeds, water, nutrients, pesticides and machineries increasing the use efficiency of these inputs is always a challenge to producers. The glory of green revolution was on the basis of the use of high yielding varieties (HYV), chemical fertilizers, pesticides, and farm mechanization that led to unprecedented pressure on our natural resource base including natural way of controlling pest and diseases. Green revolution has encouraged an increase in the production of mainly two crops, wheat and rice, but the cost paid was in terms of destruction of other crops (especially coarse cereals and pulses) and

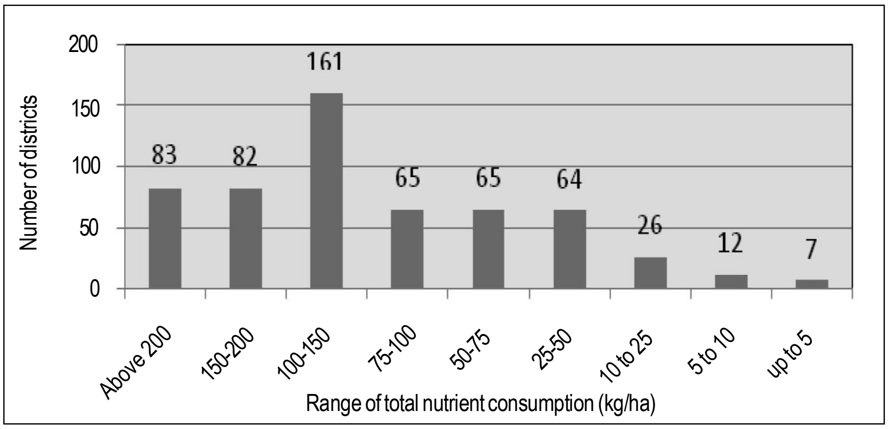

Fig. 1. Classification of districts according to range of total nutrient consumption (kg/ha) during 2013-14 (*Source:* FAI, 2014)

over exploitation of precious water resources and fertile soils. The high dosage application of fertilizers (Fig. 1) deteriorated the physical, chemical and biological properties of soil on one side, on the other, increased soil salinity and pollution of ground water resources. The use of pesticides has been posing serious environmental and health problems. The 59th round of survey conducted by National Sample Survey Organization during 2003 indicates over dependency of farmers for seeds, fertilizers and pesticides from outside farm makes farming costlier.

1. SOIL HEALTH

Total factor productivity and growth rate of productivity of crops are decreasing year after year and deterioration of soil health is the major contributor for the same. Inspite of 326 districts receiving more than 100 kg of nutrient/ha, it has been found that, soils in majority of the districts are low in nitrogen (228 districts), phosphorus (170 districts) and potassium (47 districts). Exhaustive cropping systems cause mining of soil nutrients far in excess of external supply. Nutrient uptake of major systems (Table 1) indicates continuous mining of soil nutrient resource in the intensively cultivated areas. Rice-wheat-cowpea fodder system removes around 800 kg/ha. Further, wider nutrient application gap between recommended and farmers practice also adds to the problem. Across the major systems, farmers are applying 33.3, 38.8, 57.1 and 93% less application of NPK and micro nutrients compared to recommended doses. Among the systems, rice-rice is having the minimum gap in application in terms of NPK (1.1, 12.6, 36.4%, respectively). Continuous application of under doses of nutrients and wider NPK ratio (8.2:3.2:1 during 2012-13 reported by Ministry of Chemicals and fertilizers, 2013) to intensive systems like rice-rice, rice-wheat, and maize-wheat leads to decline in soil health.

