CONSERVATION AGRICULTURE TECHNOLOGIES INCREASE PRODUCTIVITY AND PROFITABILITY OF CEREAL BASED FARMING SYSTEM IN EASTERN PLAINS OF NEPAL

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ABSTRACT

This study was conducted to assess the impacts of conservation agricultural practices on crop productivity, profitability and ultimately sustainability of the cereal based farming system of eastern plain region of Nepal. Sustainable and Resilient Farming System Intensification (SRFSI) has been working in responses to the concerns about the sustainability of the cereal based farming system (rice-wheat and rice-maize) in Sunsari and Dhanusha districts. Productivity was measured using production per unit area and profitability was measured in terms of gross return, gross margin, return and benefit cost ratio. It has been found that there ae several tangible benefits like lower labor utilization per hectare (71 people day^{-1} ha^{-1} as compared to 106 for conventional), lower input cost (NRs. 78,395 ha^{-1} as compared to 102,727 ha^{-1}), less irrigation with regards to ponding time (50%), and higher crop productivity (8.11tha^{-1} as compared to 8.08 tha^{-1} in rice-wheat and 13.1 tha^{-1} as compared to 11.75 tha^{-1} in conventional rice-maize) farming system through the adoption of conservation practices.

Keywords: Conservation agriculture; plain region; cereal cropping system; productivity, profitability

INTRODUCTION

Rice (*Oryza sativa* L.), maize (Zea mays), and wheat (*Triticum aestivum* L.) are the most important cereal crop in Nepal. Rice has been grown in 1,362,000 ha of land with productivity 3.15 t ha^{-1}, wheat in 745,000 ha of land with productivity 2.32 t ha^{-1}, and maize in 892,000 ha of land with productivity 2.5 t ha^{-1}(MOAD, 2017). Cereal crops stand the most important crop for the plain and terai regions of Nepal. Maize is grown throughout the year however winter season maize is third important crop in terms of its area under cultivation in many plain and terai areas of Nepal (Paudyal et al., 2001).

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The rice-wheat and rice-maize production system is a major farming system of plains and terai region of Nepal which is also called the food basket of the country, therefore, assumes paramount importance in contributing to the national pool of food and providing employment and livelihoods to millions of rural people (Sekar and Pal, 2012; SRFSI, 2016; Pokharel *et al.,* 2018). The major cereal-based farming systems in this region are less profitable because of the shortage of labor, agricultural water, capital and energy as a resulting rural exodus occurring in many Asian countries (Mehla *et al.,* 2000; Bhatt *et al.,* 2016; Keil *et al.,* 2017, Pokharel *et al.,* 2018).

Majority of the farmers in this region are adopting conventional agricultural practices and crop production which is influenced by varieties of factors like tillage, residue, nutrient, water, and types of cultivar (Duxbury *et al.,* 2000; Panday, 2012; Pokharel *et al.,* 2018). Additionally, there is an acute shortage of agricultural labors, lack of quality inputs, site-specific nutrient management, and pest management options for the mechanization and sustainable intensification in cereal-based farming system (Panday *et al.,* 2018). The existing practices of the farmer in this region such as crop residue removal and excessive tillage on farming land lead to loss of residual moisture and ultimately the fertile soil becomes prone to nutrient depletion and damage to soil structure. Many studies support that there is a huge yield gap between potential and actual crop yields realized by the farmers due to lack of good agricultural management practices, poor germination of seeds, and poor nutrient content of chemical fertilizers (Sekar and Pal, 2012; Pokharel, 2016). In addition, several climatic variations like high temperature and low rainfall have escalated yield gap for most of the food crops (Duxbury *et al.,* 2000; Panday, 2012). The area under cereal crops has been found diminished due to several constraints majorly including labor shortage, increased cost of production, population growth and urbanization. Decreased soil fertility and low crop productivity escalated the problems (Saharawat *et al.,* 2010).

Hence, the research and development of new integrated resource management strategies are needed for sustainable crop production in the terai and plain region of Nepal which ultimately can increase productivity and profitability which ultimately for the sustainability of cereal-based farming system. These technologies in cereal based farming system have been working in responses to concerns since 2014 in eastern plains of Nepal (SRFSI, 2016). Therefore, this aim of this study is to assess crop productivity and profitability as a result of the conservation agriculture (FAO, 2018) practices in rice-wheat and rice-maize farming system in eastern plains of Nepal and seeks farmer's perceptions on conservation agricultural practices for sustainable intensification agriculture in the region.

