

Research Article

Resource use efficiency of maize production with and without irrigation system in Kaski, Nepal

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ABSTRACT

The study examined the resource use efficiency of maize production in rainfed and irrigated conditions in Kaski, Nepal. It focused specially on the production function of maize, resource use efficiency and socioeconomic characteristics of the farmers. A well-structured interview schedule was used in this study. Out of the 368 households interviewed, 165 farmers cultivated maize and a total of 157 farmers (59 from irrigated and 98 from rainfed) provided useful data. The data analysis was done by using Stata and SPSS. Cobb-Douglas production function was used to determine the resource use efficiency of maize production. Compared to rainfed system, maize productivity in irrigated system was higher despite the use of fewer input implying irrigation. Increase in seed use by 10% increased the yield by 1.9% in case of rainfed system and 0.05% in case of the irrigated system. The major implication for the study is that farmers should make proper utilization of their resources to achieve higher level of resource use efficiency.

Keywords: Efficiency, irrigated, maize, resource

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INTRODUCTION

Agriculture is the source of livelihood for 60.4% of the total population of Nepal and it contributes 26.5% of the national GDP (AITC, 2020). 85% of the total cultivated 2.6 million hectares of Nepal has potential for irrigated agriculture and only 20% of this 2.2 million hectares of land area that could be irrigated is irrigated and there lies the potential of increasing the agricultural production through more effective irrigation (Regmi, 2008). Farmers Managed Irrigation System (FMIS) is the indigenous irrigation system on which the Nepalese agricultural economy was always based (Gautam, 2012). Although 70% of irrigated land areas in Nepal fall in the category of the farmer-managed irrigation system (Pradhan, 2012), the produce of FMIS contributes only 40% of the country's food requirement (Gautam, 2012). The

government of Nepal has tried to address the issues of increasing the performance and potential of irrigation sector through the National Water Resources Strategy (Pradhan, 2012). The FMIS have been changing according to time and have sustained themselves contributing significantly to the rural livelihood of Nepal (Sijapati & Paudel, 2010). Agriculture can significantly improve the economic condition of a country but to do so it is a must to improve the efficiency of water resource use. Nepalese farmers understood the importance of water resources for a long time and that's why they have developed irrigation systems at their own for increasing their agricultural production (Pradhan, 2000).

Agriculture Perspective Plan (APP) of Nepal defined irrigation as a strategic input (Dahal, 2015). Irrigation has been the subject of study for a long time but systematic attempts on the effect of irrigation project on agricultural productivity are rare (Dahal, 2015). Irrigation water has increased food security and improved living standard, in overall irrigation has been of prime importance in feeding the citizens of developing nations (Schoengold & Zilberman, 2014). Irrigated agriculture is of prime importance in Nepal to ensure food security and poverty reduction. Irrigation helps households to reduce incidence and severity of poverty, enhance food security and self-sufficiency, furthermore increase in cereal production can be attributed to the expansion in irrigated area (Hussain & Hanjra, 2003). Irrigated land and the output from the irrigated land must be increased to the extent possible to meet the increasing food demand in the upcoming years (Sampath, 1992). Increased intensity of farming has caused the decrease in marginal returns to increased input use leading to reduced investment in irrigation infrastructure (Rosegrant & Svendsen, 1993). This decline in investment calls for better water resource management to maintain its sustainability.

Paddy, maize, wheat and millet are the major cereal crops of Nepal (B. M. Dahal, 2010). Maize sector alone contributes about 7% to agricultural GDP (Gross Domestic Product) whereas the whole cereal sector contributes 49% to agricultural GDP (MOF, 2015). There is a huge gap between maize demand and maize production in our country which asks for the more efficient production of maize (KC et al., 2015). The better technical support, supply of quality inputs and better irrigation facility are the key for encouraging farmers in maize seed production and enhancing their production and profitability (Shrestha & Shrestha, 2018). If the resources are utilized such that there is minimum cost of production then the resources are said to be efficiently utilized (Dhakal et al., 2015). Efficiency analysis of small holder farmers are not abundant in Nepal and the findings of the previous studies are also not consistent with one another. The reasons for these differences in findings may be due to the differences in location and methodological approaches used (Gebregziabher et al., 2012). Any knowledge or technology that can contribute to increase the maize productivity using the given resources can bring gain in real income for the vast majority of Nepalese farmers. Maize is the second most important crop of Nepal after paddy with an area of 956447 ha. and production of 2713635 M.T. (AITC, 2020).

