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Is conservation agriculture a potential option for cereal-based sustainable farming system in the Eastern Indo-Gangetic Plains of Nepal?

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Abstract: A decline in land and water productivity, increase in the cost of cultivation, and labor-intensive practices are affecting the cereal-based farming system in Nepal, particularly in the Indo-Gangetic Plains (IGP). Conservation agriculture (CA) practices have been found to be the climate-, energy-, and labor-smart and sustainable agricultural production technologies. Sustainable and Resilient Farming System Intensification (SRFSI) has been working since 2014 in response to the sustainability of the cereal-based (rice–wheat and rice–maize) farming in Sunsari and Dhanusha districts of Nepal. This study was conducted to assess the adoption and scaling up of CA in addition to input usage, production, net profit, benefit to cost (B:C) ratio, and labor use of CA practice on average scale land holdings in Sunsari district. The study employed structured questionnaires and key informant surveys as the main data collection tools and project reports were used as secondary data. Results revealed that farmers had several tangible advantages: lower labor utilization per area (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%) as compared to conventional practice, and higher crop productivity (8.11 t ha^{-1} as compared to 8.08 t ha^{-1} in rice–wheat and 13.1 t ha^{-1} as compared to 11.75 t ha^{-1} in conventional rice–maize) farming system through the adoption of CA practices. This study assessed the potential of CA-based

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Dipendra Pokharel, a System Agronomist at District Agriculture Development Office, Sunsari (Nepal) has an acquaintance in project development, climate adaptation, natural resources management, food security, and farmer's empowerment for over eight years. His research area is focused on agronomic management for boosting crop productivity. The research teams are the project members working jointly to increase the productivity and profitability along with the sustainable intensification of cereal based farming system of Eastern Indo-Gangetic Plains (EIGP) of Nepal. The research findings reported in this paper assists in better understanding of the productivity and profitability of the sustainable cereal based farming system in Nepal.

PUBLIC INTEREST STATEMENT

Speedy decline in land and water productivity, increased cost of cultivation, low priced agricultural commodities are the major impediment behind substandard cereal based farming system in Nepal. Conservation agricultural technologies including climate smart models are the need of an hour to boost productivity and reduce labor drudgery of the country. This work investigates the advantages perceived by the farmers/adopters in the region, as well as assists in ensuring sustainability of the cereal based farming system. Our results indicate that there are multiple advantages under conservation agriculture for sustainable intensification in the region.

practices in a cereal-based cropping system to improve the yields and net profit for sustainability.

Subjects: Agriculture & Environmental Sciences; Soil Conservation Technology; Agronomy

Keywords: conservation agriculture; EIGP; farming system; rice–maize; rice–wheat

1. Introduction

The Indo-Gangetic Plains (IGP) is a vast area of fertile land that includes around 255 million hectares (ha) across four major countries: India, Pakistan, Nepal, and Bangladesh (Soneja, Tielsch, Khatry, Curriero, & Breysse, 2016). Eastern IGP (EIGP) is endowed with more abundant natural resources, particularly land and water, compared with the western IGP (WIGP). The rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L.) production system in IGP, therefore, assumes paramount importance in contributing to the national pool of food and providing employment and livelihoods to millions of rural people (Sekar & Pal, 2012). Several factors including lack of quality inputs, lack of appropriate technology, illiteracy among farmers, and the changing climate, the productivity of rice–wheat farming system is getting lower in the EIGP (6.2 t ha^{-1}) as compared with the WIGP (10 t ha^{-1}) (Chapagain & Raizada, 2017; Yadav, Yadav, Singh, & Kumar, 2008).

Agriculture in Asia is based on cereal-based farming systems rice–wheat and rice–maize (*Zea mays* L.); however, input-use efficiency is low (Drechsel, Heffer, Magen, Mikkelsen, & Wichelns, 2015). The major cereal-based farming systems in this region, such as rice–wheat and rice–maize farming system are less profitable because of the shortage of labor, agricultural water, capital, and energy as a resulting rural exodus occurring in many Asian countries (Bhatt, Kukal, Busari, Arora, & Yadhav, 2016; Keil, D'souza, & McDonald, 2017; Mehla, Verma, Gupta, & Hobbs, 2000). Majority of the farmers in this region are adopting conventional agricultural practices, which are water-, capital-energy-intensive, and thus a serious threat to the sustainability of the cereal-based farming system (Bhatt et al., 2016) and crop production is influenced by numbers of factors like tillage, residue, nutrient, water, and types of cultivar (Duxbury, Abrol, Gupta, & Bronson, 2000; Panday, 2012). 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 these EIGP, 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. The organic matter content in the soil is low (less than 1%) since there is a very low use of farm-yard manure (FYM) and also low residual nutrients on it (Gupta, Naresh, Hobbs, & Ladha, 2002; Ladha et al., 2003). For instance, Nepalese farmers use 2.5–3 t ha^{-1} of FYM annually for soil fertility management (Pandey et al., 2018). 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 (Pokharel, 2016; Sekar & Pal, 2012). 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).