METHODOLOGY

STUDY LOCATION

This study was conducted in Sunsari district in Province No.1 of eastern plains of Nepal located in the latitude of 26° 25' to 26° 55'N and the longitude of 86°55' to 87°21' E (Figure 1). The total area of the district is 1257 km^2 of which 81756 ha of land is cultivated area from a total land area of 125700 ha. The temperature of the district varies from 10 to 20 °C in the winter and up to 35 to 43 °C in the summer, and the average annual rainfall is around 1943 mm. Farmers follow rice-wheat and rice-maize as the major cropping practices (DADO, 2017).

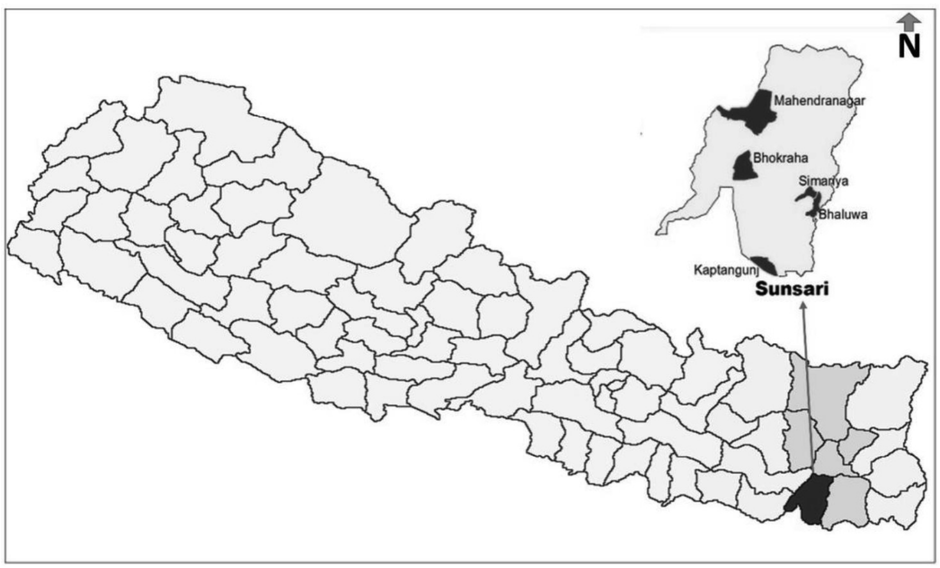

Figure 1. Map of Nepal showing study sites (5 nodes) in Sunsari district.

DATA COLLECTION

The study was conducted in five nodes of Sunsari district where the conservation agriculture practices are getting introduced and gaining popularity among farmers since 2014. These are shown (with red patches in Figure 1) for long term field trials in Mahendranagar, Bhokraha, Kaptanjung, Simariya, and Duhabi rural metropolitan since the beginning of project (2014 to 2018). The experiments were conducted with three major cereal crops in two cropping system (n= 18 in rice-wheat and n=6 in rice-maize; although n=20 were planned 4 each from the node) and random sampling survey (60 farmers/adopters randomly selected from different nodes were taken into account with the semi-structured questionnaire).

The long term field level experiment was conducted in the year 2015-16 with blocks with 400 m^2 as the plot size were taken from the adopter farmer's for the data related to inputs, associated costs and other parameters in the study. There were three treatments in rice: zero tillage direct seeded rice (ZTDSR), unpuddled mechanized or manually transplanted rice (UPTPR) which eliminate puddling and transplant rice seedlings using self-propelled mechanical rice transplanter) (Malik *et al.,* 2011) and CTTPR (conventional tillage and manual transplanting which includes massive puddling of soil and manual transplanting of rice seedlings). A ZTDSR is a method for rice where seeds are sown directly without raising them in a nursery, and can be done in zero-tillage conditions (Gopal *et al.,* 2010). A UPTRP is a method which eliminate puddling and transplant rice seedlings using self-propelled mechanical rice transplanter (Malik *et al.,* 2011). In the same way, CTTPR is a method which includes massive puddling of soil and manual transplanting of rice seedlings.

