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

ABSTRACT

Rice is the primary staple food crop of Nepal with significant contribution to the gross domestic product from agriculture. Although rice holds primary share of cereals in terms of area, the increasing cost of production and inefficient allocation of resources are a major issue. Thus, to assess the profitability and the resource use efficiency of rice production, this study was done in the three major districts of Nepal, Jhapa, Chitwan and Bardiya, belonging to Terai belt having significant contribution to 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 production in the study area was 1.67 signifying the profitable nature of rice production in Nepal. The average cost of rice production in the study area was NPR. 96, 905/ha. The profit obtained from rice production per hectare was NPR. 58, 559. The resource use efficiency analysis showed that the resources needed to be optimally utilized through seed costs and irrigation costs reduction by 129 and 218%, respectively, while the use of organic manures, harvesting cost and post-harvest costs need to be increased by 97, 74 and 76%, respectively. The study is useful for rice growers, stakeholders and the government to formulate the policies that improve the resource use efficiency of rice production.

Keywords:*Rice, resource use efficiency, BC ratio, production function, input*

1. INTRODUCTION

Rice (*Oryza sativa L.*) is the primary staple food crop of Nepal, ranking first among cereal crops in terms of cultivated area (1,477,378 ha), production (5,130,625 metric tons), and productivity (3.47 metric tons per hectare) (MoALD, 2023). Globally, rice is the staple food for more than 50% of the population (Thapa & Bhusal, 2020; Simkhada& Thapa, 2020). As a member of the Poaceae family, rice includes twenty-three species, but only two-*Oryza sativa* (Asian rice) and *Oryza glaberrima* (African rice)are commercially valuable, with *Oryza sativa* being the most significant for commercial production (CDD, 2015).

In Nepal, the agriculture and forestry sectors contribute nearly one-fourth (24.12%) to the national Gross Domestic Product (GDP), with rice being the most important agricultural crop due to 13.60% contribution to the Agricultural Gross Domestic Product (AGDP) and the livelihoods of the people (MoALD, 2023). Rice is cultivated across three distinct agro-ecological zones: Terai and Inner Terai (60-900 meters above sea level), Mid-hills (900-1,500 masl), and Mountains/High hills (1,500-3,050 masl). The Terai region, in particular, accounts for more than two-thirds of the country's rice output. Jhapa, a district in the Terai region, is notable for having the highest rice production in Nepal and has been designated as the first 'ricesuperzone' under the Prime Minister Agriculture Modernization Project (PMAMP), which requires nearly 1,000 hectares of land for such a designation (MoAD, 2016). The area, production, and productivity of rice in Jhapa district are reported to be 85,879 ha, 365,845 metric tons, and 4.26 metric tons per hectare, 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 of rice production in Nepal is rising due to increasing costs of inputs such as chemical fertilizers, seeds, labor, farm machinery, and other resources. Additionally, many farmers lack adequate knowledge of resource optimization, preventing them from using these inputs at economically optimal levels. The ultimate goal of any agricultural endeavor is to maximize profit and minimize costs through efficient resource use (Parajuli & Thapa, 2024). Inefficient and irrational use of inputs leads 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.

Given rice's status as the major staple food crop in Nepal, it is essential to evaluate the costs, benefits, and allocative efficiency indices of rice production comprehensively (Thapa & Dhakal, 2024b). This study aims to assess the 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

Jhapa, Chitwan and Bardiya district were purposely selected for the study as they havea high rice production in the Eastern, Central and Western region of Nepal (Thapa & Dhakal, 2024a). The major rice growing areas of the district were selected for the purpose of the study, having consultation with the agricultural officials of rice super zone and the local government.

2.2 SAMPLING PROCEDURE AND DATA COLLECTION

The simple random method of sampling was used to select the sample from the sampling frame of the rice growing farmers of the study area, obtained from the concerned agricultural officials. 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, 300 samples were taken, 100from selected clusters and pockets of the local levels in each of the district for the purpose of the study.