Rice, maize, and wheat 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) in 2015/2016. Cereal crops stand the most important crop for the plain or 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 areas of EIGP in Nepal (Paudyal et al., 2001). Most of the varieties grown by farmers are of hybrids and targeted to sale as raw materials to feed industry.

The area under cereal crops has been found diminished due to several constraints. One of the major reasons include land preparation—after rice harvesting, the same field needs to till at least two times, higher labor cost, unavailability of labor, and lack of quality of inputs on time. Decades of intensive tillage, removal of crop residues, and imbalance use of chemical fertilizers have contributed to decrease soil fertility and leading to low crop productivity in many countries of EIGP including Nepal (Saharawat et al., 2010). In many parts of EIGP, fertilizer recommendations are entirely based on soil types and agro-ecological zones. Regardless of recommendations, farmers mostly use acid forming nitrogenous fertilizers (Panday et al., 2018). Hence, the research and development of new integrated resource management strategies mostly conservation agriculture (CA) technologies are urgently needed for sustainable crop production in the region that can ultimately increase water productivity, soil nourishment, and assurance of quality inputs in an appropriate quantity for the sustainability of cereal-based farming system. CA is a farming system that promotes maintenance of a permanent soil cover, minimum soil disturbance (i.e., zero tillage or ZT), and plant species diversification for improved and sustained productivity, increased profits and food security along with the conservation of the natural resources and environment (FAO, 2018).

There is a demand of different climate-smart and efficient technologies in these farming systems which are able to reduce the cost of cultivation and boosting the productivity of the cereal-based farming system including rice, wheat, and maize crops (FAO, 2018; Thierfelder, Mwila, & Rusinamhodzi, 2013). Puddled soil as required by rice in conventional practices consumes a lot of water, increases the cost of cultivation and deteriorates the soil structure (Bhatt et al., 2016). Increased use of chemical fertilizers, asymmetry of planting schedules in the region has increased the susceptibility of the pests in the rice–wheat farming system (Panday, 2012).

The Sustainable and Resilient Farming Systems Intensification (SRFSI), a collaborative project between the Australian Center for International Agriculture Research (ACIAR) and the International Maize and Wheat Improvement Center (CIMMYT) in the EIGP has been working in responses to concerns about the sustainability of the rice–wheat, rice–maize, and rice–lentil (*Lens culinaris* L.), rice–mungbean (*Vigna radiata* L.) systems (SRFSI, 2016). Therefore, this study is focusing on breaking the yield barriers and ensuring sustainability of rice–wheat and rice–maize farming system in the EIGP of Nepal. It aims to explore advantages of CA based on field experiment for improving the productivity of rice–wheat and rice–maize-based cereal farming system and seek farmer's perceptions on adoption of conservation agricultural practices for sustainable intensification agriculture in the region.

2. Methodology

2.1. Study location

This study was conducted in Sunsari district in the Eastern Region of Nepal that also belongs to the EIGP of Nepal. Geographically, Sunsari district is 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 1,257 km^2, of which 81,756 ha of land is cultivated area from a total land area of 125,700 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 1,943 mm. The soil textural class in the nodes are clay loam to silty clay loam in almost all nodes except sandy to sandy loam in the southern (Kaptangunj) node of the study area. Farmers follow rice–wheat and rice–maize as the major cropping practices (DADO, 2017).