There were only two treatments in wheat and maize: ZTM/ZTW (zero tillage maize/wheat includes sowing maize/wheat seeds without tillage and sown behind the zero till drill machine) and CTM/CTW (conventional tillage maize/wheat in which multiple tillage done before sowing the seeds. Thus, we considered four treatments in rice-wheat (CTTPR+CTW; CTTPR+ZTW; ZTDSR+ZTW and UPTPR+ZTW) and rice-maize (CTTPR+CTM; CTTPR+ZTM; ZTDSR+ZTM and UPTPR+ZTM) farming system to assess a potential intervention in the existing farming system of the region. The rice-wheat treatments were set on lowland areas of the nodes whereas the rice-maize treatments were taken on upland environment conditions.

A semi-structured questionnaire was developed to explore the advantages experienced, input costs, management costs, and problems with the resource conservation technologies (RCT) on cereal-based farming system with the randomly selected 60 farmers/adopters from the of different treatments of conservation agriculture in Sunsari district (10 each from 5 nodes and the rest 10 from Devanjung rural metropolitan, a neighbor village of Kaptanjung).

DATA ANALYSIS

The respective grain yield and biomass yield in t ha^{-1} for each of the different treatments were recorded. The respective crop yield data of rice-wheat and rice-maize farming system, and the crops recorded from the long term trials were recorded and subjected to two way ANOVA (not shown here). The harvest index was calculated by using the formula as the ratio of economic yield to the biomass yield (Huhen, 1993). The crop establishment cost, total variable costs (of inputs) were considered and valued at market prices to calculate the cost of production. The costs of cultivation (seeds, fertilizers, manures, irrigation, labor, herbicides) at the time of sowing/transplanting; crop establishment cost and other variable cost incurred during production (Total variable cost) were recorded for each of the treatments and valued at the current market prices of the year 2016 to calculate the cost of production.

Crop establishment cost (TC) = C(seed)+C(labor)+C(manure)+C(chemicals) + C(machine)

Total variable cost (TC) = C(labor)+C(chemicals)+C(machine)

Where, C(seed)= cost on seed (NRs./ha), C(labor)= Cost on human labor (NRs./ha), C(manure)= Cost of manures (NRs./ha), C(chemicals)= Cost of chemical fertilizers, and other chemicals (NRs//ha) and C(machine)= Cost of machine (NRs./ha).

Gross return was calculated by multiplying the total volume of an output/product y the average price in the harvesting period (Dillon and Hardarker, 1993).

Gross return (GR)= $Y_mP_m + Y_bP_b$

Where, Y_m = Yield of main product per unit area

P_m = Price of main product

Y_b = Yield of by-product per unit area

P_b = Price of by-product

Net profit was calculated by deducting all costs from the gross return.

Net profit (NR) = GR-TVC

Where, GR= Gross return

TVC= Total variable cost.

Benefit cost Ratio was calculated to compare the return per unit of cost in each of the different treatments. The undiscounted BCR was calculated as

BCR = GR/GC

Where, GR = Gross return

GC = Gross cost

The labor use (person day^{-1} ha^{-1}) was recorded in each of the different treatment to assess the total number of labor used in each treatment. The data collected in 2015 to 2016 were analyzed with descriptive and quantitative statistics of Microsoft Excel 2010.

RESULTS AND DISCUSSION

MAJOR INPUTS USED IN CA PRACTICES

Farmers used 20 kg more rice seeds than the recommended rate from the Government of Nepal while lesser in DSR and UPTPR practices in the research area of the district (Figure 2). Similarly, the other fertilizer inputs such as diammonium phosphate (DAP), urea, and muriate of potash (MOP) was also varying among the different treatments. Trends show that DSR and UPTPR consumed significantly lesser amount of fertilizer than the puddle and manual transplanted system.

