Resource use efficiency and profitability of rice production in the Terai Belt of Nepal

ABSTRACT

Rice is the major cereal crop in terms of area under cultivation and known as primary staple food with significant contribution to gross domestic product in Nepal. The high production cost and inefficient use of available resources are major problems observed in rice production. The study was carried out in three major rice producing districts of Terai belt of Nepal to analyze the level of resources used and profitability in rice production. A total of 100 samples from each district were taken using simple random sampling technique. The benefit cost ratio was used to determine the profitability while the Cobb-Douglas production function was used to determine the resource use efficiency analysis. The study revealed that the average land holding size under the rice production was more than the national average and the average productivity (4.86mt/ha) of rice production in the districts were also higher than the national average (3.47mt/ha). The BC ratio of rice (1.67) production was found more than which implies the profitable nature of rice production in Nepal. The per hectare total cost incurred in rice production from land preparation to marketing was found NPR. 96, 905 (±24044)/ha and the profit after deducting cost incurred for rice production was NPR. 58, 559. The costs on seed and irrigation were found overused, however the costs incurred in organic manures, harvesting and post-harvest operations were found underused. The cost on seed and irrigation need t0 be decreased by 129 and 218% whereas the cost on organic manures, harvesting and post-harvest operations need to be increased by 97, 74 and 76%, respectively for optimal allocation of resources used in rice production. The return from rice production is low as compared to other major economic crops in Nepal, thus this study helps the policy makers, producers and other stakeholders for better planning and policy formulation for massive promotion of rice cultivation as it has high contribution to food and nutrition security of Nepali people.

Keywords:*BC ratio, profitability, resource, resource use efficiency rice*

1. INTRODUCTION

Rice crop (*Oryza sativa* L.), member of Poaceae family, is the staple food for the majority of the population in world. In Nepal, it is also one of the major staple food crop and found cultivated in 1,477,378 hectare (ha) with production of 5,130,625 metric tons (mt) and productivity of 3.47 mt/ha (MoALD, 2023). The joint contribution of agriculture and forestry sector is 24.12% to the national Gross Domestic Product (GDP) and rice alone has around 13.60% contribution to Agriculture GDP (MoALD, 2023). Topographically, Nepal is divided into three belts and one of this Terai belt is known as ‘granary of Nepal’ because of ample rice production (around two-third) and three districts representing East, Central and West Nepal were selected for this study. The Jhapa district representing East Nepalhas been designated as the first 'ricesuperzone' under the Government of

Nepals' Prime Minister Agriculture Modernization Project (PMAMP), which requires 1,000 ha of land for such a designation (Adhikari and Thapa, 2023; MoAD, 2016). The area, production, and productivity of rice in Jhapa district are reported to be 85,879 ha, 365,845 mt, and 4.26 mt/ha respectively (MoALD, 2020). Chitwan and Bardiya, also located in the Terai region, are prioritized under the PMAMP project for rice production and commercialization due to their high potential.

Despite its importance, the cost incurred in rice production from land preparation stage to marketing is high because of scattered land and lack of use of farm machinery and equipment and use of low yielding varieties Lack of quality seed at the time of sowing and timely unavailability of chemical fertilizers are the major cause of low yield of rice. In general, Nepali farmers are poor and level of education is also less and lack of knowledge in optimal use of the available resources for minimization of cost and maximization of profit(Parajuli & Thapa, 2024) are the barriers of rice promotion. The incapacity of Nepali farmers for efficient and rational use of available resources led to wastage of time, money, and effort, reducing both output and profitability, which can weaken the economic status of agricultural households and the broader economy.

Previous studies, such as those by Sapkota et al. (2018), who estimated the resource use efficiency (RUE) of maize seed production in Palpa district, and Dhakal et al. (2020), who estimated the RUE of rice production in Chitwan district, have provided insights into the efficiency of agricultural practices. However, comparative studies on the costs, input use, and overall RUE of rice production across different districts representing Eastern, Central, and Western Nepal have not been conducted, leaving a significant research gap. Addressing this gap is crucial for understanding the diverse practices and challenges in rice production across these regions. This study uses the Cobb-Douglas production function model which is the widely used model. However, the other production functions have not been considered which can be considered as limitations of this study.