Table 1. Nutrient uptake in high intensity cropping in India

Cropping systems	*System yield (t/ha)*	*Nutrient uptake (kg/ha/year)*		
		N	P_2O_5	K_2O
Rice-wheat	8.8	235	92	336
Pigeonpea-wheat	4.8	219	71	339
Maize-wheat-greengram	8.2	306	62	278
Rice-wheat-greengram	11.2	328	69	336
Maize-potato-wheat	8.6 +11.9 (t)	268	96	358
Rice-wheat-cowpea	9.6 +3.9 (f)	272	153	389

t, f represents tuber and fodder yield

(*Source:* Tandon and Sekhon, 1988)

2. CURRENT STATUS OF VARIOUS SOIL AND CROP MANAGEMENT PRACTICES ON INPUT USE EFFICIENCY

2.1 Soil management

Soil management practices like balanced fertilization, application of amendments and integrated nutrient management, inclusion of crop rotation, mulching with crop residues and tillage influences the nutrient and water use efficiency. Dwivedi *et al*. (2003) indicated in rice, puddling reduces leaching of nutrients and provides effective control of weeds. The partial factor productivity in rice was better with increase in the number of passes (Table 2). In the rice-wheat system, due to acute shortage of time, direct seeding was found to improve crop yields as it gave solution to delayed sowing associated with conventional tillage. Similarly, reduced tillage practices resulted in improving rainfed seed cotton yields as well as the factor productivity (Table 3).

Table 2. Effect of puddling in rice on the grain yield and partial factor productivity (PFP) of nitrogen in rice at Modipuram (Dwivedi *et al*., 2003)

Puddling passes	*90 kg N/ha*		*120 kg N/ha*	
	Grain (kg/ha)	*PFPn*	*Grain (kg/ha)*	*PFPn*
One	3496	38.8	4165	34.7
Two	3747	41.6	5077	42.3
Four	3996	44.4	5452	45.4

Table 3. Effect of tillage methods on seed cotton yields and factor productivity in Bt transgenic cotton at Nagpur

Tillage method	*Yield (kg/ha)*	*PFP (kg seed cotton/kg NPK)*
Conventional till	1526	9.8
Reduced till-1	1874	12
Reduced till-2	2054	13.2

Conservation tillage is found to reduce the cost of production thus increases the IUE. These practices affect crop growth and development depending upon many specific factors *viz* soil type, climate, cropping pattern and other attributes of overall farming operations. In certain situations, a combination of various components of the conventional and conservational tillage i.e. integrated tillage management system may be more profitable than either conventional or conservation tillage alone. Acharya *et al*. (1998) reported higher grain yield under conservation tillage owing to greater root proliferation and utilization of higher amount of soil moisture stored in 0-30 cm soil layer (Table 4). Superiority of conservation tillage with respect to yield of wheat was more pronounced at 60 kg N/ha than 120 kg N/ha thus saving of 60 kg of N/ha. This shows that moisture conserved under conservational tillage was just optimum for more efficient N utilization at 60kg N/ha.

Table 4. Effect of tillage and N on grain yield of rainfed wheat

Tillage practices	*Grain yield (Mg/ha)*		
	Nitrogen	*1989-90**	*1990-91***
Lantana application to preceding maize and its incorporation at sowing of wheat (T1)	N^{60}, N^{120}	2813.27	3494.29
T1 + conservation tillage in wheat	N^{60}, N^{120}	3103.83	4124.27
Repeated tillage in maize (farmers practice)	N^{60}, N^{120}	1631.83	2232.77
CD (P=0.05)	-	0.27	0.24

*5 rains of 69.5 mm in Nov., 5 rains of 114 mm in Dec.; **3.4 mm in Nov., 7 rains of 262 mm in Dec.

2.2 Mulching

Mulching is needed on soil surface to check evaporation and improve soil water. It influences nutrient use efficiency (NUE) and water use efficiency (WUE) of crops. Mulching affects biological processes of nutrient transformation and chemical processes of sorption, desorption and fixation, and diffusion of nutrients in soil through moderation of temperature and moisture in the soil. Acharya and Kapur (2001) reported that application of pine needle mulch @ 10 t/ha at the time of sowing of potato in a shallow depth silty clay loam soil significantly improved tuber yield and WUE, and resulted in saving of one irrigation equivalent to 40 mm. Application of mulch @ 10 t/ ha with 60kg N/ha registered significantly higher tuber yield and WUE than 120kg N/ha without mulching, indicating saving of 60kg N/ha through the former treatment.