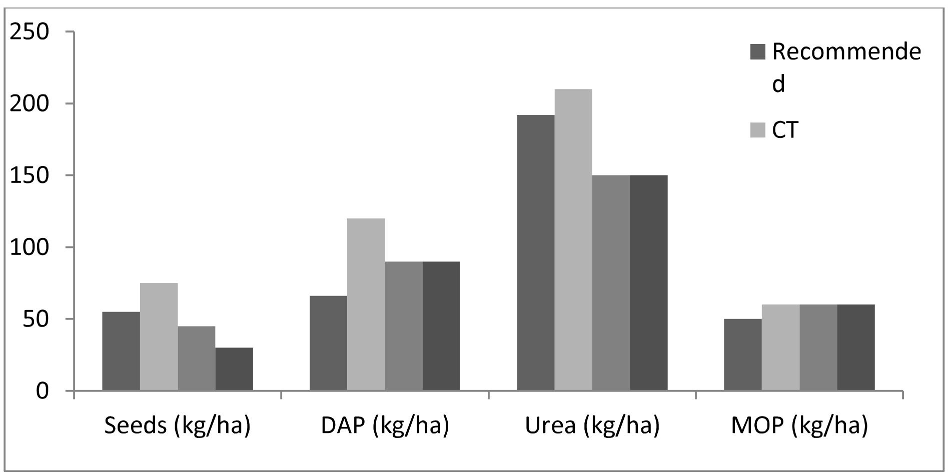

Figure 2. Quantity of inputs (seed and fertilizer types) used for rice cultivation under different system in Sunsari district of Nepal in 2015 and 2016.

Farmers were using almost two times higher seed rate in conventional practices than the recommended seed rate of 100 kg $ha^{-1}$for wheat production. Under ZT management, farmers were using the wheat seeds near to the national government recommended quantity (to ensure crop geometry and effective plant population of the crop) i.e. 100 kg ha^{-1}. The rates of chemical fertilizers and seed for wheat production are shown in Figure 3.

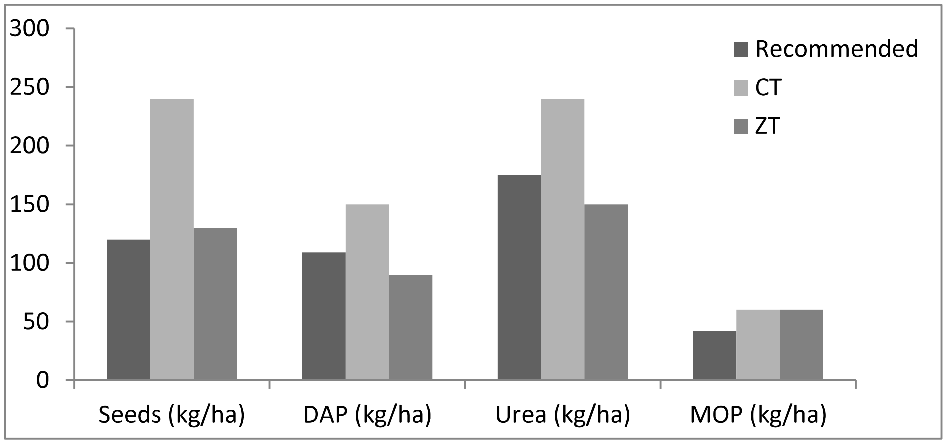

Figure 3. Quantity of inputs (seed and fertilizer types) used for wheat cultivation under different system in Sunsari district of Nepal in 2015 and 2016.

Majority of the maize growing farmers were using 6 kg ha^{-1}of seeds in ZT management as compared to the conventional practice. The application rate of chemical fertilizer was also low as compared to the CT Maize shown in Figure 4.

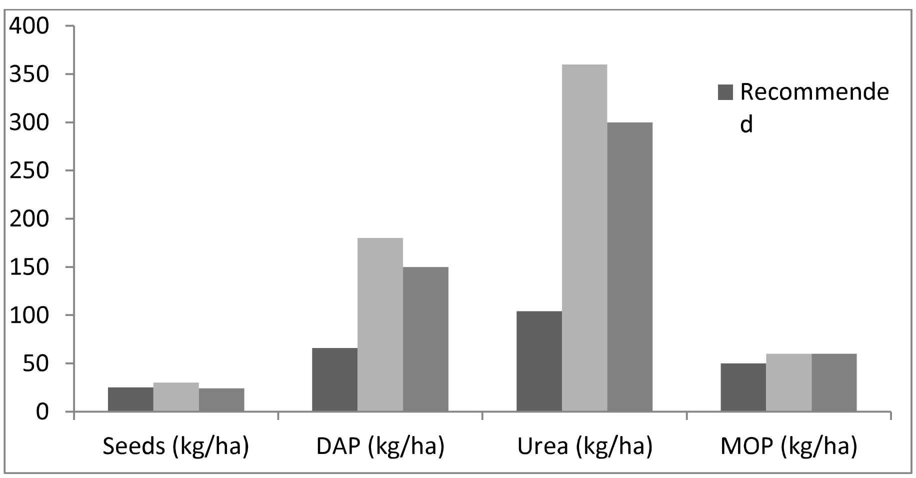

Figure 4. Quantity of inputs (seed and fertilizer types) used for maize cultivation under different system in Sunsari district of Nepal in 2015 and 2016.