Rice which is the primary staple food crop in Nepal having significant contribution on food and nutritional security of Nepali people urge the need of analyzing the cost, return, profitability and efficiency of resources used (Poudel et al., 2024; Thapa & Dhakal, 2024b) for maximization of profit from rice production, therefore, this paper provide the assessment of profitability and resource use efficiency of rice production across three major rice-producing districts in Nepal, providing insights into optimizing resource use for enhanced productivity and profitability.

2. METHODOLOGY

2.1 STUDY AREA

Topographically, Nepal is divided into three belts namely Terai in the South, Hill in the mid and Mountain in the North. Since the Terai belt accounts for more than two-third of rice production, it is known as 'granary of Nepal'. The Terai belt is spread from East to West of Nepal and the three districts within the Terai belt Jhapa in the East, Chitwan in the Mid and Bardiya in the Westwere purposively selected for the study as they havea high rice production in the Eastern, Central and Western region of Nepal (Thapa & Dhakal, 2024a) and the rice growing clusters were selected in consultation with federal and provincial level agricultural offices and local bodies. The Government of Nepal has also prioritized rice promotion in these districts through Prime Minister Agricultural Modernization Project (PMAMP).

2.2 SAMPLE SIZE

The rice producing farmers were identified with the help of federal and provincial level agricultural offices and also in consultation with local level bodies which helped in determination of sampling frame of rice growers in the study area. This identification was done separately in each three districts. The simple random sampling techniques was used for the selection of household for primary data collection. A pre-tested semi structured interview schedule was administered to the respondents for the collection of primary data. The 100 rice producing households from selected clusters were selected in each district which comprise to the total of 300 sample size for this study. The two Key Informant Interviews (KII) in each district and two FGDs per districts were conducted for triangulation of primary data. The secondary sources of information from several government and non-governmental offices, journal articles, books and bulletins were collected.

2.3 DATA ANALYSIS

The data were coded and entered in Statistical Package for Social Sciences (SPSS) and necessary inferences were derived using SPSS, Stata and Microsoft excel based on the suitability of the data.

2.4 COST AND RETURN ANALYSIS

The total cost associated with rice production were calculated by summing the cost incurred in seed, chemical fertilizer, organic manures, human labor, plowing, harvesting, irrigation, pesticides, All the cost associated with rice production from initial land preparation stage to marketing of rice produced were calculated to determine the total variable cost of rice production in hectare. Similarly, for the calculation of per hectare gross return from the rice production, the return from major and by-products of rice were calculated. The return from major rice products was calculated by multiplying the total volume of rice produced and the average price at the harvesting period (Dilon & Hardaker, 1993). The by-products of rice namely straw also has economic value and was calculated by multiplying the total volume of straw produced by average price. The summation of these both returns is gross return from rice production.

The per hectare gross margin from the rice production was calculated by deducting the total variable cost from the gross return from rice production (Olukosi et al., 2006).

Gross margin = Gross return – total variable cost

The undiscounted benefit cost ratio was estimated using the formula applied by Dhakal et al. (2015) and Subedi et al. (2019) as:

Benefit cost ratio (BCR) = Gross return / Total variable cost

2.5 COBB-DOUGLAS PRODUCTION FUNCTION

In order to determine the level of resources/inputs used in rice production, the Cobb-Douglas production function model was used. The dependent variable was gross income from rice production and explanatory variables in this model were the cost associated to produce gross income from rice production. The natural logarithm of both the dependent and explanatory variables eased in computation and the regression coefficient obtained is the elasticity of respective resources used in rice production and measure of Marginal Value Product (MVP) helped to determine the over and under use of the respective resources (Gujarati, 2009).