2.3 Irrigation management

Under optimum nitrogen application, both water and nitrogen efficiency varies with varying irrigation schedules (Table 5). Normally WUE values are higher under water stress condition as compared to optimum and sub-optimum levels of irrigation. The total water use and water use efficiency of consumptive use increased in all the crop sequences with the increase in frequency of irrigation, whereas the water use efficiency was highest under irrigation at 0.75 IW/ CPE ratio in case of high water requirement crops such as wheat and groundnut and at 0.40 IW/ CPE in case of low water requirement crops *viz.* safflower, sorghum and gram (Bharambe *et al.*, 2003). Singandhupe *et al.* (2003) observed that the application of nitrogen through the drip irrigation in ten equal splits at 8-days interval saved 20-40% nitrogen on a clay loam Inceptisol as compared to the furrow irrigation when nitrogen was applied in two equal splits (at planting and 1 month thereafter). Experiments carried out on cash crops like sugarcane, cotton, banana, and other high value crops (Table 6.) in various agro-ecological regions of India in medium to fine textured soils showed that the drip fertigation technology has the potential to maximize the yield levels and enhance the input use efficiency.

2.4 Fertilizer Management *vis-à-vis* Input use Efficiency

2.4.1 Nutrient Management

Fertilizer use efficiency/ NUE depend upon the right rate, right time, and right method of application and sources. Split application of N during the growing season, rather than a single, large application prior to planting, is known to be effective in increasing N use efficiency (Cassman *et al.*, 2002). Numerous studies have demonstrated that interaction between N and other nutrients, primarily P and K, impact crop yields and N efficiency. Adequate and balanced application of fertilizer nutrients is one of the most common practices for improving the efficiency of N fertilizer and is equally effective in both developing and developed countries.

2.4.2 Partial Factor Productivity (PFP)

Partial factor productivity (PFP) being a measure of unit quantity of grain produced from unit quantity of applied and native nutrient was proved to be higher under balanced nutrient application in all the systems compared to application of N alone or with P and with K PFP of N can be increased to 55.6% and 54.6% in maize-wheat and rice-rice systems, while in rice-greengram and rice-wheat, it was found to be 35.7 and 33.9 % respectively (Fig 2). The increase in recovery of N was observed in all the systems by way of combining recommended quantity of P and K with Nitrogen application. Similarly, the recovery of P and K was higher when the same is applied together with N in all the systems. Among the different systems, rice-rice system recorded higher PFP of P (116 kg/ha) with NK followed by rice-greengram system (101.3 kg/kg of P with NK). However, PFP of K was higher in maize-wheat system (147.3 kg/kg of K with NP) followed by rice-rice and rice-wheat system. Balanced application of nutrients have helped in better recovery of N, P and K from native soil as well as from the applied fertilize as it is evident from the partial factor productivity analysis of nutrients in major cereal based systems.

Table 5. Input use efficiency of different crops under irrigated conditions in different agro-ecological situations of India

Crops	*Locations*	*Soil Types*	*Nitrogen level (kg/ha)*	*IW/CPE schedule*	*No. & depth of irrigations*	*Yield (t/ha)*	*WUE (kg/hacm)*	*NUE (kg grain/kg of N)*
Wheat	Belvatgi (Karnataka)	Clay	80	0.80	4 (6)	3.73	155	47
				0.90	5 (6)	3.83	128	48
				1.00	6 (6)	3.92	109	49
Maize	Rahuri (MS)	Clay loam	50	0.50	2(6)	3.00	250	60
				0.60	3(6)	3.50	194	70
				0.80	4 (6)	3.61	150	72
Pigeonpea	Morna (TN)	Sandy loam	20	0.80	2 (7)	1.78	127	89
				0.90	3 (7)	2.00	95	100
				1.00	4 (7)	2.12	76	106
Chickpea	Kota (Rajasthan)	Clay loam	30	0.50	1 (6)	2.41	204	80
				0.60	2 (6)	2.45	204	82
				0.80	2 (6)	2.46	205	82

