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Research Article

Rice production in Chitwan district of Nepal: An analysis from economic and environmental perspectives

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ABSTRACT

Rice (*Oryza sativa* L.) is the major staple food in the Nepalese context. Chitwan district of Nepal was purposively selected to analyze the rice production from the socio-economic and environmental perspective. A total of 100 rice growing farmers, 50 organic and 50 inorganic were selected as the sample for the purpose of the study using the simple random method of sampling. Primary data were collected through a pre-tested semi-structure interview schedule and key informant interviews; secondary data were collected reviewing related publications. Descriptive statistics, multiple regression and chi-square test were used for data analysis. The multiple regression revealed that the four explanatory variables included in the model: age of the household head, primary occupation of the household head, number of family members involved in agriculture and subsidy in inputs for rice farming were found to have positive and statistically significant effect on rice yield ($P<0.01$). Moreover, chi-square test revealed that the farming practices that contributes to climate change mitigation such as: minimum tillage practice ($P<0.05$), crop diversification ($P<0.01$), green manuring ($P<0.01$), agro forestry practice ($P<0.05$), incorporating crop residues ($P<0.1$), weed management practice ($P<0.01$) and pest management practice ($P<0.01$)were found to be well adopted by the organic rice farmers, in contrast, the farming practices of inorganic rice farmers were statistically and significantly different in this respect. Government should make such policy that could grave the attention of the Nepalese people towards organic agriculture; moreover, encouraging them to make it their primary occupation.

Keywords: Climate change mitigation, organic agriculture, rice, yield

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INTRODUCTION

Rice (*Oryza sativa* L.) is the major staple food crop of Nepal. It ranks the first among cereal crops in terms of area, production, and livelihood of the people (MoALD, 2020). Moreover, it is the foremost staple food for more than 50% of the world's population (Fageria, 2007). Rice is the member of the Poaceae family and out of twenty three species of rice, *Oryza sativa* is the most important commercial species of rice (CDD, 2015). Agriculture and forestry sector

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contributes more than one fourth (28 %) share in the national Gross Domestic Product (GDP) of Nepal; rice has the highest contribution to Agriculture Gross Domestic Product (AGDP). The total area, production and productivity of rice in Nepal has been reported 1,491,744 ha, 5,610,011 mt and 3.76 t/ ha respectively. Rice is grown in three distinct major agro-ecological zones, which are Terai and Inner Terai (60-900 masl), mid hills (900-1,500 masl) and Mountains/high hills (1,500 - 3,050 masl). The total area, production and productivity of rice in Chitwan (inner Terai district) has been reported 26,539 ha, 105,360 mt and 3.97 mt/ha respectively (MoALD, 2020).

It is anticipated that by the year 2025, the world's farmers should produce about 60% more rice than at present to meet the food demands of the projected world population at that time (Fageria, 2007). Lots of attempts and new ideas are emerging to increase the productivity of rice (Uprety, 2006). In this scenario, climate change is exponentially emerging as global burning issue affecting many sectors in the world and is considered to be one of the most serious threats to sustainable development. Rice cultivation is highly dependent on climatic condition and is highly vulnerable to climate change (Malla, 2008). According to IPCC (2005), the annual amount of greenhouse gases (GHGs) emitted by the agriculture sector is 10 to 12% of the global emission through the agriculture accounted for by the IPCC are nitrous oxide (N_2O) and methane (CH_4). DFID (2004), Kassie and Zikhali (2009) reported that the inorganic farming has been criticized for it brought environmental, economic and social concerns.

Considering the high contribution of agriculture to anthropogenic GHG emissions, adoption of environmentally friendly food production practices will be quite helpful in addressing climate change. Organic systems do not apply herbicides, aquatic weeds are likely to present in organic rice paddies and weeds have an additional decreasing effect on methane emissions (Inubushi *et al*., 2001). Organic agriculture is being considered as one of the appropriate sustainable farming system that could serve the twin objectives of climate change mitigation and adaptation. Besides, the yields in organic and conventional rice production do not differ significantly (Rasul & Thapa, 2004).