$Y = aX_1^{b_1} X_2^{b_2} X_3^{b_3} X_4^{b_4} X_5^{b_5} X_6^{b_6} X_7^{b_7} X_8^{b_8} e^u$

The above equation is transformed to linear form as:

$\ln Y = \ln a + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + b_5 \ln X_5 + b_6 \ln X_6 + b_7 \ln X_7 + b_8 \ln X_8 + u$

Where,

Y = Gross return from rice production (NPR/ ha)

X_1 = Seed cost (NPR/ ha), X_2 = tillage cost (NPR/ ha), X_3 = Human labor cost (NPR/ ha), X_4 = organic manure (NPR/ ha), X_5 = micronutrient cost (NPR/ ha), X_6 = harvesting cost (NPR/ ha), X_7 = post-harvest cost (NPR/ ha), X_8 = irrigation cost (NPR/ ha), and u = error term, a = Intercept, e = Base of natural logarithm, ln = Natural logarithm, b_1, b_2, b_3… b_8 = Coefficients of respective variables.

The method for the estimation of return to scale was adopted from Dhakal et al. (2015). The summation of regression coefficients of respective input variables provides the value of return to scale of rice production.

The efficiency of respective resources was estimated as:

r = MVP/MFC (Goni et al., 2007)

Where, r = Efficiency ratio, MVP= Marginal value product; MFC= Marginal factor cost

Furthermore, MVP= dy/dx, which is the product of regression coefficient with ratio of geometric mean of gross return to the level of use of respective resource. Again, following Mijindadi(1980), the relative percentage change in MVP of each resource required to obtain optimal resource allocation, i.e. r =1 or r= MVP was estimated using the equation below;

$D = (1 - MFC/MVP) \times 100$ Or, $D = (1 - 1/r) \times 100$

Where, D = absolute value of percentage change in MVP of each resource, r = efficiency ratio

Decision rule:

RTS<1: Decreasing return to scale and this implies percentage change in output is less than percentage change in input,

RTS = 1: Constant return to scale and this implies percentage change in output is equal to percentage change in input

RTS> 1: Increasing return to scale and this impliespercentage change in output is more than percentage change in input.

3. RESULTS AND DISCUSSION

3.1 SOCIOECONOMIC AND DEMOGRAPHIC CHARACTERISTICS

The socio-economic and demographic characteristics of rice farmers in three districts is represented in Table 1 below. Dependency ratio is calculated as the ratio of total number of dependent members to the total number of active members in the household (CBS, 2014). Dependent members belong to the members under 15 years of age group and above 60 years of age group whereas active members belong to the age group of between 15 to 60 years. From Table 1, it can be observed that all the socio-economic and demographic characters are statistically different in all the three districts reflected by the p-value of F-test.

The average age of the respondent in the study area was nearly 43 years. This indicates that most of the farmers were elderly. The average landholding size in the study area was 0.77 ha which is higher than the average landholding size of farmers mentioned by CBS 2023, i.e. 0.55 ha. The average land size underrice cultivation was 0.75 ha which shows the preference of farmers to grow rice crop in their fields. The irrigated land was 0.45 ha which shows relatively higher percentage of land under irrigation.

Table 1. Socioeconomic and demographic characteristics of sampled households in study area (continuous variables)

Variables	Overall (n=300)	District			F-value	p-value
		Jhapa (n=100)	Chitwan (n=100)	Bardiya (n=100)		
Age of respondent (year)	42.83 (11.52)	45.04 (10.60)	45.39 (10.77)	38.07 (11.73)	13.972***	0.001
Age of household head (year)	47.39 (10.90)	49.27 (12.01)	49.28 (8.38)	43.61 (11.08)	9.518***	0.001
Household size	5.75 (1.90)	5.73 (1.48)	5.45 (1.63)	6.08 (2.42)	2.787*	0.063
Dependency ratio	0.66 (0.51)	0.65 (0.46)	0.85 (0.55)	0.49 (0.45)	13.556***	0.001
Dependent members	2.03 (1.30)	2.03 (1.08)	2.26 (1.19)	1.81 (1.56)	3.047**	0.049

