Original Research Article

Optimizing Resource Utilization for Paddycultivation in Eastern Uttar Pradesh, India: A Study on Efficiency and Sustainability

Abstract

Agriculture is a cornerstone of the Indian economy, essential for providing food and livelihoods to millions. Efficient resource management of key resources such as land, water, labour, and inputs like fertilizers and pesticides enhance productivity, reduce production costs and environmental sustainability. Rice is a major food source and a vital agricultural commodity in India. This paper examines resource use in paddy cultivation across different farm sizes inChandauli and Mirzapur districts in Eastern Uttar Pradesh.The selected districts are among the highest in the state in terms of productivity.Resource use efficiency was assessed using the well-known Cobb-Douglas, or log-log, production function.Thefindings reveal a general trend of under-utilization of crucial inputs such as seeds, fertilizers, and machinery, with varying levels of efficiency across farm categories. The analysis underscores the need to better utilize these resources to improve profitability and efficiency in paddy farming in the study area. Improving resource management and adopting technological advancements, such as direct-seeded rice, the use of nano fertilizers, and the incorporation of rice straw into fields to enhance soil fertility, can significantly increase production outcomes on farmers' fields while promoting sustainable practices.

Keywords: Resource use efficiency, Allocative efficiency, Paddy farming, Sustainable

Introduction

The importance of Indian agriculture in India's economic and social landscape surpasses its contribution to the nation's GDP. It continues to employ a significant portion of India's population, not only providing essential food supplies but also serving as a safety net for millions when other sectors of economy falter.It plays a crucial role in ensuring food security, fostering rural development, and driving economic growth (Pingali, 2012; Norton, 2021).

Effective management of resources such as land, water, labor, and inputs like fertilizers and pesticides can significantly enhance agricultural productivity and environmental sustainability (Tilman et al., 2002; Pretty, 2008).Rice farming is critically important both globally and in India due to its role in ensuring food security and supporting livelihoods. Worldwide, rice is a staple food for more than half of the global population, providing a significant portion of daily caloric intake, especially in Asia (Seck,2012).

In India, rice is not only a primary food source but also a key agricultural commodity, supporting the livelihoods of millions of farmers and contributing significantly to the national economy (Mohanty, 2013). Effective management of water, fertilizers, pesticides, and labor can significantly improve productivity and environmental outcomes in rice cultivation.

Proper water management, for instance, through techniques like alternate wetting and drying, can save water and enhance yields (Bouman et al., 2007). Additionally, the judicious use of fertilizers and integrated pest management practices can improve nutrient uptake and reduce chemical usage, leading to better soil health and reduced environmental impact (Dobermann and Fairhurst, 2000). Efficient resource use is crucial for sustainable rice production and long-term food security (Hafeez et al., 2007,2014).

Additionally, improving resource use efficiency can help in addressing the challenges of food security and rural the concept of "resource use efficiency in agriculture" includes various dimensions such as technical efficiency and allocative efficiency. An efficient farmer is one who allocates resources like land, labour, and water optimally to maximize income while minimizing costs, all within a sustainable framework. Furthermore, a farmer's efficiency is greatly influenced by their access to technology, credit, markets, infrastructure, and governmental support, as well as their ability to perceive and manage risks in changing weather and market conditions.

The farmers who avoid unsustainable practices may incur high opportunity costs. therefore, many farmers might lack awareness or proper guidance on more sustainable alternatives for utilizing their limited resources, such as land and water. Therefore, considering the economic aspects is essential when assessing resource use efficiency in agriculture.Therefore, an empirical analysis is essential to evaluate how resources are being used by paddy farmers in Eastern Uttar Pradesh.

This analysis would be helpful in formulating policies and providing recommendations to support farmers in optimizing resource use, thereby improving productivity and ensuring sustainable agricultural practices in the region.

Objectives:-

1) To find out the factors affecting the Paddy production in the study area;

2) To assess the resource use efficiency of paddy cultivation

Materials and methods

Study Area:

The research was conducted in two districts, Mirzapur and Chandauli, situated in Uttar Pradesh, India. Mirzapur is positioned at 25°15'N latitude, 82°56'E longitude, and 83 meters altitude, while Chandauli lies at 25°27'N latitude, 83°27'E longitude, and 39 meters altitude.Mirzapur is known for its diverse geography, while Chandauli is renowned as the "DhaanKaKatora of Uttar Pradesh" due to its highly fertile alluvial soil of the Gangetic Plain.