There has been past studies on impact assessment of climate change on rice production and adaptation strategy (Khanal *et al.*, 2015) and assessment on economics of organic rice production (Adhikari, 2011) in Chitwan district of Nepal. Apart from these, studies on adoption of improved varieties of rice (Timsina *et al*., 2012) and wheat (Subedi *et al*., 2019) have been carried out in Terai districts of Nepal. However, there is still need of an assessment to explore an environment friendly rice farming method, also identifying the factors affecting the rice yield. In this context, this research aims to assess the socio-economic and farm characteristics affecting the rice yield. Moreover, it also aims to examine whether there is any relationship between organic rice farming and adoption of climate change mitigating farming practices.

METHODOLOGY

Selection of the study area

Chitwan district was purposively selected for this study; moreover, the Fulbari area which comes under Bharatpur Metropolitan City was selected. The selection of the study area was done on the basis of consultation with Agriculture Knowledge Centre, Chitwan and review of past works which showed that there is a good practice of organic rice farming.

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Description of the study area

Chitwan, the inner Terai district of Nepal, popularly known as Rapti valley or Chitwan Doon valley covers an area of approximately 2238.39 sq. km. The geographical location of this district is between 27^0 21' 45'' to 27^0 52' 30'' north latitude and 83^0 54' 45'' to 84^0 48' 15'' east longitude, about 139 km southwest of capital Kathmandu. The elevation varies from 144 to 1947 masl. Chitwan valley has a subtropical and tropical climate with hot and moist summers and cool and dry winters. Fulbari area has the tropical climate, and is located at 27.64 N and 84.37E in central part of Chitwan (DDC, 2004). Fulbari was the smallest VDC of Chitwan but after the formation of local government, it was tied to Bharatpur Metropolitian City. At present, Chitwan lies in the Bagmati province of Nepal.

Sampling procedure and data collection

The sampling frame of the organic and inorganic rice growing farmers was prepared from the study area. The simple random method of sampling was used to select the sample from the sampling frame. Altogether, 100 respondents, 50 organic and 50 inorganic rice growing farmers were selected for the purpose of the study. All the respondents selected for the study were the household heads. A pre-tested interview schedule was used to collect the primary information; in addition, two Key Informant Surveys were performed. Also, relevant literatures were reviewed for the secondary information. Altogether, 100 samples were taken for the purpose of the study.

Methods and techniques of data analysis

Data entry and analysis were done using the computer software packages like: Statistical Package for Social Science (SPSS), STATA and Microsoft Excel (MS-Excel). The following analyses were performed using descriptive statistics, multiple regression, chi-square and indexing technique.

Statistical description of the major socio-economic variables and farm-characteristics

The descriptive statistics was used for the statistical description of the variables such as age of the household head, gender of the household head, primary occupation of the household head, number of family members involved in agriculture, Livestock Standard Unit (LSU), membership of the organization, subsidy in inputs, total rice cultivated land and rice yield which are used in the multiple regression model.

Assessment of the factors affecting the rice production

A multiple regression model was used to analyze the factors affecting the rice yield. The rice productivity (yield) was used as dependent variable whereas different socio-economic and demographic characteristics of the respondents were used as explanatory variables. Multiple regression models have been used in several studies to assess the factors affecting the crop yield (Adhikari *et al*., 2018; Subedi *et al*., 2020; Bhattarai *et al*., 2020). The multiple regression model specified in this study is,

Y (rice yield) = f (age of the household head, gender of the household head, primary occupation of the household head, number of family members involved in agriculture, livestock standard unit, membership of any organization, subsidy from the government in inputs, area of rice cultivated land)

Also,

$LnY = \alpha 0 + \beta iXi + ei$

Where;

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LnY = Rice yield (in natural log form)
α0 = Constant
βi = Coefficient
Xi = Explanatory variables
ei = Error term

Table 1. Detail description of the dependent and explanatory variables used in the multiple regression model.