Active members	3.72 (1.50)	3.70 (1.27)	3.19 (1.36)	4.27 (1.64)	14.210***	0.001
Owned land (ha)	0.77 (0.42)	0.64 (0.32)	0.79 (0.27)	0.88 (0.58)	8.116***	0.001
Lowland (ha)	0.71 (0.41)	0.59 (0.31)	0.73 (0.26)	0.79 (0.56)	6.623***	0.002
Upland (ha)	0.06 (0.04)	0.05 (0.02)	0.06 (0.03)	0.08 (0.06)	16.911***	0.001
Irrigated land (ha)	0.48 (0.31)	0.37 (0.21)	0.49 (0.18)	0.57 (0.44)	11.610***	0.001
Rice area (ha)	0.75 (0.37)	0.66 (0.27)	0.82 (0.26)	0.78 (0.50)	5.337***	0.005
Livestock holding (LSU[1])	1.63 (1.46)	1.42 (1.34)	1.35 (1.20)	2.13 (1.69)	9.037***	0.001

Notes: Figures in parentheses indicate standard deviation. ***, **, * indicate significant at 1, 5 and 10 percent level of significance respectively.

The association among the different socio-economic characters with the districts is shown in Table 2 below. The gender of household, ethnicity, family type and migration status are considered for the study of association. The study revealed that the gender of household, ethnicity and family type are significantly associated with the location of the study area. Chitwan had the highest number of males involved in rice production (94%) compared to Jhapa and Bardiya which had only 79%. A total of 84% respondents were male in the study area.

Table 2. Socioeconomic and demographic characteristics of sampled households in study area (categorical variable)

Variables	Overall (n=300)	Jhapa (n=100)	Chitwan (n=100)	Bardiya (n=100)	χ^2-value	p-value
Gender of household head						
Male	252 (84.0)	79 (79.0)	94 (94.0)	79 (79.0)	11.161***	0.004
Female	48 (16.0)	21 (21.0)	6 (6.0)	21 (21.0)		
Ethnicity						
Brahmin/Chhetri	159 (53.0)	63 (63.0)	68 (68.0)	28 (28.0)	57.901***	0.001
Janajati/Aadibasi	125 (41.7)	32 (32.0)	22 (22.0)	71 (71.0)		
Dalit	6 (2.0)	2 (2.0)	4 (4.0)	0 (0.0)		
Others	10 (3.3)	3 (3.0)	6 (6.0)	1 (1.0)		
Family type						
Nuclear	152 (50.7)	46 (46.0)	34 (34.0)	72 (72.0)	30.192***	0.001
Joint	148 (49.3)	54 (54.0)	66 (66.0)	28 (28.0)		
Migrated members from household						
Yes	249 (83.0)	82 (82.0)	78 (78.0)	89 (89.0)	4.394	0.111
No	51 (17.0)	18 (18.0)	22 (22.0)	11 (11.0)		

Notes: Figures in parentheses indicate percent. p-values are the result Pearson Chi-square test. ***, **indicate significant at 1 and 5 percent level of significance.

[1] LSU is calculated as: 1 cattle/buffalo = 10 goats = 143 chicken/ducks = 4 pigs (Kattel, 2015).

3.2 AMOUNT OF INPUTS USED IN RICE PRODUCTION

The amount of different inputs required for rice production in three districts is shown in Table 3 below. From Table 3 it can be observed that the type of tillage used, amount of seed used, organic manure, chemical fertilizers used, harvesting and labor used are statistically different in the three study areas confirmed by the significant F-value.The study analyzed the use of various agricultural inputs and practices across three districts of Nepal—Jhapa, Chitwan, and Bardiya. The results revealed significant differences in the use of bullock days, with Bardiya having the highest average use (5.31 days), followed by Jhapa (4.11 days) and Chitwan (2.35 days) (F-value = 8.536, p < 0.001). Similarly, the use of tractors also varied significantly among districts, with Chitwan reporting the highest average tractor hours (8.68 hours) compared to Jhapa (8.09 hours) and Bardiya (5.89 hours) (F-value = 7.621, p < 0.001). Seed usage was highest in Jhapa (66.20 kg), followed by Bardiya (65.80 kg) and Chitwan (59.52 kg), with significant differences observed across districts (F-value = 40.988, p < 0.001).

The application of organic manure showed a marked variation, with Jhapa having a substantially higher average (4503.87 kg) compared to Chitwan (2767.50 kg) and Bardiya (2177.40 kg) (F-value = 70.608, p < 0.001). Chemical fertilizer usage also differed significantly, with Bardiya using the most (432.45 kg), followed by Jhapa (404.27 kg) and Chitwan (363.57 kg) (F-value = 16.381, p < 0.001). Among specific types of fertilizers, urea usage was highest in Bardiya (224.63 kg) and lowest in Chitwan (194.68 kg) (F-value = 10.895, p < 0.001), while DAP and potash usage were also significantly higher in Bardiya compared to the other districts (F-values = 27.745 and 38.538, respectively, both p < 0.001).