2.2. Study design and treatment

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 conventional tillage and manual transplanting (CTTPR, 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 that

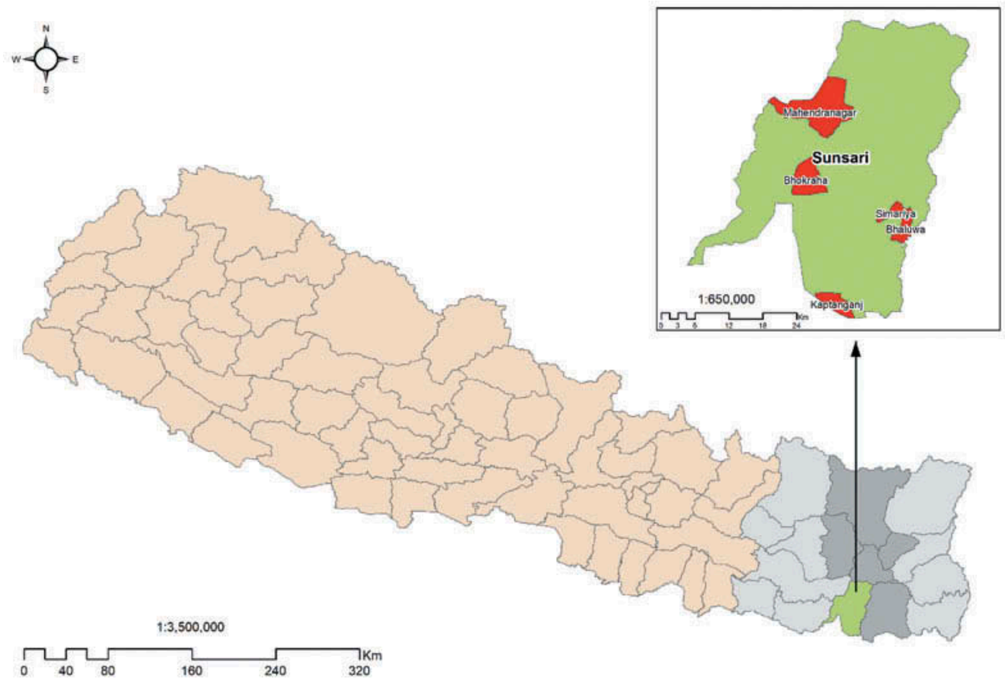

Figure 1. Map of Nepal showing study sites in Sunsari district.

eliminates 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: zero tillage maize/wheat (ZTM/ZTW; includes sowing wheat/maize seeds without tillage and sown behind the zero till drill machine) and conventional tillage maize/wheat (CTM/CTW in which multiple tillages were carried out 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.

2.3. Data collection

Data for this study were collected from three different experiments: (i) farmers field level out-scaling blocks, (ii) long-term trial plots, and (iii) random sampling survey. The primary data related to inputs, associated costs, and other parameters from the farmers field level out-scaling blocks with 400 m^2 as the plot size (n = 162 in rice, n = 153 in wheat, and n = 100 in maize); long-term trial plot on rice–wheat (n = 18) and rice–maize (n = 6) farming system were taken from the CA practices adopter farmers with the help of field technicians for the SRFSI project, Sunsari. Although, it was planned to make 36 plots in each node and altogether 180 for different cropping system, due to several problems: poor germination, disease infestation, disturbance in treatment results the lesser number of the farmers level blocks. There were altogether five nodes (shown with red patches in Figure 1) for long-term continuous trial and farmers field level out-scaling blocks in Mahendranagar, Bhokraha, Kaptanjung, Simariya, and Bhaluwa villages since the beginning of a project (2014–2018).

The long-term trials on rice–wheat (n = 18) farming system and rice–maize (n = 6) farming system; farmers field level out-scaling blocks were conducted among different farmers of the study district.

The costs of cultivation (seeds, fertilizers, manures, irrigation, labor, and herbicides) were recorded for each of the treatments. The respective grain yield and biomass yield in t ha^{-1} were recorded. The crop establishment cost, total variable costs (of inputs) were considered and valued at market prices to calculate the cost of production. 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 respective farming system.

More than 150 farmers throughout the district with at least 20 farmers in each node including the farmers conducting trials on their land are adopting different treatments of conservation agricultural practices, whereas rests of the farmers are adopting conventional farming practices. 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 CA in Sunsari district (10 each from 5 nodes and the rest 10 from Devanjung rural metropolitan, a neighbor village of Kaptanjung).

2.4. Data analysis

The respective crop yield data of rice–wheat and rice–maize farming system, and the crops recorded from the farmers level field trial, long-term trials were recorded and subjected to two way ANOVA. The harvest index was calculated by using the formula as the ratio of economic yield to the biomass yield (Huehn, 1993). The total variable cost was summed from all the expenses incurred, gross return was calculated from the economic yield by the market price. The budgeting technique employed in this study was the gross return and net profit. All variable inputs like labor, machine costs, seeds, manures and fertilizers, irrigation were considered and valued at market prices of the year 2015–2016 to calculate cost of production. Gross return was calculated by multiplying the total economic yield of respective crops by the average price at the harvesting period (Dillon & Hardaker, 1993). In addition to this benefit–cost (B:C) ratio was calculated as the ratio of gross return to the total variable cost. A comprehensive questionnaire was developed for the data collection regarding the advantages associated with the conservation agricultural practices. The data collected from 2015 to 2016 were analyzed with descriptive and quantitative statistics of Microsoft Excel 2016. All the figures were drawn using SigmaPlot 13.0 version.