Source: Annual Reports, AICRP (WM) 2004-06, 2006-07

Table 6. Effect of drip fertigation splitting on yield and input use efficiency of crops

Crops	*Locations*	*Soil types*	*Drip schedule*	*Nitrogen level (kg/ha)*	*No. of splits*	*Yield (t/ha)*	*WUE (kg/ha cm)*	*NUE (kg grain /kg N)*
Sugare	Sriganganagar (Rajasthan)	Sandy clay loam	80 % PE	225	10	160	640	711
					15	175	700	778
					20	185	740	822
Cotton	Ranhuri (MS)	Clay loam	80 % PE	120	3	2.51	125	21
					5	2.65	132	22
					6	2.94	147	24
Banana	Bhavanisagar (TN)	Sandy loam	100 % PE	200	10	82	532	41
					20	98	637	49

Source: Annual Reports, AICRP (WM), 2004-05, 2005-06 and 2007-08

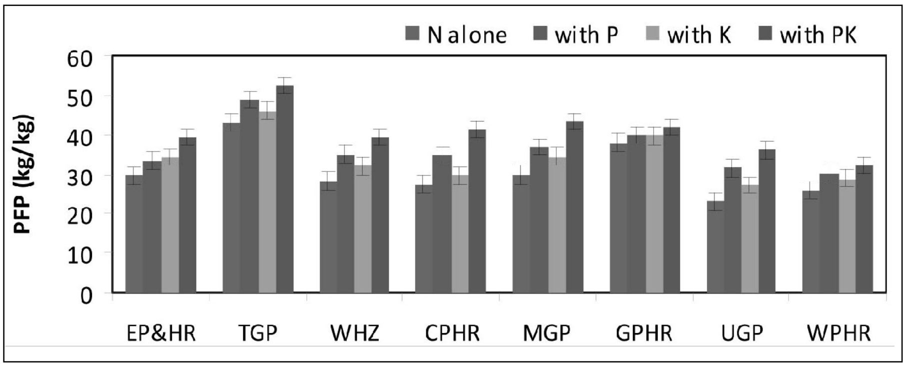

Fig. 2. Partial factor productivity of N in rice-wheat system

2.4.3 Agronomic Efficiency (AE)

Farmers, specially the marginal and dryland farmers, generally, tend to apply only N. However, the AE_N of applied N can be largely increased by adequate P and K fertilization. Agronomic efficiency of N can be increased to 238.9 % in rice-rice system by applying the recommended quantity of N with recommended quantity of P and K instead of N alone as being practiced in many regions having the cereal based systems. Rice-greengram recorded 167.7% (Fig 3) increased AE of N with PK followed by maize-wheat systems (140.7 %). Though, application of N with P or K had registered increase in AE of N in all the systems compared to N alone, the magnitude of increase was lesser than the balanced application of NPK. Similar to N, AE of P was found to be better in all the systems when P is applied with N and K rather than N alone which can be attributed to positive interaction effect of these nutrients in growth and