However, no significant differences were found in micronutrient use across the districts (F-value = 0.181, p = 0.834). Harvesting time and labor inputs also varied, with Bardiya requiring more labor (67.84 person days) and time (11.60 hours) for harvest compared to Jhapa and Chitwan (F-values = 8.825 and 11.250, respectively, both p < 0.001). These results suggest substantial regional differences in agricultural practices and input use, reflecting variations in local farming conditions, practices, and possibly access to resources.

Table 3. Inputs used in rice production (in ha)

Variables	Overall (n=300)	District			F-value	p-value
		Jhapa (n=100)	Chitwan (n=100)	Bardiya (n=100)		
Tillage						
Use of bullock (day)	3.92 (5.21)	4.11 (5.93)	2.35 (4.22)	5.31 (4.96)	8.536***	0.001
Use of tractor (hr)	7.55 (5.45)	8.09 (5.65)	8.68 (4.55)	5.89 (5.72)	7.621***	0.001
Seed (kg)	63.84(11.58)	66.20 (11.29)	59.52 (6.11)	65.80 (14.57)	40.988***	0.001
Organic manure (kg)	3149.59	4503.87	2767.50	2177.40	70.608***	0.001

	(1742.40)	(632.90)	(1767.18)	(1640.40)		
Chemical fertilizer (kg)	400.10 (89.86)	404.27 (83.57)	363.57 (53.78)	432.45 (109.96)	16.381***	0.001
Urea (kg)	214.41 (53.45)	223.91 (49.27)	194.68 (34.42)	224.63 (66.53)	10.895***	0.001
DAP (kg)	102.80 (23.61)	102.24 (22.16)	91.63 (13.03)	114.51 (27.52)	27.745***	0.001
Potash (kg)	82.89 (16.28)	78.11 (14.29)	77.25 (8.42)	93.31 (18.98)	38.538***	0.001
Micronutrient (kg)	2.42 (1.95)	2.49 (2.03)	2.33 (1.73)	2.44 (2.07)	0.181	0.834
Harvest (hr)	10.62 (3.84)	11.04 (3.71)	9.21 (1.85)	11.60 (4.92)	11.250***	0.001
Labor (person days)	59.16 (28.89)	58.50 (17.95)	51.15 (22.96)	67.84 (39.11)	8.825***	0.001

Notes: Figures in parentheses indicate standard deviation. ***indicate significant at 1 percent level of significance. The input variable chemical fertilizer is derived as the sum of quantity of urea, DAP and potash used.

3.3 COSTS INCURRED IN RICE PRODUCTION

The analysis of costs incurred in rice production across three districts of Nepal—Jhapa, Chitwan, and Bardiya—revealed significant variations in several cost components as observed in Table 4. The average tillage cost was significantly higher in Jhapa (NPR 12,622 per hectare) compared to Chitwan (NPR 10,791) and Bardiya (NPR 10,739) (F-value = 9.044, $p < 0.001$). Similarly, the seed cost was highest in Bardiya (NPR 3,667) and lowest in Jhapa (NPR 3,127), with Chitwan in between (NPR 3,582) (F-value = 13.384, $p < 0.001$).

Labor costs were found to be highest in Chitwan (NPR 39,128), which was significantly more than the costs in Jhapa (NPR 29,504) and Bardiya (NPR 33,473) (F-value = 6.662, $p < 0.001$). Organic manure costs also showed substantial differences, with Jhapa incurring the highest costs (NPR 22,519) compared to Chitwan (NPR 13,837) and Bardiya (NPR 10,887) (F-value = 70.608, $p < 0.001$). The cost of chemical fertilizers was significantly higher in Bardiya (NPR 14,619) compared to Jhapa (NPR 12,335) and Chitwan (NPR 11,493) (F-value = 35.732, $p < 0.001$).