GRAIN YIELD OF CEREALS

The summary statistics for cereals grain yields and harvest index from different treatment in 2015 and 2016 in Sunsari district of Nepal is presented in Table 1. Although, there was no significant difference for grain yield of rice or wheat, however maize grain yield showed statistically significant differences at $P \leq 0.05$ confidence limit (not shown here) among treatments. Most of the farmers growing with direct seeded rice (DSR) and un-puddled transplanted rice (UPTPR) experienced two to three weeks early in harvesting of the crop. UPTPR followed by zero tillage wheat (ZTW) was found to be more beneficial than other treatments of which grain yield was 8.11 t ha^{-1} with harvest index of 0.52 (Table 1).

Table 1: Grain yield, biomass yield and harvest index of long term trials on rice-wheat farming system in 2015 and 2016 in Sunsari district of Nepal (n=18).

Treatment	**Grain yield**	**Biomass**	**Harvest Index**
	t ha^{-1}		
Aman rice 2015			
CTTPR	6.57	12.89	0.51
ZTDSR	5.61	11.21	0.50
UPTPR	6.69	12.58	0.53
Wheat 2015-16			
CTTPR-CTW	1.51	3.02	0.50
CTTPR-ZTW	1.62	3.2	0.51
ZTDSR-ZTW	1.54	3.21	0.48
UPTPR-ZTW	1.42	3.14	0.45
Rice-Wheat system 2015-16			
CTTPR+CTW	8.08	15.91	0.51
CTTPR+ZTW	8.19	16.09	0.51
ZTDSR+ZTW	7.15	14.42	0.50
UPTPR+ZTW	8.11	15.72	0.52

Farmers who were opting zero tillage maize (ZTM) experienced several advantages for example, less seed requirement (Figure 4), fertilizer use efficiency, less water for irrigation, proper crop stand, etc. Maize yield was found the highest in UPTPR-ZTM system with grain yield and harvest index as 6.86 t ha^{-1} and 0.50, respectively (Table 2). Simiarly, the UPTPR+ZTM yields highest grain yield 13.1 t $ha^{-1}$with harvest index 0.49 as shown in Table 2 for the rice-maize farming system in the eastern plain of Nepal.

Table 2: Grain yield, biomass yield and harvest index of long term trials on Rice-Maize farming system in 2015 and 2016 in Sunsari district of Nepal (n=6).

Treatment	Grain yield	Biomass	Harvest Index
	t ha^{-1}		
Aman rice 2015			
CTTPR	5.26	11.35	0.46
ZTDSR	5.2	10.92	0.48
UPTPR	6.24	12.89	0.48
Maize 2015-16			
CTTPR-CTM	6.49	12.78	0.51
CTTPR-ZTM	5.81	12.79	0.45
ZTDSR-ZTM	5.86	12.59	0.47
UPTPR-ZTM	6.86	13.65	0.50
Rice-Maize system 2015-16			
CTTPR+CTM	11.75	24.13	0.49
CTTPR+ZTM	11.07	24.14	0.46
ZTDSR+ZTM	11.06	23.51	0.47
UPTPR+ZTM	13.1	26.54	0.49

ESTIMATION OF PRODUCTION COST AND RETURNS

This research was done to evaluate the profitability of major cereal crops based on system approach. The total cost includes: seed, labor, machine, manure, fertilizers, herbicides, irrigation and depends upon the time. The cost incurred during the crop establishment was taken separately to distinguish differences among the treatments. The crop establishment cost was found lowest in ZTDSR (NRs. 7010 ha^{-1}) (NRs. 103 = $1 USD) followed by UPTPR (NRs. 11683 ha^{-1}) with highest in CTTPR (NRs. 26588 ha^{-1}) for rice while in wheat ZTW (NRs. 7171 ha^{-1}) and CTW (NRs.16920 ha^{-1}). It was found that highest net profit in UPTPR+ZTW (NRs. 157514 ha^{-1}) and least with CTTPR+CTW (NRs. 130040 ha^{-1}) which is shown in Table 3. Similarly, the crop establishment cost and total variable cost were lower under conservation agricultural practices in rice-maize farming system (Table 4). There is highest net profit with UPTPR+ZTM (NRs. 237440 ha^{-1}) and lowest with ZTDSR+ZTM (NRs. 175320 ha^{-1}).