The aim of this research is to understand the extent to which the socioeconomic and input factors affect the farmers' ability for maize production in two different contexts of irrigated and rainfed conditions.

MATERIALS AND METHODS

Study area

Shardikhola Puranchaur Irrigation System (SPIS) of Kaski district was selected as the study area as it is a successfully operating farmers managed irrigation system for more than twenty years. The users of this irrigation system are satisfied with this irrigation system and are motivated for the proper management of this irrigation system (key informant interview with Irrigation Division Office, Kaski). The district is one of the districts of Gandaki province in western Nepal. It mostly has a subtropical climate with an altitude ranging from 300 to 6400 meters above sea level. Located at the mid-hills of Nepal, the district is situated geographically at 28° 19' north latitude and 84° 00' east longitude.

Sampling design

There were 342 farmers as the users of the SPIS. The sample size of 184 was determined using the Slovin's formula at 5 % margin of error and the samples were selected using simple random sampling technique. The sampled households were representative of the irrigation system (about 54% representative). As the sample is 54% representative of the study area, the study of resource efficiency of production reflects the situation of the whole irrigation system. For the purpose of comparison of with and without irrigation system, similar number (184) of farmers without access to irrigation system were selected randomly from the surrounding area of the irrigation system using the simple random sampling technique. Among them 62 farmers with irrigation facility were engaged in maize cultivation whereas only 103 farmers without irrigation facility were involved in maize cultivation, therefore the total sample size of our study is 165 composed of 62 irrigated farmers and 103 rainfed farmers. Among those farmers only 59 farmers of irrigated system and 98 farmers of rainfed system had data regarding yield and inputs use, thus only these farmers were used during resource use efficiency analysis.

Data collection

After pretesting of the interview schedule among the 25 farmers of the Machhapuchhre Rural Municipality of the Kaski district, required amendments and corrections were made in the interview schedule before using them with the actual respondents for collecting primary data. For triangulation of data collected with the face to face interview, Focus Group Discussion (FGD) and Key Informant Interview (KII) was done. Secondary data was collected from the publications of various governmental and non-governmental organizations.

Analytical methods

Stata and SPSS software were used for data analysis, after the data was entered using the SPSS software. For better results, data quality was improved by working on missing and cleaning data. Comparison of mean, descriptive statistics and regression analysis were used to reach to the desired result.

Cobb Douglas production function was used for the estimation of resource use efficiency, as given below:

$$Y = aX_1^{b_1}X_2^{b_2}X_3^{b_3}X_4^{b_4}U_i$$

Where, Y is the yield of maize (kg/ha), X₁, X₂, X₃, X₄ represent the quantities labor (man days/ha), bullock (oxen days/ha), fertilizer (kg/ha) and seed (kg/ha) respectively.

The estimated regression coefficients were used to calculate the marginal value product (MVP) and the resources use efficiency (r) using the equation given below (Suresh & Reddy, 2006) :

$$r = \frac{MVP}{MFC}$$

Where, $MVP_i = \beta_i \frac{Y_g}{X_{gi}} P_i$

Here, MVP_i = Marginal Value Product of the i^{th} input,

Y_g = Geometric mean of the value of output,

X_{gi} = Geometric mean of the i^{th} input,

B_i = Estimated coefficient,

P_i = Price of output.

RESULTS AND DISCUSSION

Socioeconomic and demographic characters of the respondents

The socioeconomic variables as age and years of schooling of household head (HHH) and total income of the household (HH) were statistically significant at 1% level of significance (Table 1) whereas other variables as household size, economically active members in the family, total landholding and area under maize cultivation were not found to be statistically significant. Years of schooling and age of the HHH and income of the farm family were higher for irrigated farmers in comparison to rainfed farmers. Maturity with higher age and higher education might have motivated the farmers for the adoption of irrigation system or in the process of development of irrigation system in their locality and presence of irrigation system might have led to their higher income also.