Variables	Description of variables	Value	Expected sign
	Dependent variable		
yield	Rice yield	kg/ha (natural log)	
	Independent/Explanatory variables		
Age	Age of the household head	Years (in number)	+/-
Gen	Gender of the household head	Male=1; 0 otherwise	+/-
prim_occu	Primary occupation of the household head	Agriculture= 1; 0 otherwise	+
fm_ag	Number of family members involved in agriculture	Persons (in number)	+
Lsu	Livestock standard unit	Numeric value	+/-
mem_org	Membership of any organization	If had membership = 1, 0 otherwise (Dummy)	+/-
Subsidy	Subsidy from the government in inputs	Yes=1; 0 otherwise	+
ln_rice_cul_land_ha	Area of rice cultivated land	In hectares (natural log)	+/-

Note: + indicates positive sign; - indicates negative sign

Relationship between rice farming methods and climate change mitigation

A chi-square test was done to examine whether there is relationship between choice of rice farming method (organic or inorganic) and climate change mitigation. For this, review of relevant literatures and past works was done to identify different farming practices that has been either practiced or recommended for climate change mitigation. Some of the farming practices that had been revealed in this regard are: agro forestry, growing cover crops, green manuring, crop diversification, mixed cropping, eco-friendly pest management (use of biocontrol agents, bio-pesticides and botanical pesticides/ using non-chemical method), eco-friendly weed management (manual weeding/using non-chemical method), minimum tillage and incorporating the crop residues in the field (Paudel, 2012; Paudel, 2016; Gupta *et al.*, 2007; Reiner & Aulakh, 2000; Dhakal *et al.*, 2015; Rashid *et al.*, 2009; Kaye & Quemada, 2017; Toppo & Raj, 2018; Regnold *etal.*,1987). Khanal and Kattel (2015) also used to chi-square test to study the adaptation strategies on climate change in rice cultivation in Kaski and Chitwan district of Nepal.

The chi square test of independence begins with the hypothesis of no association, or no relationship, between the two variables. The test for independence of X and Y begins by assuming that there is no relationship between the two variables. The alternative hypothesis states that there is some relationship between the two variables. In this case, the null hypothesis and alternative hypothesis can be written as,

Null hypothesis: H_0: There is no relationship between organic rice farming and adoption of climate change mitigating farming practices.
Alternative hypothesis: H_1: Some relationship between organic rice farming and adoption of climate change mitigating farming practices.
The chi square statistic was calculated following Gujrati (2003).

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$$\chi^2 = \sum_i \frac{(O_i - E_i)^2}{E_i}$$

where, χ^2 = chi-square calculated value
O_i = observed value
E_i = expected value
$\sum$ = summation

The observed numbers of cases, O_i, represents the numbers of respondents that take on each of the various combinations of values for the two variables. The chi square statistic computed from the observed and expected values was calculated. The simple statistical rule applied was: if the chi square statistic exceeds the critical chi square value, reject the null hypothesis and accept the alternative hypothesis that there is a relationship between the two variables. If the chi-square statistic does not exceed the critical value, then do not reject the null hypothesis that there is no relationship between the two variables.

RESULTS

Description of socio-economic and demographic variables

The statistical description of the socio-economic and demographic characteristics of the respondents were done by using descriptive statistics; measures of central tendency such as mean and standard deviation for continuous variables while measures of dispersion such as percentage, frequency for the dummy variables used in the multiple regression model. It is shown in table 2.

Table 2. Scio-economic and demographic characteristics of the respondents (N=100)

Continuous variables	Mean	Standard deviation
Age of the household head (in years)	48.84	10.34
Number of family members involved in agriculture (in number)	3.38	1.11
Livestock standard unit (numeric value)	1.61	2.23
Area of rice cultivated land (in ha)	0.63	0.55
Rice productivity (kg/ha)	5000.6	516.7
Dummy variables	Frequency	Percentage
Membership of organization (Yes=1)	60	60
Gender of the household head (Male = 1)	62	62
Subsidy in inputs (Yes = 1)	69	69
Primary occupation of the household head (Agriculture = 1)	66	66

Source: Field survey, 2020

Determination of the factors affecting the rice yield

The multiple regression model estimated the value of the coefficient of multiple determination, R square (R^2) 0.78, which showed that 78% of the variation in the dependent variable (rice yield) is explained by the explanatory variables included in the model. The F-statistics, F (8, 91) = 39.65, Prob>F = 0.0000 indicated the stability of the overall regression equation and joint significant at 1% level. The mean Variance Inflation Factor (VIF) is 1.45, and none of the variables had VIF greater than 2.41, which indicated that there is no such multicollinearity between the independent variables which could affect the interpretations that the model has revealed.