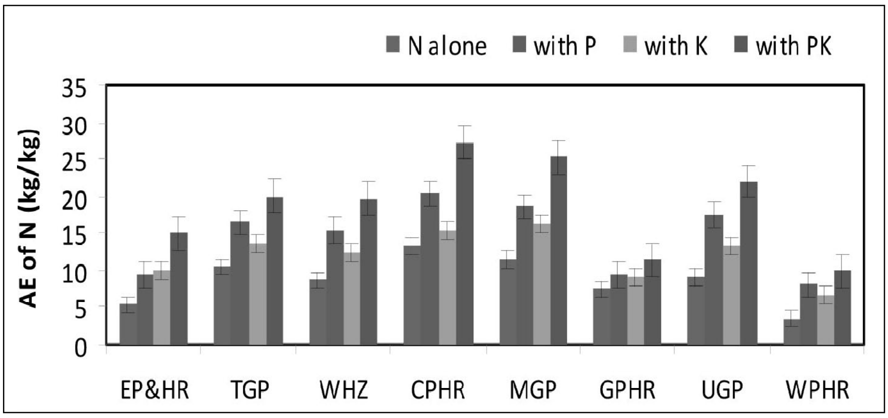

Fig. 3. Agronomic efficiency of N in rice-wheat system in different agro-climatic zones.

development of plants. Among the systems, AE of P and K was found to be higher in rice-rice and rice-greengram systems. More recovery of K due to balanced application was found in maize-wheat system (70.1%). On an average, AE of N, P and K can be increased to the tune of 165, 40.4 and 57.9% respectively through balanced application of nutrient in major cereal cropping systems.

2.4.4 Relative Response and Native Nutrient Supply

Relative response of balanced application of nutrients over control also exhibited the similar trend as that of partial factor productivity and Agronomic efficiency. Relative response of application of NPK over control was found to be 1.04, 1.14, 0.74 and 1.79 in rice-rice, rice-wheat, rice-greengram and maize-wheat systems respectively, which is higher than the N, NP and NK treatments. Among the various system evaluated, maize-wheat had recorded higher relative response with NPK over control which is mainly due to the fact of higher and efficient utilization of nutrients by this system which is also evident from higher partial factor productivity of N and K. Inclusion of greengram in the system led to higher supply of native soil N to the rice-greengram system (47 kg REY/kg of native nutrient). Among the different systems, higher P and K supply from soil was observed in rice-rice and rice-greengram systems. In case of maize-wheat systems, one kg of native N, P, K have contributed for 17.5, 39 and 55.8 kg REY.

2.5 Effect on Economics

Cost of cultivation was higher in balanced application of nutrient in all the systems and it ranged from Rs. 6825 /ha in rice-greengram to as high as Rs. 11651 /ha in rice-rice system. However, the net returns were found to be much higher in all the systems under NPK application compared to control, N alone, NP and NK combinations. The increase was found to be 87.5, 64.6, 53.7 and 127.3% under NPK over N alone in rice-rice, rice-wheat, rice-greengram an maize-wheat systems, while the cost of cultivation increase due to additional application of P and K was found to be only 14, 13.3, 16.1 and 11.2 for the respective systems. Marginal returns were found to be higher with combined application of NPK than N alone, NP and NK. Among the systems, maize-wheat recorded higher (476%) marginal returns under balanced application followed by rice-rice (426%), rice-greengram (339%) and rice-wheat (254%) systems. Application of N alone or with P and with K recorded lower marginal returns in all the systems compared to balanced application of nutrients.

3. FARMING SYSTEMS APPROACH FOR IMPROVING RESOURCE USE EFFICIENCY

Crop and livestock cannot be separated for small holder agriculture as crop + livestock is the pre-dominant farming system existing in the world and livelihood of millions of marginal and small farm holdings revolves around this system. Natural and intentional integration of components takes place in the farming systems being practiced by the cultivators. Natural integration is one that exists in the farm households while intentional integration aims for higher profitability through better recycling and reduced external inputs. Vertical expansion in small farms is possible by integrating appropriate farming system components requiring less space and time and ensuring periodic income to the farmers.