CROP PRODUCTIVITY AND PROFITABILITY ESTIMATION

The partial economics of long-term trials on rice-wheat farming system 2015-16 in Sunsari district is shown in Table 3. The CTTPR+ZTW have the highest grain and biomass yields as 8.19 and 16.09 t ha^{-1}, respectively. The net profit was found the highest in UPTPR+ZTW treatment NRs. 157514 $ha^{-1}$with B:C ratio 2.96 followed by ZTDSR+ZTW with net profit NRs. 139386 ha^{-1} with B:C ratio 2.78. The conventional practices of rice transplanting followed by conventional sown wheat has a net profit of NRs. 130040 ha^{-1} with B:C ratio 2.27. It is found that the labor use (person day^{-1} ha^{-1}) has also lower in the conservation based agricultural practices (Table 3) in rice-wheat farming system.

Table 3: Partial economics of long term trials on rice-wheat farming system in 2015 and 2016 in Sunsari district of Nepal (n=18).

Treatment	Crop establishment cost	Total variable cost	Gross return	Net profit	Benefit cost ratio	Labor use (person day^{-1} ha^{-1})
	NRs ha^{-1}					
Aman rice 2015						
CTTPR	26588	47939	144140	96201	3.01	59
ZTDSR	7010	31986	123433	91447	3.86	27
UPTPR	11683	33356	145509	112153	4.36	41
Wheat 2015-16						
CTTPR-CTW	16920	54788	88627	33839	1.62	41
CTTPR-ZTW	7171	46328	93783	47456	2.02	30
ZTDSR-ZTW	7171	46408	94347	47939	2.03	30
UPTPR-ZTW	7171	47053	92414	45361	1.96	30
Rice-Wheat system 2015-16						
CTTPR+CTW	43508	102727	232767	130040	2.27	100
CTTPR+ZTW	33759	94267	237923	143656	2.52	89
ZTDSR+ZTW	14180	78395	217781	139386	2.78	57
UPTPR+ZTW	18853	80409	237923	157514	2.96	71

Similarly, the partial economics of long-term trials on rice-maize farming system 2015-16 in Sunsari district is shown in Table 4. The UPTPR+ZTM treatment has the highest grain yield 13.1 t ha^{-1} with biomass yield

26.54 t ha^{-1}. Results show that the net profit was also the highest for this treatment with NRs. 237440 ha^{-1} with B:C ratio 3.47. The conventional practice of rice transplanting followed by conventional maize has net profit NRs. 179510 ha^{-1} with B:C ratio. It was found that labor use (person day^{-1} ha^{-1}) as 74 for CA-based treatment (UPTPR+ZTM) and 106 for conventional practice in rice-maize farming system.

Table 4: Partial economics of long term trials on Rice-Maize farming system in 2015 and 2016 in Sunsari district of Nepal (n=6).

Treatment	**Crop establishment cost**	**Total variable cost**	**Gross return**	**Net profit**	**Benefit cost ratio**	**Labor use (person day^{-1} ha^{-1})**
	NRs ha^{-1}					
Aman rice 2015						
CTTPR	17323	39560	117390	77831	2.97	47
ZTDSR	8460	41091	115376	74286	2.81	31
UPTPR	10232	34323	138016	103694	4.02	38
Maize 2015-16						
CTTPR-CTM	16275	66470	168150	101679	2.53	59
CTTPR-ZTM	6123	54868	154614	99746	2.82	35
ZTDSR-ZTM	5882	53982	155017	101035	2.87	34
UPTPR-ZTM	7010	61717	195463	133746	3.17	36
Rice-Maize system 2015-16						
CTTPR+CTM	33598	106030	285540	179510	2.69	106
CTTPR+ZTM	23446	94428	272004	177576	2.88	82
ZTDSR+ZTM	14341	95073	270393	175320	2.84	65
UPTPR+ZTM	17242	96039	333479	237440	3.47	74