2.3 METHODS AND TECHNIQUES OF DATA ANALYSIS

Data entry and analysis were done using the computer software packages like: Statistical Package for Social Sciences (SPSS), Stata and Microsoft Excel (MS-Excel) based on the suitability of the data. The following analyses were performed.

2.4 COST AND RETURN ANALYSIS

The benefit cost analysis was done after calculating the total cost and gross return from the rice cultivation. Cost of production was calculated by summing the variable cost items such as: cost incurred in seed, fertilizer, human labor, tractor and thresher and others like cost of herbicides and pesticides and irrigation in the production process. For calculating gross return, income from product sales (grains, straw) were accounted. Following Dillon and Hardaker (1993), return from rice grains was calculated by multiplying the total volume of output by the average price at harvesting period. In a similar manner, the return from the straw was calculated. Finally, the gross return was calculated by summing the returns from the grain and straw.

2.4.1 GROSS MARGIN

The gross margin was calculated by deducting the total variable cost from gross return. Gross margin calculation was done to have an estimate of the difference between the gross return and variable costs. Gross margin was calculated by using the method as given by Olukosi et al. (2006) using following formula;

Gross Margin (NPR/ha) = Gross return (NPR/ha) – Total variable cost (NPR/ha)

2.4.2 BENEFIT COST RATIO

The undiscounted benefit cost ratio was estimated as a ratio of gross return and total variable cost. The benefit cost ratio was calculated by using the formula:

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

The above formula to calculate the BCR has also been used in the studies, Dhakal et al. (2015) and Subedi et al. (2019).

2.5 COBB-DOUGLAS PRODUCTION FUNCTION

It has been revealed that Cobb-Douglas production function is useful in computation of marginal value product (MVP) which is the important component to determine optimum,over and underuse of resources (Gujarati, 2009). The Cobb Douglas production function of the following form was fitted to examine the resource productivity, efficiency and return to scale.

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

Transformed to linear form for ease in computation by taking natural logarithm on both sides, we have, $\ln Y = \ln a + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + b_5 \ln X_5 + b_6 \ln X_6 + b_7 \ln X_7 + b_8 \ln X_8 + u$

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 = Random disturbance term or error term, a = Intercept or constant term, e = Base of natural logarithm, ln = Natural logarithm, b_1, b_2, b_3… b_8 = Coefficients of respective variables.

The return to scale of rice production was calculated by summing the coefficients of all the explanatory variables estimated from the linearized Cobb-Douglas production function. Dhakal et al. (2015) had also calculated the return to scale in a similar manner. The allocative efficiency of a resource used was estimated taking the ratio of Marginal Value Product (MVP) of variable input and the Marginal Factor Cost (MFC) for the input and tested for its equality to one.

Taking reference of Goni et al. (2007), the resource use efficiency was calculated using the formula;

r = MVP/MFC

Where, r = Efficiency ratio, MVP= Marginal value product of a variable input; 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; percentage change in output is less than percentage change in input, RTS = 1: Constant return to scale; percentage change in output is equal to percentage change in input, RTS> 1: Increasing return to scale; percentage change in output is more than percentage change in input.

3. RESULTS AND DISCUSSION

3.1 SOCIOECONOMIC AND DEMOGRAPHIC CHARACTERISTICS

The different socio-economic and demographic characteristics of rice farmers in the 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 implies 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

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

Notes: Figures in parentheses indicate standard deviation. p-values are the result of f-test. ***, **, * 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.

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 (1742.40)	4503.87 (632.90)	2767.50 (1767.18)	2177.40 (1640.40)	70.608***	0.001
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	11.250***	0.001

				(4.92)		
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. p-values are the result of f-test. ***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	12622	10791	10739	9.044***	0.001

	(3660)	(5370)	(1368)	(2726)		
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. p-values are the result of f-test. ***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).

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).

[2] 1 quintal = 100 kilograms.

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. p-values are the result of f-test. ***, **, * 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.

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