Furthermore, the four explanatory variables in the regression model: age of the household head, primary occupation of the household head, number of family members involved in agriculture

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and subsidy in inputs for rice farming were found to have positive and statistically significant effect on rice yield. The age of the household head has positive and statistically significant effect to rice yield (P<0.01). With the increase in age of the household head by one year, the rice yield increases by 0.3%. Similarly, the rice yield was found to be 4.7% more for the farm households whose household head's primary occupation is agriculture as compared to their counterparts (P<0.01).

Table 3. Factors affecting the rice yield

Variables	Coefficients	Standard error	T value
Age	.0034***	.0008	4.18 (0.000)
Gen	-.0098	.0114	-0.86 (0.394)
prim_occu	.0473***	.0134	3.51 (0.001)
fm_ag	.0430***	.0072	5.93 (0.000)
Lsu	-.0003	.0025	- 0.15 (0.885)
mem_org	.0087	.0129	0.68(0.499)
Subsidy	.0377***	.0123	3.06 (0.003)
ln_rice_cul_land_ha	-.00009	.0076	- 0.01 (0.990)
Constant	8.142***	.0308	263.81 (0.000)
Summary Statistics			
Number of observation(N)		100	
Rsquare		0.78	
Adjusted R square		0.76	
F value		F(8, 91) = 39.65, Prob> F= 0.0000	
Variance Inflation Factor (VIF)		1.45 (mean VIF)	

Source: Field survey, 2020, *****P<0.01; figure in parentheses indicates P value

Moreover, the number of family members involved in agriculture was found to be positively and significantly related to the rice yield (P<0.01). With the increase in number of family members involved in agriculture by one, the rice yield increases by 4.3%. Furthermore, the rice yield was 3.8% more for the farmers who had got subsidy in inputs from the government for rice production as compared to farmers who hadn't (P<0.01).

Assessment on relationship between rice farming methods and climate change mitigation

A chi-square test was used to analyze whether there is relationship between choice of rice farming method (organic or inorganic) and adoption of climate change mitigating farming practices. The interpretation is shown in table 4.

Out of nine different farming practices contributing to climate change mitigation, the chi-square test showed that the seven farming practices statistically and significantly vary across organic and inorganic rice growers. They are: minimum tillage practice (P<0.05), crop diversification (P<0.01), green manuring (P<0.01), agro forestry practice (P<0.05), incorporating crop residues (P<0.1), weed management practice (P<0.01) and pest management practice (P<0.01) (Table 4).

More than two third- of the organic rice growers (68%) were found to be practicing the minimum tillage, while majority (56%) of the inorganic rice growers weren't having the minimum tillage practices. Similarly, about to two-third of the organic rice growers (66%) were found having the practice of crop diversification, in contrast, majority of the inorganic rice growers (60%) were found not having the crop diversification practices (Table 4).

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Table 4: Relationship between rice farming method and adoption of climate change mitigating farming practices