The cost of micronutrients and pesticides did not vary significantly across the districts, with similar averages reported for Jhapa (NPR 3,310), Chitwan (NPR 2,904), and Bardiya (NPR 3,268) (F-value = 0.986, $p = 0.374$). In terms of irrigation costs, Bardiya had significantly higher costs (NPR 5,623) compared to Jhapa (NPR 3,667) and Chitwan (NPR 3,572) (F-value = 32.956, $p < 0.001$). Harvesting costs were also highest in Bardiya (NPR 6,502), while Jhapaand Chitwan reported lower costs (NPR 5,497 and NPR 5,051, respectively) (F-value = 12.922, $p < 0.001$).

Finally, postharvest costs displayed the most significant variation, with Chitwan incurring an exceptionally high cost (NPR 17,408) compared to very low costs in Jhapa (NPR 746) and Bardiya

(NPR 839) (F-value = 5217.165, p < 0.001). These results indicate that there are considerable differences in the costs of various inputs and activities involved in rice production across the three districts, which may reflect differences in local farming practices, resource availability, and economic conditions.

Table 4. Cost of rice production (in NPR, ha)

Variables	Overall (n=300)	District			F-value	p-value
		Jhapa (n=100)	Chitwan (n=100)	Bardiya (n=100)		
Tillage cost	11384 (3660)	12622 (5370)	10791 (1368)	10739 (2726)	9.044***	0.001
Seed cost	3459 (826)	3127 (656)	3582 (629)	3667 (1032)	13.384***	0.001
Labor cost	34035 (19090)	29504 (8945)	39128 (20308)	33473 (23685)	6.662***	0.001
Organic manure cost	15748 (8712)	22519 (3164)	13837 (8836)	10887 (8202)	70.608***	0.001
Chemical fertilizer cost	12816 (3004)	12335 (2658)	11493 (1708)	14619 (3462)	35.732***	0.001
Micronutrient and pesticide cost	3161 (2247)	3310 (2590)	2904 (1570)	3268 (2444)	0.986	0.374
Irrigation cost	4287 (2221)	3667 (1766)	3572 (1080)	5623 (2813)	32.956***	0.001
Harvesting cost	5683 (2149)	5497 (1900)	5051 (1115)	6502 (2824)	12.922***	0.001
Postharvest cost	6331 (7957)	746 (110)	17408 (2295)	839 (119)	5217.165***	0.001

Notes: Figures in parentheses indicate standard deviation. ***indicate significant at 1 percent level of significance.

3.4 PRODUCTION, PROFITABILITY AND REVENUE OF RICE PRODUCTION

The analysis of production, costs, and revenue of rice production across the three districts of Nepal—Jhapa, Chitwan, and Bardiya—shows notable differences in several key metrics. The total cost of rice production was significantly higher in Chitwan (NPR 107,768 per hectare) compared to Jhapa (NPR 93,328) and Bardiya (NPR 89,618) (F-value = 17.680, p < 0.001). In terms of rice production, Jhapa reported the highest average yield (49.41 quintals[2] per hectare), slightly more than Chitwan (48.12 quintals) and Bardiya (48.29 quintals), with these differences being statistically significant (F-value = 3.315, p = 0.038).

[2] 1 quintal = 100 kilograms.

Rice straw production was significantly higher in Chitwan (20.84 quintals per hectare) compared to Jhapa (19.69 quintals) and Bardiya (19.70 quintals) (F-value = 10.242, p < 0.001). For rice not suitable for use and husk, Bardiya had the highest quantity (6.65 quintals per hectare), followed by Jhapa (6.39 quintals) and Chitwan (6.30 quintals), with these differences being statistically significant (F-value = 3.981, p = 0.020).

Gross revenue from rice production varied significantly across districts, with Chitwan achieving the highest average revenue (NPR 172,278 per hectare), compared to Jhapa (NPR 147,974) and Bardiya (NPR 146,140) (F-value = 73.129, p < 0.001). Consequently, profit was also highest in Chitwan (NPR 64,510), significantly more than Jhapa (NPR 54,646) and Bardiya (NPR 56,522) (F-value = 4.738, p = 0.009).