Integrated Farming System (IFS) is considered to be powerful tool and holds the key for ensuring income, employment, livelihood and nutritional security in a sustainable mode for small and marginal farmers who constitute 84.97 % of total operational holdings in India and has 44.31 % operational area. Integrated system meets the above goals through multiple uses of natural resources such as land, water, nutrients and energy in a complimentary way thus giving scope for round the year income from various enterprises of the system. Besides ever growing population, the consumption pattern in rural and urban areas is fast changing due to the raising income and economic liberalization. The share of calories by food crops are already declining and it is expected to be below 50 % by 2050 indicating the increase in requirement of non-grain crops and animal products. IFS is whole system approach and linked to horse hoeing husbandry prescribed by Jethrotull (1674 -1741). Tillage is the oldest art associated with development of agriculture and farming system. The best examples include "pig tractor" systems where the animals are confined in crop fields well prior to planting and "plow" the field by digging for roots, poultry used in orchards or vineyards after harvest to clear rotten fruit and weeds while fertilizing the soil, cattle or other livestock allowed to graze cover crops between crops on farms that contain both cropland and pasture. Water based agricultural systems also provides way for effective and efficient recycling of farm nutrients besides irrigation water in the process.

3.1 Farming System Approach and its Principles

Farming system can be simply defined as a positive interaction of two or more components within the farm to enhance productivity and profitability in a sustainable and environmental friendly way. A judicious mix of two or more of these farm enterprises with advanced agronomic management tools may compliment the farm income together with help in recycling the farm residues. The selection of enterprises must be based on the cardinal principles of minimizing the competition and maximizing the complementarity between the enterprises. In general, farming system approach is based on the following objectives:

- Sustainable improvement of farmhouse hold systems involving rural communities
- Farm production system improvement through enhanced input efficiency
- Raising the family income
- Satisfying the basic needs of farm families

Major steps involved in farming systems approach are i) Systematic characterization of existing farming systems in various agro-climatic regions, ii) Farm constraints identification, iii) Collective, compatible and convenient farm interventions iv) Convergence of resources for making a self-reliant farm, v) Auditing of input-output vi) Assessing the impact of interventions on employment generation, productivity enhancement, sustainability of natural resources and vi) Large scale demonstration of farming systems in participatory mode.

In the intentionally integrated farming system models, the crop, livestock, complimentary and supplementary enterprises are selected aiming higher profitability by way of resource recycling. Proper recycling of farm wastes and crop residues within the system could reduce cost of production to the extent of 42 to 75 % depending upon the components and its connectivity. In the natural integrations, the internal supply of N, P_2O_5 and K_2O in crop + livestock system is only 80, 33 and 80 kg/ha where as in the intentionally integrated farming systems, it increases to 170, 110 and 150 kg/ha. In the improved farming systems, about 65, 85 and 100 % of N, P_2O_5 and K_2O requirement can be met with in the farm. Further, the recycling of wastes also supplies sufficient level of micronutrients.

In India, 19 pre-dominant farming systems exists with majority as crop + livestock (85%). Livestock is a major source of supplementing family incomes and generating gainful employment in the rural sector, particularly among the small and marginal farmers and farm women besides serving as nutrient source. The results of on-farm farming system modules evaluated in various NARP zones through AICRP on Integrated Farming Systems promises 6.8 times increase in net returns over variable cost of interventions in improved farming systems with value of household consumption (produced within the farm) increasing by 51.4 %. Further, the recycling of wastes increases by 40-45 % against the <20 % in the naturally integrated systems.

3.2 Enhancing Water Productivity Through Farming System

Integrated farming system provides a better scope for most effective use of water by putting the same water for several uses like producing crop, fish, dairy, mushroom, poultry, duckery etc. simultaneously within a farm. Multiple uses of water are best possible through diversification of farming systems. Rice-fish system can be described as micro-watershed for effective land and water uses. The system explored synergy leading to increased grain yield of rice by 5–15 %, enrichment of organic matter and nutrients. On-farm studies reveals that integration of fishery and piggery gave maximum water productivity (net returns of Rs. 5.67/m^3, 1.23 kg grain of rice/m^3 of water). The technologies viz. adoption of furrow irrigation instead of check basin or border method of irrigation, raised bed planting technology, pressurized irrigation system, laser land leveling etc. are suitable under diversified farming systems and lead to considerable amount of saving in water use.