Selection of Sample:

To gather primary data for the study, a multi-stage stratified random sampling technique was employed. Mirzapur and Chandauli districts were selected out of 75 districts in Uttar Pradesh based on their high productivity in rice cultivationduring the kharif season.The rice cultivation productivity in Chandauli and Mirzapur for the fiscal year 2022 was 33.60 and 31.25 Q/ha, respectively. (GoUP,2024).Two blocks were randomly chosen from each selected district, followed by the random selection of two villages from each block. Farmers engaged in rice cultivation during the kharif season were identified, and a sample of 15 farmers from each village was randomly drawn, totalling 120 farmers. This sample included 72 marginal and small farmers (< 2 ha), as well as 48 semi medium andmedium farmers (> 2 ha to <10 ha), ensuring a representative distribution.The farmers were categorized based on the definition of farmers according to their land holdings as outlined in the Agriculture Census. To ensure a sufficient sample size for more accurate regression results, marginal and small and medium and semi medium categories were combined.The data collection was conducted during the 2023-2024 period to provide insights into resource utilization among farmers in the selected districts.

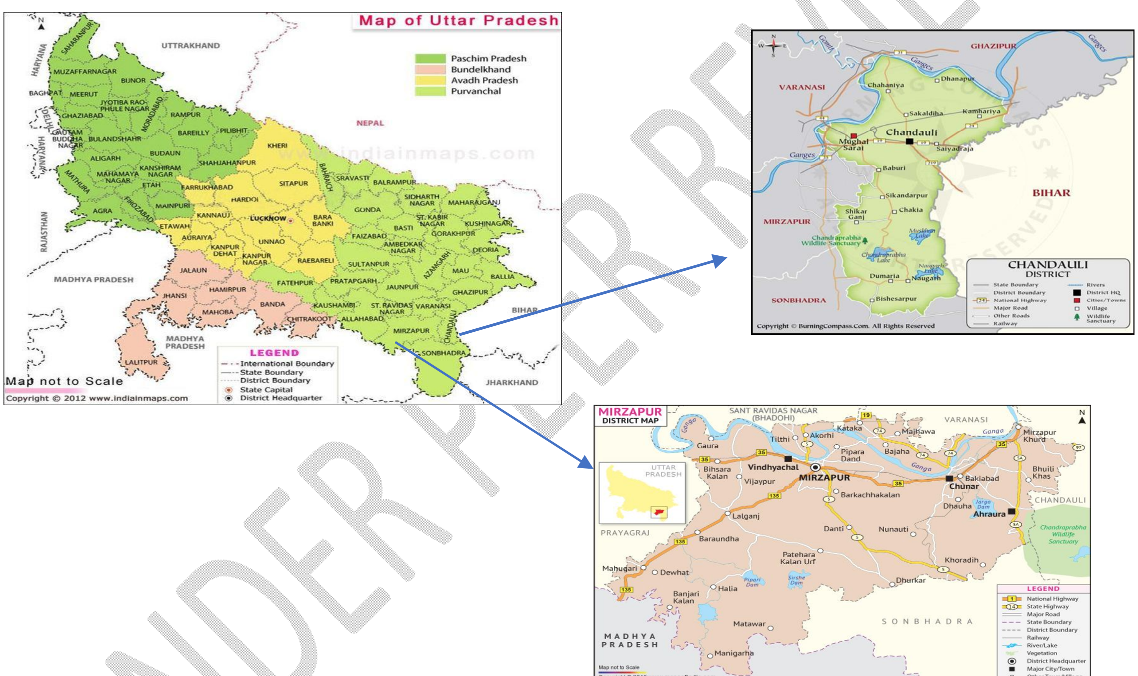

Fig.1. The map indicating selected districts for the study

Resource use efficiency

Economic efficiency is commonly seen in the production literature as an elusive term and is a consistent question in empirical studies. It is one of the most relevant criteria for assessing decision-making in the production process. Since the launch of the high yielding varieties program in agriculture, the study of economic efficiency in the field of economic analysis has gained in importance. In other words, the concept of economic efficiency is vital to both micro and macro-level policy-makers. It will help them in formulating farm planning relating to the widespread reasonable use of farm resources.

To workout efficiency, Cobb Douglas production function has been fitted to estimate production elasticities of given inputs which in turn will be used to calculate their Marginal value products. The resource use of farmers has been judged using the Neo-classical criterion that each factor of production has been paid equal to its marginal productivities. A significant difference between marginal value product and factor cost of given input will reveal that farmers are not using the inputs provided efficiently, with this knowledge farm plans can be formulated for refining the input efficiency so that it will help in an overall improvement in agricultural productivity.

Cobb-Douglas production function

Resource use efficiency of paddy crop was studied by using the Cobb-Douglas production function to the farm-level data. The model specified was as follows

$Y = a\ X_1^{bl}\ X_2^{b2}\ X_3^{b3}\ X_4^{b4}\ X_5^{b5}\ X_6^{b6} e^u$. … (1)

Where, Y_t= Output,

a = Constant

u = Random variable

e = Error term

bi= elasticity coefficient of i^{th} input and X_1 to X_6 are independent variables

The independent variables [inputs] included were seeds (Kg.), fertilizers (Kg.) labour (man-days), Machinery (hours), years of schooling (years), and Farming experience(years) in the case of paddy [6 variables].