ADVANTAGES ASSOCIATED WITH CA PRACTICES

Survey (n=60) results and interviewwith the field technicians of SRFSI at five different nodes within the project area indicates increasing trends during the recent years and the number of farmers adopting different CA practice varies from node to node depending upon the socio-economic characteristics, availability of quality inputs and topography of the land.It was reported that there are altogether 250 farmers with 350 hectares throughout the district opting ZT technology in different cereal crops (DADO, 2017; Pokharel *et al.,* 2018).

Most of the farmer's experienced the advantage of optimum sowing time in rice (96%), maize (70%) and rice (87%). More than 90% farmers observed lower seeds requirement per unit area of land as per the better germination and excellent crop establishment except in the case of DSR rice, the sweep away of seeds and higher weed infestation has observed by farmers. As, rainy season coincides break the herbicide layer from the soil surface as a result increases weed infestation problem in rice crop. Farmer's observed lesser weed infestation in ZT wheat and ZT maize (90%) mostly due to rationale use of herbicides. As, these technologies require lesser water and utilizes the residual moisture more efficiently reduces the ponding time as well as increased the irrigation efficiency (100%) and increased fertilizer efficiency (95%, 85% and 78%, respectively) in rice, maize and wheat crops. Large number of farmers observed early maturity of the crops (81.67% in maize, 90% in wheat and 100% in rice) along with lesser disease/insect infestation as compared to conventional practices. Most of the farmers observed that these CA based practices increased crop yield (68.34% in wheat, 61.67% in rice and 53.34% in maize).

PROBLEMS ASSOCIATED WITH THE CA PRACTICES

Majority of the farmers under CA practices in cereal-based farming system in Sunsari district were facing a problem with the availability of zero till drill and or happy seeder machine (Iqbal et al., 2017) in time. There are altogether 12 ZT machines (including multi-crop) and one happy seeder machine (aka Turbo) used for sustainable intensification of CA in Sunsari district. The other problems included clay attachment in the zero tiller nearer to the seed and fertilizer drill pipe, due to which clogging was observed. Although the application of FYM or compost to cereal crops in district was negligible, its use and the best application of nitrogenous fertilizers were also found problem to farmers. Regarding, weed management for the few years was also found problem in the study area. As there is an Innovation Platform (IP) (Homann-KeeTui et al., 2013); bringing together different concerned stakeholders to achieve common goals, were well established and functional in each node the newly released and developed technique was quickly diffused through IP so that these problems (of weed management) along with the quality inputs can be managed in Sunsari district.

CONCLUSION

The study concludes that conservation agriculture practices in rice-wheat and rice-maize farming system, especially in the eastern plain region of Nepal, was appreciated and successfully able to increase productivity and reduce variable costs of the cereal based farming system. The findings shows the increment of crop productivity (8.11 tha^{-1} as compared to 8.08 t ha^{-1}in Rice-Wheat and 13.1 t ha^{-1}as compared to 11.75t ha^{-1}in conventional rice-maize), reduces the cost of cultivation (NRs. 78395ha^{-1}as compared to 102727ha^{-1}), increased net benefits, reduces irrigation time for most of the crops, and decreases labor use per hectares (71 people $day^{-1}ha^{-1}$ as compared to 106 for conventional) In addition to these, farmers adopting CA practices perceived early maturity of crop i.e, 7-15 days, lower seed requirements and several environmental benefits including saving of water and energy (not discussed in this paper). It is also evident that if the farmers in the eastern plains region would adopt CA practices, would be more profitable as compared to the conventional cereal based farming system. The establishment of custom hiring center as an novel approach of Ministry of Agriculture and Livestock Development, Nepal aims to assist a large number of farmers with types of machinery and agricultural equipment's will help in sustainable intensification and out-scaling in the plain region. In addition, some policy recommendations regarding mechanization, crop insurance, adoption of CA practices, and motivation & extension services of Agriculture Knowledge Center and selected rural/metropolitans' agriculture sections should be enhanced to out-scale the adoption among wider farmers. Therefore, there is a great scope to improve the overall economic condition of small-scale farmers of the eastern plains of Nepal.

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