4. LESSONS LEARNT SO FOR

Input use efficiency increases the conservation of resources but it should not be at the cost of yield and economic returns of the cropping systems. Resource conservation practices needs to be adopted based on the locational requirements along with best management practices.

5. POSSIBLE RESOURCE SAVING

Costs of inputs would make the difference on the total production costs. In a system where herbicides would replace land preparation activities the overview could look like figure 4 in conservation and conventional systems (Montoyo, 1984).

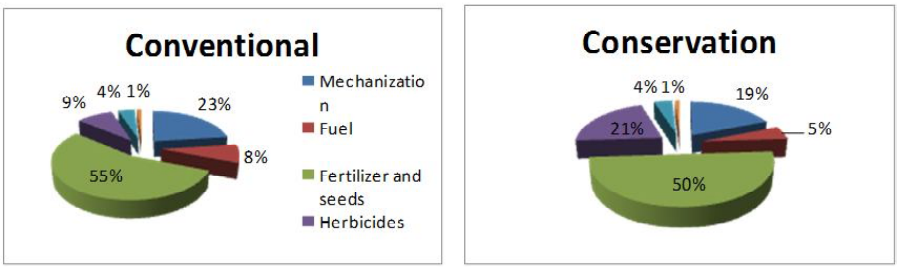

Fig. 4: Changes in different costs under conventional and conservation system

6. CONCLUSION

Improving input use efficiency is a worthy goal and fundamental challenge facing the agriculture in general. One should be cautious that improvements in efficiency do not come at the expense of the farmers' economic viability or the environment. Farm input interactions play an important role in determining the resource use efficiency of the vitalinputs *viz* water, fertilizer and energy, and it is therefore, important that the management practices that moderate and modify these relationships are evaluated and understood.

7. MAJOR FUTURE CONCERNS

- Integration of compatible components in farming systems mode for reduce, reuse, recycle and recovery of resources is essential for enhancing the input use efficiency to greater extent.
- Possible positive interactions of physical inputs of agriculture are to be evaluated which can contribute notably to the resource conservation and efficiency.
- Study on nutrient-water-seed nexus for optimizing the use efficiency of inputs and farm productivity
- Development and propagation of low cost energy sources are essential for resource conservation especially in the fuel, fertilizer and mechanization.

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The present publication deals with the scope and significance of refinement, adoption and dissemination of conservation agriculture (CA) in Indian *vis-à-vis* global context. Through this book, an attempt has been made to help readers to gain a precise understanding of the role of mechanization and the necessity for suitable modifications in the existing machinery for efficient residue recycling, crop establishment, optimized nutrient and water use, and weed management. Highlighting the collective work of various CA researchers, this reference book helps to understand the aspects like dynamics of macro and micro-nutrients along with the desired management alterations as per the CA principles. For the wider adoption of CA, location-specific crop diversification suited for different soil types has also been discussed in the book. The approaches like integrated farming system and organic farming in conjunction with CA principles for enhanced resource recycling, sustained livelihood in long-term perspective has been documented in the book. The impact of CA on soil quality, technologies designed for adaptation/mitigation for climate vulnerability, economics and system sustainability has been the focal point in the present book.

. . . This book is a perfect compilation of consorted efforts of various researches done in the direction of development, standardization and dissemination of the refined CA technologies. The emerging concerns of environmental unsustainability raised in the book necessitates the development of a policy framework promoting CA . . . I strongly believe that the book would be of great value to various stakeholders in addressing the goals of achieving sustainable agricultural systems through conservation agriculture . . .

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Vice-Chancellor
Rani Laxmi Bai Central Agricultural University, Jhansi

Readership: Researchers working on conservation agronomy, soil science, soil physics, environmental sciences, farm machinery and power, agricultural economics and extension. Undergraduate, post graduate students of different natural resource management disciplines in SAUs, all the stake holders including policy makers, state agriculture development departments involved in agricultural production in general and conservation agriculture in particular.

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