Table 1: Description of socioeconomic and demographic characteristic (continuous variable) of maize producing farmers

Variables	Overall	Production system		Mean difference	P value
		Irrigated	Rainfed		
Age of HHH	53.92	60.27	47.56	12.71***	0.000
Years of schooling of HHH	6.41	7.53	5.28	2.25***	0.001
Household size	5.61	5.52	5.70	-0.19	0.649
Economically Active members	3.70	3.55	3.84	-0.29	0.343
Total landholding (ha)	0.44	0.43	0.45	-0.01	0.814
Maize plant area (ha)	0.135	0.13	0.14	0.01	0.810
Total income (NRs./ha)	371626	498718	244533	254185***	0.000

Note: *** indicate significance at 1% level of significance

Source: Household survey

Irrigated and rainfed HHs were significantly different at 1% level of significance on the basis of sex of the HHH, access to cooperatives and receiving of agriculture related trainings whereas on the basis of taking loans they were significantly different at 5% level of significance and on the basis of family type they were significantly different at 10% level of significance (Table 2). Majority of the family were nuclear family with male as the household head. Majority of the family in the study area had access to cooperatives and they took loans. Majority of the farmers in the study area hadn't received any agriculture related trainings whereas very few farmers with irrigation system had received agriculture related trainings whereas none of the rainfed farmers had received any agriculture related trainings.

Table 2: Description of socioeconomic, demographic and institutional characteristics (categorical variables) with maize production

Variables	Overall	Production system		Chi square value	P value
		Irrigated	Rainfed		
Sex of HHH					
Male	101	53 (85.48)	48 (46.60)	26.64***	0.000
Female	64	9 (14.52)	55 (53.40)		
Family type					
Nuclear	99	32 (51.61)	67 (65.05)	2.911*	0.088
Joint	66	30 (48.39)	36 (34.95)		
Access to cooperatives					
Yes	128	60 (96.77)	68 (66.02)	21.04***	0.000
No	37	2 (3.23)	35 (33.98)		
Take loans					
Yes	91	42 (70)	49 (47.57)	6.34**	0.012
No	74	20 (30)	54 (52.43)		
Agricultural Training received					
Yes	20	20 (30)	0 (0)	37.81***	0.000
No	145	42 (70)	103 (100)		
Abroad migration					
Yes	38	17 (27.42)	21 (20.39)	1.08	0.299
No	127	45 (72.58)	82 (79.61)		

Note: ***, ** and * indicate significance at 1%, 5% and 10% level of significance

Source: Household survey

Inputs use and yield of maize production systems

The rainfed and irrigated farmers were found to be different statistically at 1% level of significance on the basis of bullock labor used, rainfed farmers used more bullock labor than irrigated farmers (Table 3). Whereas the seeds used and labor used were found to be different statistically at 5% and 1% level of significance respectively. Human labor, bullock labor and fertilizer use were higher per hectare in case of rainfed farmers whereas the use of seed was higher in the case of irrigated farmers. Yield per hectare of maize was higher in case of irrigated farmers than rainfed farmers. This implies that the irrigation water is the most strategic input as simply the use of higher amount of seed is attributing towards the higher yield of maize.

Table 3: Various inputs used and yield in maize production per hectare

Variables (/ha)	Overall	Production system		Mean difference	P value
		Irrigated	Rainfed		
Labor (man-days)	153.75	142.54	164.95	-22.42*	0.081
Bullock (Oxen days)	15.21	12.16	18.25	-6.09***	0.000
Fertilizer (kg)	13660.5	12733	14588	-1854.48	0.544
Seed (kg)	50.58	56.70	44.46	12.25**	0.044
Yield (kg)	1970.15	2156.57	1783.72	372.85	0.134

Note: ***, ** and * indicate significance at 1%, 5% and 10% level of significance

Source: Household survey

Estimation of coefficients of inputs in maize production system

Estimated coefficients of the inputs used is presented in the Table 4. Only seed in case of rainfed system and bullock labor in case of irrigated system were found to be significant. Increase in seed use by 10% increased the yield by 1.9% in case of rainfed system and 0.05% in case of the irrigated system whereas the impact of seed was significant and impact of fertilizer was insignificant and similar results were revealed by Kuwornu et al. (2013), Akram

et al. (2008) and Ahmed et al., (2006). Increase of bullock labor by 1% would increase the maize production by 0.325%. Here the sum of coefficients of inputs in both cases is smaller than 1 representing the decreasing returns to scale. In rainfed system, 10 % increase in labor contributed in 1% increase in production and 1.5% increase in irrigated system and similar results were found in similar research to maize production in Eastern Ghana (Kuwornu et al., 2013). Bullock labor which is generally for the purpose of tillage was found to be positively correlated with yield, in case of rainfed system for 10% increase in bullock labor yield would increase by 2.64% and in case of irrigated condition for 10% increase in bullock labor yield would increase by 3.25% and in case of irrigated system it was found to be significant. The results regarding the use of bullocks were contradicting with the findings of similar research on maize production by (Katel et al., 2020).