3. Results and discussion

3.1. Grain yield of cereals

The summary statistics (mean ± standard error) for cereals grain yields from different treatment in 2015 and 2016 in Sunsari district of Nepal is presented in Table 1. Treatment-wise, there were no significant differences for grain yield of rice or wheat, however, maize grain yield showed a statistically significant difference at $P \leq 0.05$ confidence limit (Table 2). Most of the farmers growing with direct-seeded rice (DSR) and UPTPR experienced two to three weeks early in the

Table 1. Summary results for cereals (rice, wheat, and maize) grain yields in 2015 and 2016 in Sunsari district of Nepal

Yield (t ha^{-1})	*N*	Treatment			
		CTTPR-CTW	**CTTPR-ZTW**	**ZTDSR-ZTW**	**UPTPR-ZTW**
Rice	162	3.02 ± 0.05	3.2 ± 0.04	3.21 ± 0.04	3.14 ± 0.04
		CT		**ZT**	
Wheat	153	3.15 ± 0.04		3.06 ± 0.04	
		CTTPR-CTM	**CTTTPR-ZTM**	**ZTDSR-ZTM**	**UPTPR-ZTM**
Maize	100	6.49 ± 0.06	5.81 ± 0.06	5.86 ± 0.04	6.86 ± 0.06

CTTPR = Conventional tillage and manual transplanted rice, ZTDSR = Zero tillage direct seeded rice, UPTPR = Unpuddled mechanized or manually transplanted rice, CTW = Conventional tillage wheat, ZTW = Zero tillage wheat, CT = Conventional tillage, ZT = Zero tillage, CTM = Conventional tillage maize, and ZTM = Zero tillage maize.

Table 2. ANOVA analysis: two way factor analysis

ANOVA: Two factor without replication			
Crop yield	***F***	***P* value**	***F* crit**
Rice			
Rows	1.194	0.078	1.228
Columns	4.070	0.007	2.623
Wheat			
Rows	0.957	0.607	1.307
Columns	1.879	0.172	3.903
Maize			
Rows	1.598	0.001	1.297
Columns	88.826	0.000	2.635

harvesting of the crop due to the reduction of vegetative lag phase with the aerobic environment (Hongyan et al., 2015).

Results from rice–wheat farming system revealed that there was an average grain yield advantage of 5.4% over CTTPR (not shown in table). UPTPR followed by 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 and B:C ratio of 2.96 (Table 3).

Farmers who were growing ZTW experienced two weeks early in the harvesting of wheat crop and relatively higher thousand grain weight. In a field trial of rice–wheat farming system, the wheat grain yield under two different treatments is shown in Table 1. Results showed that CT grown wheat yields more than ZT in the initial year, however, CTTPR-ZTW followed by ZTDSR-ZTW was found to be advantageous over the cropping system as shown in Table 3. A ZTDSR can be defined as method for rice where seeds are sown directly without raising them in a nursery and can be done in zero-tillage conditions.

Farmers who were opting ZTM experienced several advantages, for example less seed requirement, fertilizer use efficiency, less water for irrigation, proper crop stand, etc. In long-term trial of rice–maize farming system, the maize yield under four different treatments is shown in Table 1. 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 3). The yield advantage of 5.63% has been achieved under the UPTPR-ZTM over the CT maize (CTM) practices, whereas in the CT rice field followed by ZT and DSR followed by ZTM was facing yield loss with 10% and 9%, respectively in the initial years (not shown in table 1).

3.2. Advantages associated with CA practices

The area under conservation agricultural practices in Sunsari district is in increasing trends during the recent years. The out-scaling is going through the DADO, Sunsari (the scale of outscaling is discussed in a separate section). Following advantages were observed from the household survey from the CA adopters farmers (n = 60) with at least 10 farmers from 5 different nodes may include the farmers trials on their land selected randomly from the sampling frame of 150 farmers as presented in Table 4.