Finally, the Benefit-Cost (BC) ratio, which indicates the economic efficiency of production, showed a slight but statistically significant (at 10% level) difference across the districts, with Bardiya having the highest ratio (1.73), followed by Chitwan (1.67) and Jhapa (1.62) (F-value = 2.359, p = 0.096). These findings suggest that while Chitwan incurs higher costs, it also achieves higher revenue and profit, likely due to greater production efficiency or market access. The differences across districts could be attributed to varying agro-ecological conditions, input usage, and management practices.

Table 5. Production, cost and revenue of rice production

Variables	Overall (n=300)	District			F-value	p-value
		Jhapa (n=100)	Chitwan (n=100)	Bardiya (n=100)		
Total cost (NPR)	96905 (24044)	93328 (16023)	107768 (24623)	89618 (26406)	17.680***	0.001
Rice production (qtl)	48.61 (3.87)	49.41 (3.68)	48.12 (2.83)	48.29 (4.76)	3.315**	0.038
Rice straw production (qtl)	20.07 (2.13)	19.69 (1.32)	20.84 (2.93)	19.70 (1.59)	10.242***	0.001
Rice not suitable for use, husk (qtl)	6.45 (0.93)	6.39 (0.78)	6.30 (0.51)	6.65 (1.29)	3.981**	0.020
Gross revenue (NPR)	155464 (20774)	147974 (15402)	172278 (14664)	146140 (20519)	73.129***	0.001
Profit (NPR/ha)	58559 (24363)	54646 (18354)	64510 (26235)	56522 (26686)	4.738***	0.009
BC ratio	1.67 (0.36)	1.62 (0.25)	1.67 (0.36)	1.73 (0.45)	2.359*	0.096

Notes: Figures in parentheses indicate standard deviation. ***, **, * indicate significant at 1, 5 and 10 percent level of significance, respectively.

The BC ratio more than 1 implies that the rice grain production enterprise is profitable in all the three districts. The rice production in all the three districts and on average is more than 34.7 qt/ha which is the national average rice production of Nepal. This implies that the districts are suitable for production of rice with respect to agro-climatic suitability.

3.5 RESOURCE USE EFFICIENCY OF RICE PRODUCTION IN NEPAL

The Cobb-Douglas production function model provides valuable insights into the efficiency and utilization of various input costs in rice production. The overall model has an R-squared value of 0.422, meaning that approximately 42.2% of the variation in gross revenue from rice production is explained by the model's independent variables. This indicates a moderately strong fit, suggesting that the model adequately captures the relationship between input costs and production revenue. The F-value of 23.54 is highly significant (p-value < 0.001), demonstrating that the model as a whole is statistically significant. This supports the reliability of the estimated coefficients in explaining the variation in rice production revenue.

The seed cost has a negative coefficient (-0.076), which is statistically significant at the 10% level, indicating that an increase in seed cost slightly reduces gross revenue. The negative MVP (-3.455) compared to the MFC of 1 results in an efficiency ratio of -3.455, suggesting that seed costs are overused. This implies that the current level of seed input is beyond the optimal point for maximizing revenue, and reducing seed costs could lead to more efficient production.

Similarly, tillage cost shows a negative but not statistically significant coefficient (-0.022). The efficiency ratio of -0.307 also indicates underuse of tillage costs, although the lack of statistical significance suggests that changes in tillage cost may not have a strong impact on revenue. However, the negative ratio still implies that increasing tillage activities slightly could improve production efficiency.

The model indicates that labor cost has a negative coefficient (-0.034) with a very low t-value, showing a minimal and non-significant effect on revenue. The efficiency ratio of -0.171 suggests overuse of labor. This result implies that current labor usage exceeds the optimal level for cost efficiency, and reducing labor inputs could potentially enhance productivity.

Organic manure cost has a positive coefficient (0.181), significant at the 10% level, suggesting that increasing organic manure input positively impacts revenue. The high efficiency ratio (39.306) indicates that organic manure is underused. This means there is potential to increase the use of organic manure to achieve higher revenue from rice production, highlighting an opportunity for farmers to invest more in organic manures.