Table 4: Estimated values of the coefficient of the inputs

Variables	Rainfed system			Irrigated system		
	Coefficient	Std. Error	P-value	Coefficient	Std. Error	P-value
Constant	5.861***	0.974	0.000	5.025***	1.063	0.000
Labour	0.100	0.167	0.548	0.154	0.184	0.401
Bullock	0.264	0.228	0.246	0.325**	0.149	0.030
Fertilizer	0.007	0.084	0.930	0.103	0.095	0.274
Seed	0.191*	0.088	0.029	0.053	0.137	0.700
Number of observations	98			59		
Prob > chi ²	0.0751			0.0425		
Log -likelihood	-92.028			-30.848		

Note: ***, ** and * indicate significance at 1%, 5% and 10% level of significance

Resource use efficiency of maize production systems

The resource use efficiency scenario of maize production is presented in the Table 5. Except seed all other resources are overutilized in case of rainfed system and it is the only factor that is significant in rainfed maize production system. In case of irrigated system labor and fertilizer are overutilized whereas bullock and seed are underutilized but only bullock was significant. As most of the inputs like fertilizer and human labor are overutilized, increase in seed rate or cost of seed in proper amount can increase the productivity of maize due to increase in plant population which would utilize the available resources. The result is in line with the similar studies conducted for the resource use efficiency of maize production (Dahal & Rijal, 2019; Ghimire & Dhakal, 2014). In case of irrigated systems, cost on bullock labor should be increased as bullock labor are utilized for tillage purpose, increased bullock labor means increase tillage of the maize field. Different studies have shown the positive impact of tillage to yield attributing to better soil aeration and organic nitrogen mineralization (Dinnes et al., 2002). Similarly, in case of rainfed system the cost on bullock labor should be reduced which is in line with the similar research conducted in Palpa district of Nepal (Sapkota et al., 2018). Similarly, human labor and fertilizer are overutilized as the human labor is expensive labor and it can't contribute marginal value productivity in comparison to its marginal factor cost, thus the human labor should be reduced or utilized properly or replaced by machinery. The over utilization of labor in both the cases is that the labor is mostly the labor of family members who spend more time on maize field as there are lack of other income generating opportunities (Kuwornu et al., 2013). In both the cases human labor or cost on the human labor must be reduced for optimum resource use efficiency (Danso-abbeam et al., 2015). Decreasing the

cost of human labor is supported by similar researches conducted to determine the resource use efficiency of maize production (Dhakal et al., 2015). Similarly the fertilizer mostly used is farm yard which is not properly prepared (Shrestha, 2009), thus the use of fertilizer or the cost on the fertilizer should be reduced Ojo et al. (2008), Dahal and Rijal, (2019).

Table 5: Resource use efficiency of with and without IS maize at current price

Variables	Without irrigation system					With irrigation system				
	Coeff.	MVP	MFC	r	Decision rule	Coeff.	MVP	MFC	r	Decision rule
Labor	0.10	28.66	500	0.06	Overutilized	0.15	66.97	500	0.13	Overutilized
Bullock	0.26	580.35	1000	0.58	Overutilized	0.33**	1741.43	1000	1.74	Underutilized
Fertilizer	0.01	0.04	2.86	0.01	Overutilized	0.10	0.54	2.86	0.19	Overutilized
Seed	0.19*	236.76	50	4.74	Underutilized	0.05	60.80	50	1.22	Underutilized

CONCLUSION

This paper analyzed the performance of maize production systems in irrigated and rainfed conditions using resource use efficiency. Maize productivity in irrigated system was higher despite the use of fewer input implying irrigation as the most strategic input. Allocative inefficiencies were seen in both the maize production system. Both of the systems were suffering from decreasing returns to scale. All inputs except seed were overutilized in rainfed system and in irrigated system labor and fertilizer were overutilized whereas bullock and seed were underutilized. But only seed in case of rainfed system and bullock in case of irrigated system were significant. Thus, farmers should increase the use of seed in rainfed system and bullock labor in case of irrigated system. The findings presented in this study vividly illustrated that inefficiency existed in maize production in both irrigated and rainfed systems in Kaski district of Nepal and with proper efficient utilization of inputs, yield could be increased and cost could be reduced significantly. This study covered only a small region, other researchers should consider other crops also and endeavor to address the whole nation.

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Authors' contributions

K. Khanal conducted research and wrote the paper. K.B. Adhikari, S.C. Dhakal and S. Marahatta revised and finalized the paper.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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