Most of the farmers 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

Table 3. Partial economics of long term trials on rice–wheat farming system (n = 18) and rice–maize farming system (n = 6) in 2015 and 2016 in Sunsari district of Nepal

Treatment	Grain yield	Biomass	Harvest Index	Crop establishment cost	Total variable cost	Gross return	Net profit	Benefit cost ratio	Labor use (person day^{-1} ha^{-1})
	t ha^{-1}				NRs ha^{-1}				
Rice–wheat system 2015/2016									
CTTPR+CTW	8.08	15.91	0.51	43,508	102,727	232,767	130,040	2.27	100
CTTPR+ZTW	8.19	16.09	0.51	33,759	94,267	237,923	143,656	2.52	89
ZTDSR+ZTW	7.15	14.42	0.50	14,180	78,395	217,781	139,386	2.78	57
UPTPR+ZTW	8.11	15.72	0.52	18,853	80,409	237,923	157,514	2.96	71
Rice–maize system 2015/2016									
CTTPR+CTM	11.75	24.13	0.49	33,598	106,030	285,540	179,510	2.69	106
CTTPR+ZTM	11.07	24.14	0.46	23,446	94,428	272,004	177,576	2.88	82
ZTDSR+ZTM	11.06	23.51	0.47	14,341	95,073	270,393	175,320	2.84	65
UPTPR+ZTM	13.1	26.54	0.49	17,242	96,039	333,479	237,440	3.47	74

Table 4. Advantages experienced with CA based practices of sampled households in 2015 and 2016 of Sunsari district (*n* = 60)

S.N.	Factors	ZT-wheat	ZT-maize	DS-rice
1	Optimum sowing time	58(96%)	42(70%)	52(87%)
2	Less seeds per unit area	54(90%)	54(90%)	57(95%)
3	Seed germination high	58(96%)	55(91%)	35(58%)
4	Crop establishment good	57(95%)	57(95%)	30(50%)
5	Low weed infestation	54(90%)	54(90%)	26(43%)
6	Pond time low	60(100%)	60(100%)	52(87%)
7	Increased irrigation efficiency	60(100%)	60(100%)	60(100%)
8	Increased fertilizer efficiency	57(95%)	51(85%)	47(78%)
9	Disease/Insect infestation low	33(55%)	37(61%)	26(43%)
10	Days to maturity early	54 (90)	49(81.67)	60 (100)
11	Increase in yield	41(68.34)	32(53.34)	37(61.67)

The number informs the frequency of the observed parameter and the number in bracket reflects its percentage.

problem in rice crop. Farmers observed lesser weed infestation in ZT wheat and ZT maize (90%) mostly due to rationale use of herbicides whereas there was more infestation in the initial 3 years. As these technologies require lesser water and utilize 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. A 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).

3.3. Major inputs used in CA practices

Farmers were using about 20 kg more rice seeds than the recommended (from the Government of Nepal for that particular location based upon the soil nutrient balance) seed rate of 50 kg ha^{-1} while lesser was used in DSR and UPTPR practices in the SRFSI project area of Sunsari 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 rice growing system. Trends show that DSR and UPTPR consumed a significantly lesser amount of fertilizer than the puddle and manual transplanted system.

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. Seed drill was calibrated with the standard spacing for different cereal crops which maintained particular seed rate for that crop. 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 2.

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 CTM shown in Figure 2.

Weed management in CA-based farming practices has been found to be effective by using herbicides. The weed management cost depicted a big threat to out-scale the RCT. The difference between the costs of weed management in CT and ZT/DSR practices for rice, maize, and wheat crops in Sunsari district is shown in Figure 3. The weed management in case of wheat involves using of