The coefficient for chemical fertilizer cost is negative (-0.044) and not statistically significant, with an efficiency ratio of -0.544. This suggests that chemical fertilizers are overused, and reducing their application could enhance cost-efficiency and environmental sustainability. The negative impact also aligns with growing evidence on the adverse effects of overusing chemical fertilizers on both economic and environmental outcomes.

For micronutrient and pesticide costs, the positive coefficient (0.131) is not statistically significant, but the high efficiency ratio (89.586) indicates these inputs are underused. Increasing the application of micronutrients and pesticides could potentially improve rice yields and gross revenue, as the current usage level appears below the optimal threshold for maximizing productivity.

Irrigation cost has a small but highly significant negative coefficient (-0.005) at the 1% level. The negative efficiency ratio (-0.845) indicates overuse of irrigation resources. This suggests that current irrigation practices are excessive, and reducing water usage could enhance cost efficiency without negatively affecting yield. This finding is particularly important in the context of sustainable water management and reducing production costs.

The harvesting cost has a significant positive coefficient (0.134) at the 1% level, with an efficiency ratio of 3.846, indicating underuse of resources allocated to harvesting. This result suggests that increasing investment in harvesting activities could lead to higher returns, pointing to a potential area for improvement in post-harvest handling practices to maximize revenue.

Finally, post-harvest cost shows a highly significant positive coefficient (0.061) and an efficiency ratio of 4.223, indicating it is also underused. This implies that increasing expenditures on post-harvest activities could further enhance profitability, underscoring the importance of effective post-harvest management to reduce losses and improve marketability of rice.

Table 6. Estimation of efficiency ratios using Cobb-Douglas production function model

Variables	Coefficient	Std. error	t-value	MVP	MFC	r	D	Status
Log seed cost	-0.076*	0.039	-1.940	-3.455	1	-3.455	128.946	OU
Log tillage cost	-0.022	0.030	-0.740	-0.307	1	-0.307	425.578	UU
Log labor cost	-0.034	0.021	-0.020	-0.171	1	-0.171	683.543	OU
Log organic manure cost	0.181*	0.001	1.800	39.306	1	39.306	97.456	UU
Log chemical fertilizer cost	-0.044	0.069	-0.640	-0.544	1	-0.544	283.685	OU
Log micronutrient and pesticide cost	0.131	0.001	1.000	89.586	1	89.586	98.884	UU
Log irrigation cost	-0.005***	0.002	-3.100	-0.845	1	-0.845	218.327	OU
Log harvesting cost	0.134***	0.042	3.210	3.846	1	3.846	73.998	UU
Log post-harvest cost	0.061***	0.006	10.230	4.223	1	4.223	76.322	UU
Constant	11.584***	0.479	24.170					
Observations	300							
F-value (9, 290)	23.54***							
Prob>F	0.001							
R-squared	0.422							

Adj. R-squared	0.404
Return to scale	0.325

Notes: The dependent variable is natural log transformation of gross revenue from rice production. Log indicate natural log transformation. ***, * indicate significant at 1 and 10 percent level of significance respectively. OU indicate over-used of the resources when r<1 and UU indicate under-used of the resources when r>1.

The findings revealed that seed costs and irrigation costs were overused and hence their use should be reduced by 129 and 218%, respectively. On the other hand, the use of organic manures, harvesting cost and post-harvest costs need to be increased by 97, 74 and 76%, respectively. Similar results were reported by Dhakal et al. (2019) in Chitwan district of Nepal, Subedi et al. (2020) study on RUE of rice production in Jhapa district of Nepal. For optimum allocation of these resources, the adjustment should be made as indicated by the figures.

4. CONCLUSION

The study aimed to determine the profitability and resource use efficiency of rice production in the three major rice producing districts of Nepal. It can be concluded from the study that rice production is a profitable enterprise in all the three districts with BC ratio more than 1. Similarly, the productivity of rice in all the districts is more than the national average signifying the suitable agro-climatic situation of the districts. The resource use efficiency analysis showed that the resources were not optimally utilized and to achieve the optimal efficiency, it is necessary to reduce the costs on seed and irrigation while it is important to increase the costs on organic manure use, harvesting and post-harvesting. Further study on marketing and value chain can be suggested to strengthen the rice sector enterprise.

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