Farming practices		Organic rice farmers (n=60)	Inorganic rice farmer (n=60)	Total (N=120)	Chi-Square
Practice of minimum tillage	Yes	34 (68)	22 (44)	56 (56)	5.84**
	No	16 (32)	28 (56)	44 (44)	
	Total	50 (100)	50 (100)	100 (100)	
Practice of planting cover crops	Yes	35 (70)	32 (64)	67 (67)	0.41
	No	15 (30)	18 (36)	33 (33)	
	Total	50 (100)	50 (100)	100 (100)	
Crop diversification practice	Yes	33 (66)	20 (40)	53 (53)	6.8***
	No	17 (34)	30 (60)	47 (47)	
	Total	50 (100)	50 (100)	100 (100)	
Green manuring practice	Yes	32 (64)	18 (36)	50 (50)	7.8***
	No	18 (36)	32 (64)	50 (50)	
	Total	50 (100)	50 (100)	100 (100)	
Practice of agro-forestry	Yes	35 (70)	26 (52)	51 (51)	3.41**
	No	15 (30)	34 (68)	49 (49)	
	Total	50 (100)	50 (100)	100 (100)	
Mixed cropping practice	Yes	27 (54)	23 (46)	50 (50)	0.64
	No	23 (46)	27 (54)	50 (50)	
	Total	50 (100)	50 (100)	100 (100)	
Practice of incorporating crop residues	Yes	31 (62)	22 (44)	53 (53)	3.25*
	No	19 (38)	28 (56)	47 (47)	
	Total	50 (100)	50 (100)	100 (100)	
Weed management Practice	Only hand weeding	50 (100)	15 (30)	65 (65)	53.8***
	Chemical herbicide and hand weeding	0	35 (70)	35 (35)	
	Total	50 (100)	50 (100)	100 (100)	
Pest management Practice	Using botanical pesticide	20 (40)	9 (18)	29 (29)	64.3***
	Using chemical pesticide	0	38 (76)	38 (38)	
	Naturally	30 (60)	3 (6)	33 (33)	
	Total	50 (100)	50 (100)	100 (100)	

***P<0.01;**P<0.05; *P<0.1; figure in the parentheses indicate percent

Source: Field survey, 2019

The majority of the organic farmers (64%) were found having the practice of green manuring, in contrast, majority of the inorganic farmers (64%) were found not having the green manuring practices. Similarly, more than two-third of the organic farmers (70%) were found having the practice of agro forestry, in contrast, more than two-third of the inorganic farmers (68%) were found not having the agro-forestry practices. In addition, majority of the organic farmers (62%) were found having the practice of incorporating crop-residues, while majority of the inorganic farmers (56%) were found not having the practice of incorporating crop residues (Table 4).

Furthermore, all the organic farmers (100%) were found practicing only hand weeding (manual weeding) for weed management in their rice field, while more than two-third of the inorganic farmers (70%) were found using chemical herbicide along with hand weeding. Similarly, the majority of the organic farmers (60%) were found having pest management in their rice fields naturally, while rest (40%) were found using the botanical pesticide. This showed that all the organic farmers (100%) are doing soil and environment friendly practices for pest management

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in their rice field. In contrast to this, more than three-fourth of the inorganic farmers (76%) were found using chemical pesticides for pest management in their rice field (Table 4).

DISCUSSION

Factors affecting the rice yield

Findings of this study regarding positive effect of age of the household head on rice production is similar with the findings of Subedi *et al*. (2020); with the increase in age, the farming experience increases, which might contribute to higher yield through better use of input resources and technology. Also, the study revealed that the farm households having their major occupation agriculture have higher yield as compared to their counterparts. If major occupation is agriculture, the farm household might be more receptive towards adoption of improved varieties and technology which ultimately results higher yield. Subedi and Dhakal (2015) also reported that the probability of adoption of improved agricultural technologies is significantly more for the farm households whose major occupation is agriculture as compared to those whose major occupation is otherwise. Also, Mottaleb (2018) reported that the farm households having agriculture as their major occupation are dependent on agriculture for their livelihoods, thus are more eager to adopt improved agricultural technologies agricultural machinery than others.