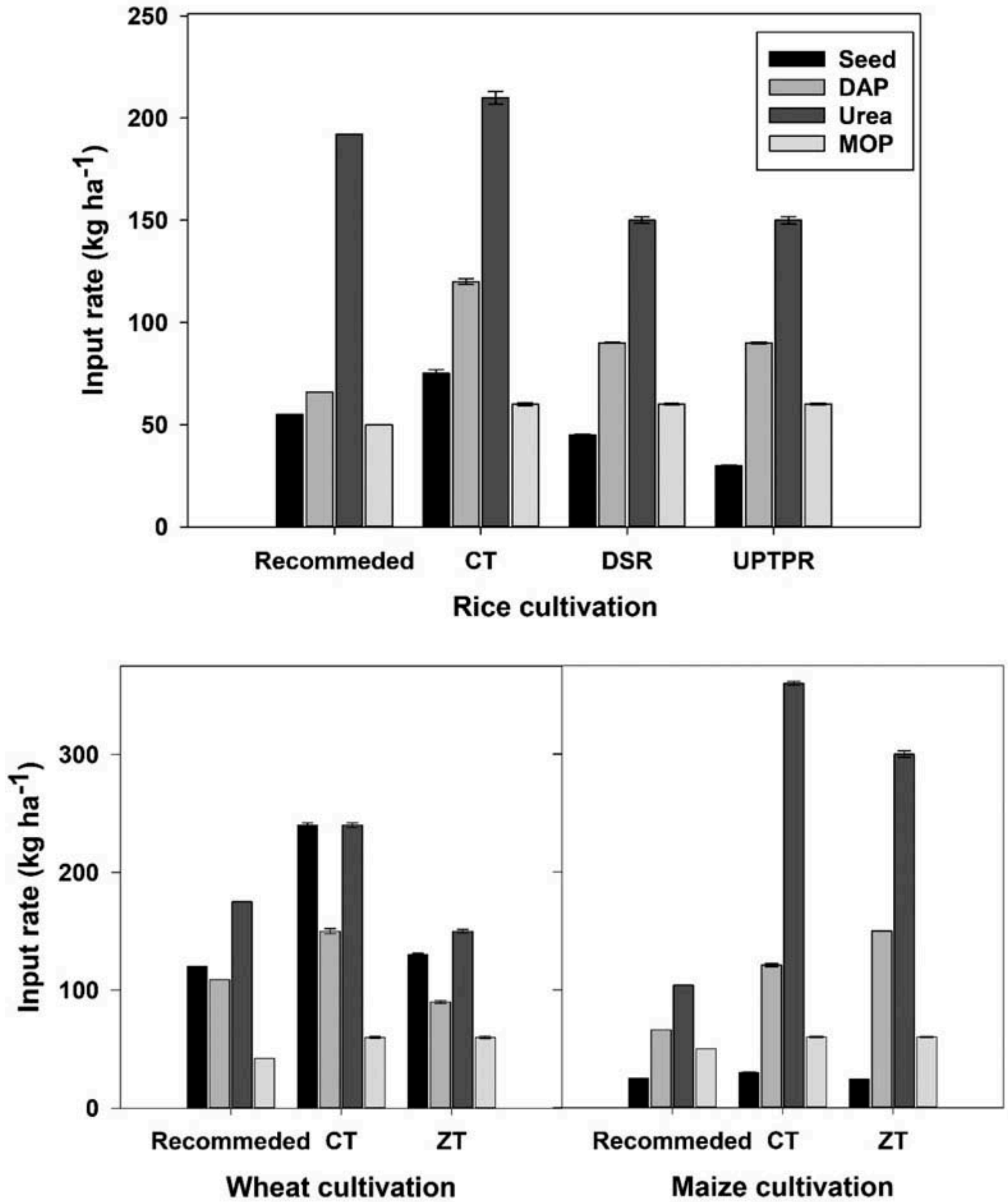

Figure 2. Quantity of inputs (seed and fertilizer types) used for different cereal cultivation under conventional tillage (CT), direct seeded rice (DSR), unpuddled mechanized or manually transplanted rice (UPTPR), and zero tillage (ZT) in Sunsari district of Nepal in 2015 and 2016. In figure, CT and ZT values are expressed with mean ± standard error. Recommended rate stands for the specific amount of inputs given by the Government of Nepal for that particular location.

selected herbicides in both the treatments, whereas in maize under CT there is involvement of manual labors for hand weeding and earthing up which escalates the weed management cost under conventional farming practices. The multi stage application of herbicides, coincidence of rainy season with the rice early growing period increases the weed infestation, thus the conventional practices of manual or machine weeding seem cost-effective over the chemical method of weed management under ZT/DSR.