With the higher number of agricultural labor in the farm household, it encourages and motivates for the adoption of improved agricultural technologies. In addition, it becomes easy to perform the agricultural activities such as transplanting, applying fertilizers, weeding, harvesting and other intercultural operations. All these contribute to increase the crop yield. Subedi *et al*. (2019) revealed that the number of family members involved in agriculture have significant and positive effect on adoption of improved varieties. In addition, Mignouna *et al*. (2011) reported that the larger household agricultural labor have the capacity to relax the labor constraints required during introduction of new technology. The subsidy supports the cost of variable inputs such as seeds and fertilizers which enhances the farmers for using them in the required quantity which ultimately results higher yield. Moreover, subsidy also supports in the adoption of improved varieties and other agricultural technologies. Mason and Smale (2013) also reported that the government subsidy can allow farmers to experiment with the technology. Moreover, Subedi *et al*. (2019) also reported that the subsidy has statistically significant and positive effect on the adoption of improved wheat varieties.

Rice farming and climate change mitigation

The different environment friendly agricultural practices such as: use of non-chemical organic fertilizers, non-chemical method of pest and weed control, green manuring, agro forestry, crop diversification, incorporation of residues plays an important role in carbon sequestration which can reduce greenhouse gases. Carbon sequestration from plant biomass is a key sequestration pathway in agriculture; offering a mitigation strategy for agriculture greenhouse gas emissions. The finding of this study regarding minimum tillage is synonymous to Teasdale *et al*. (2007) who revealed that in minimum or reduced tillage organic system; soil carbon concentrations were higher at all depths to 30 cm which plays an important role to mitigate climate change which is found lacking in the conventional complete tillage systems. Also, Uprety *et al.* (2012) mentioned that reduced tillage is one of the climate change mitigation measures to mitigate the methane emission in rice management.

Besides, it has been revealed that under the permanent organic cropping systems, higher organic carbon accumulation was obtained from the incorporation of plant residues, agro forestry practices and addition of organic manures; moreover, crop diversification with the inclusion of legume-based pastures in crop rotation (Drinkwater *et al.*, 1998; Goh, 2001). Uprety *et al.* (2012) also reported the diversified crop rotation with green manure in organic farming as a technology to mitigate climate change; also, he mentioned that green manure improves soil structure and diminishes emissions of N_2O. Apart from this, it has been reported that agro forestry has a particular role to play in mitigation of atmospheric accumulation of green house gasses (IPCC, 2000). Moreover, Lakhran *et al*. (2017) reported that crop diversification can improve resilience in a variety of ways: by engendering a greater ability to suppress pest outbreaks and dampen pathogen transmission, which may worsen under future climate scenarios, as well as by buffering crop production from the effects of greater climate variability and extreme events.

The study revealed that the organic farmers are practicing the ecologically sound weed and pest management practices; in contrast, the inorganic farmers are using the chemicals which have adverse effect on soil ecosystem. Azez (2009) also reported that the chemical herbicides have adverse effect on soil microbes, soil ecosystem and soil carbon levels; this ultimately contributes to climate change. He further reported that each 1% increase in average soil organic carbon levels could in principle reduce atmospheric CO_2 by up to 2%. Moreover, it has been reported that the pesticides in soil become toxic to earthworms, many species of insects, mammals and birds which are important actors of natural ecosystem and to beneficial soil microbes which maintains soil fertility, enhancing soil carbon levels (Pimental *et al*., 1992).

CONCLUSION

Rice production, applying the organic farming practices would be an environment friendly agricultural production that has significantly positive relation to climate change mitigation. The old aged farmers were found to have higher rice yield; the knowledge gained through the farming experience must have worked over there. Also, getting subsidy in inputs and agriculture being the major occupation of the farm household had significant contribution towards rice yield. Moreover, increased human labor for agricultural production within a farm household results higher crop yield. Government should prioritize on giving subsidies on organic farming; also, the policy should be made such that it could attract the people to invest their money and effort in agriculture with the active participation of their family members.

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Authors' Contributions

B.K. Sapkota designed the research plan. B.K. Sapkota collected the survey data with the help of the enumerators. B.K. Sapkota analyzed the data and prepared the manuscript. A.P. Subedi, K. M. Tripathi, S.C. Dhakal and J. Shrestha provided comments and feedback and revise to finalize this manuscript. Final form of manuscript was approved by all authors.

Conflict of Interest

The authors declare that there is no conflict of interest with present publication.

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