3.4. Partial economics of trials on rice–wheat and rice–maize farming systems

The partial economics of long-term trials on rice–wheat farming system 2015–2016 in Sunsari district is shown in Table 3. The CTTPR+ZTW has 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. 157,514 ha^{-1} with B:C ratio 2.96 followed by ZTDSR+ZTW with net profit NRs. 139,386 ha^{-1} (NRs. 103 = $1 USD) with B:C ratio 2.78. The conventional practices of rice transplanting followed by

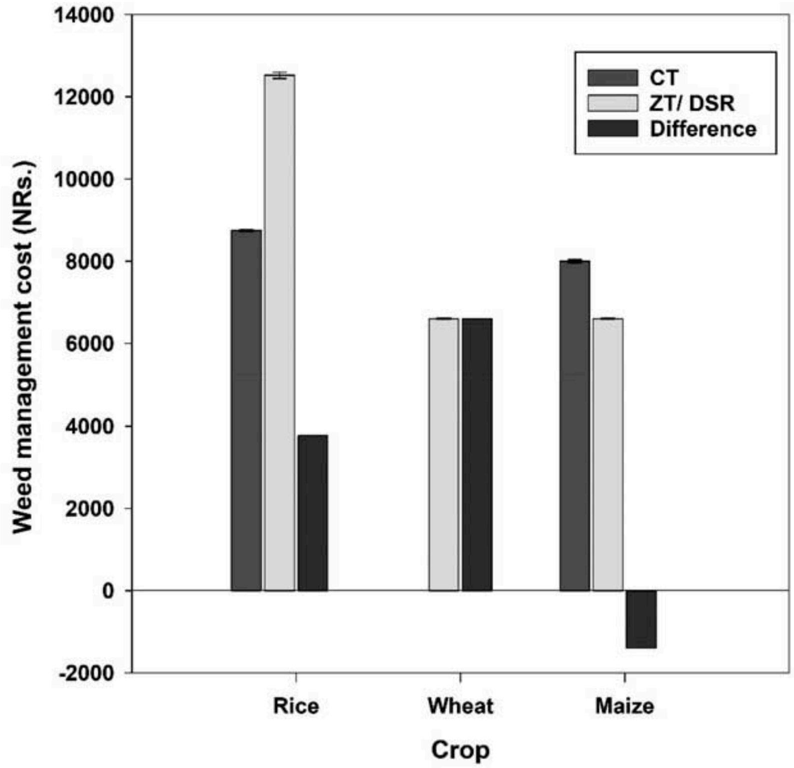

Figure 3. Weed management cost under CT and ZT/DSR practices for rice, maize, and wheat crop in Sunsari district of Nepal in 2015 and 2016. (NRs. 103 = $1 USD).In figure, CT and ZTR values are expressed with mean ± standard error.

conventional sown wheat have a net profit of NRs. 130,040 ha^{-1} with B:C ratio 2.27. It is found that the labor use (person day^{-1} ha^{-1}) have also lower in the conservation-based agricultural practices (Table 3).

Similarly, the partial economics of long-term trials on rice–maize farming system 2015–2016 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. 237,440 ha^{-1} with B:C ratio 3.47. The conventional practice of rice transplanting followed by conventional maize has net profit NRs. 179,510 ha^{-1} with B:C ratio 2.69. It was found that labor use (person day^{-1} ha^{-1}) as 74 for CA-based treatment (UPTPR+ZTM) and 106 for conventional practice.

3.5. Extent of adoption of CA technologies

Survey results and interview with the field technicians of SRFSI at five different nodes indicated that 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. In Bhokraha node, the area under CA practice was about 170 ha with wheat in 100 ha, maize in 60 ha, and sunflower (*Helianthus annuus* L.) in 10 ha whereas in Kaptanjung node 100 ha with Wheat and 60 ha with maize. Similarly, in Mahendranagar, Sallbani, the Kidney Bean (*Phaseolus vulgaris* L.) is dominant with 60 ha under ZT followed by 40 ha with maize and 5 ha with sunflower (*Helianthus annuus* L.).

In Simariya and Bhauwa villages where the Tharu community is dominant and they prefer rice most and then wheat. It occupies 25 ha wheat and 3 ha rice in Simariya and at Bhauwa, 20 ha wheat and 2 ha maize under ZT. In addition to these, some areas, such as Aaurabani, Chittaha, Rasi, Satterjhora, and Amahaiibela occupy about 80 ha under ZT wheat. Although, the area under CA technologies in the district is low several efforts are kicking start to rapid adoption on a wider scale.

3.6. Spread of the CA technologies in Sunsari district

The spread of CA technologies for wheat in Sunsari district has been facilitated through policy supported by DADO Sunsari and addition of farmers' visit to demonstration plots, training programs, dissemination of leaflets, and pamphlets about the advantages of CA technologies. It was reported that there are altogether 250 farmers with 350 ha throughout the district opting ZT technology in different cereal crops (DADO, 2017).

3.7. 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 the district was negligible, its use and the best application of nitrogenous fertilizers were also found the problem to farmers. Weed management was also been found problematic for the initial few years 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 (Homann-KeeTui et al., 2013).

3.8. Steps for up scaling of CA technologies in EIGP of Nepal

Key informant survey and focused group discussion (FGD) with the field technicians and farmers respectively in five different nodes of Sunsari district identified that many steps and activities are needed for wide-scale adoption and up-scaling of CA technologies in the EIGP of Nepal. In general, sensitization of agriculture extension agents on conservation agricultural technologies along with the establishment of demonstration plots in the respective working locations throughout the region will bring the technology on a wider scale for adoption. The further points for increased adoption at farmers level are conducting on-farm research experiments, as well as training and exchange program will aid in the increased extension contacts between the research and farmers.

As government efforts are on through group and or cooperatives approach (MOAD, 2004), so the establishment of custom hiring center to assist a large number of farmers with types of machinery and agricultural equipments will more likely to change the mindsets and perceptions of new farming methods in small-scale farming communities. As the farmers opting CA technologies observe bold size grain yield of wheat, rice, and maize, which also inculcates upscaling in the region. The subsidized inputs (seeds, fertilizers) provided by the government particularly at Sunsari district particularly in wheat crop in the past year seems outstanding results (DADO, 2017). Paying incentives to the adoption of CA technologies for the first few years will more likely to increase the area throughout the region.

4. Conclusion

The study confirms that CA-based practices in rice–wheat and rice–maize farming system, especially in the EIGP of Nepal, can be a viable option for the farmers. Our findings show that it improves the crop productivity (8.11 t ha^{-1} as compared to 8.08 t ha^{-1} in rice–wheat and 13.1 t ha^{-1} as compared to 11.75 t ha^{-1} in conventional rice–maize), reduces the cost of cultivation (NRs. 78,395 ha^{-1} as compared to 102,727 ha^{-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, it revealed that CA-based practice is for better-off farmers who initially benefit from ZT machine and indeed scaled up in the neighbor localities.

The labor used for CA-based treatment in both the rice–wheat and rice–maize farming system was very low as compared to conventional practice since cereal-based farming becomes labor intensive. The cereal-based farming system of Asia has contributed immensely in achieving food sovereignty, but as consequently led to many sustainability issues, such as declining water resources, degrading soil health, and environmental degradation which is further responsible for low land productivity. Hence, the CA-based practices in cereal-based farming systems will surmise with the benefits for the poor and small-scale farmers of the EIGP of Nepal. It may, therefore, help the EIGP rural poor farmers' adaptation to the changing climate (though climate adaptation potential of CA-based practices was not discussed in this paper).

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Competing Interests
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Questionnaire for advantages experienced with CA practices, Sunsari, 2015 and 2016

1. Have you noticed an advantage of early/timely sowing of following crops under ZT?

Wheat		Maize		Rice	
YES	NO	YES	NO	YES	NO

2. Did you observed lower seed consumption in ZT as compared to conventional treatment?

Wheat		Maize		Rice	
YES	NO	YES	NO	YES	NO

3. Did you observed higher germination percentage under ZT crops?

Wheat		Maize		Rice	
YES	NO	YES	NO	YES	NO

4. Have you observed the robust and good crop establishment under ZT? As many people say that there is topping down problem with ZT crops.

Wheat		Maize		Rice	
YES	NO	YES	NO	YES	NO

5. Did you observed lower weed infestation under ZT crops?

Wheat		Maize		Rice	
YES	NO	YES	NO	YES	NO

6. Is there any advantages of ZT of irrigation?

Wheat		Maize		Rice	
YES	NO	YES	NO	YES	NO

If any advantages please mention

7. Did you observed any advantages on irrigation efficiency under ZT treatment (irrigation timing, moisture retention in field)?

Wheat		Maize		Rice	
YES	NO	YES	NO	YES	NO

8. Did you observe advantages of fertilizer efficiency (higher: green and robust plant, lesser: fertilizer wastage, surface run off, leaching, etc.)?

Wheat		Maize		Rice	
YES	NO	YES	NO	YES	NO

9. Have you noticed a lower disease/insect infestation under ZT crops?

Wheat		Maize		Rice	
YES	NO	YES	NO	YES	NO

10. Have you noticed early maturity of the following crops under ZT?

Wheat		Maize		Rice	
YES	NO	YES	NO	YES	NO

If so how many days on an

11. Was there any yield advantages on ZT (increase in yield)?

Wheat		Maize		Rice	
YES	NO	YES	NO	YES	NO