The above equation was converted into the logarithmic form as follows to present it in a linear form:

$\ln Y = \log a + b_1 \log X_1 + b_2 \log X_2 + b_3 \log X_3 + b_4 \log X_4 + b_5 \log X_5 + b_6 \log X_6 + u \log e.$

The economic efficiency of the resource used was determined by using the MVP and MFC ratio. The estimated coefficients for calculating the MVP and its ratio (r) to MFC were used. The model used for the estimation of r was as follows:

$r = \frac{MVP}{MFC}$… (2)

Were,

r = Efficiency ratio

MVP = Marginal Value Product of variable inputs

MFC = Marginal Factor Cost (price of inputs)

The economic efficiency of resource utilization was determined by the MVP to the MFC ratio. The optimum amount of a variable input to be used when the MVP to MFC ratio (r) is equal to one. In this case, the farmer maximizes his income as per resource use. Here the resource is used effectively, which is the optimal use of the resource and hence the point of maximization of benefit. If r is < 1; reveals that MVP < MFC, the resource is over-used, thus reducing the use of that resource by quantity increases profit. Eventually, if r > 1; shows that MVP > MFC, the resource is under-used thus raising its utilization rate would increase the level of benefit.

Results and discussion

Estimation of key determinants of Rice Producion:-

To account for the fact that all farmers do not operate under the same input-output relationship and that there is dsifference in the resource endowments of the farmers, sample farmers are categorised on the basis of land area under paddy cultivation into twogroups. The results of production function for different size-groups of farms are presented in Table No.1 and 2 The estimated form of the developed Cobb-Douglas production function for Paddy farms in small and marginal category for Chandauli is given in Table 1.

Table 1: Regression coefficients of different inputs of rice production in Chandauli district

Parameters	Factors	Group-I (Marginal/ Small)			Group-II (Semi- Medium/ Medium)		
		Coefficients	**Standard Error**	**t-value**	**Coefficients**	**Standard Error**	**t-value**
β_0	Constant	2.1904*	0.3000	7.3004	2.0254*	0.2299	8.8082
β_1	Seed (Kg)	0.1391*	0.0527	2.6402	0.4617*	0.0909	5.0806
β_2	Fertilizers (Kg)	0.0670	0.1501	0.4461	0.0786	0.0568	1.3835
β_3	Labour Use (Man Days)	0.5351*	0.1364	3.9218	0.4695*	0.1179	3.9816
β_4	Machine Usage (Hrs.)	0.1780***	0.0951	1.8723	0.0886	0.1035	0.8569
β_5	Farming Experience (Years)	0.0255	0.1425	0.1791	0.1673*	0.0517	3.2330
β_6	Years of Schooling	0.0252	0.0953	0.2638	0.0479	0.0783	0.6116
	R^2	0.91			0.94		
	Adjusted R^2	0.89			0.93		
	F-value	43.85			64		
	RTS= $\sum\beta_{1-6}$	0.97			1.31		
	Observations	32			28		

*Significant at 1% level; **Significant at 5% level; ***Significant at 10% level

Source: Authors' computation.

The coefficient of determination R^2 for the two groups shows thatthe variations explained by independent variables range from 91 to 94 per cent. R^2 for each group is tested for statistical significance by considering the corresponding F-value of each group. On testing, it is inferred that R^2 is statistically significant in each group. This indicates that the fit is good. The magnitude of elasticity coefficient associated with fertilisers is positive in Group-I, negligible though positive in Group-II and but not significant in both the groups. The coefficient of seeds is significant and positive in each size-group of farms. The magnitude of elasticity coefficient with respect to labour is positive and significant in both Groups I and II. With respect to Machine usage, coefficient of elasticity is positive and significantin group I while it is positive but insignificant for group -II. The magnitude of elasticity coefficient associated with Farming experience is negligible though positive in Group-I and positive and significant only in Group-Il while in case of years of schooling which is positive but negligible in both the farm groups.

On the basis of these results, it is understood that the contribution of seeds and labour is highly significant in all the size-groups of farms. Thus, both seeds and labours contribute more in the output of paddy compared to other variable inputs used in paddy production.

Table 2: Regression coefficients of different inputs of rice production in Mirzapur district

Parameters	Factors	Group-I (Marginal/ Small)			Group-II (Semi- Medium/ Medium)		
		Coefficients	**Standard Error**	**t-value**	**Coefficients**	**Standard Error**	**t value**
β_0	Constant	2.0277*	0.1954	10.3781	2.3608*	0.1538	15.3458
β_1	Seed (Kg)	0.0082	0.0666	0.1224	0.1158*	0.0382	3.0318
β_2	Fertilizers (Kg)	0.1630***	0.0880	1.9669	0.1382	0.1709	0.8086
β_3	Labour Use (Man Days)	0.4636*	0.1186	3.9101	0.2676***	0.1541	1.7361
β_4	Machine Usage (Hrs.)	0.2059**	0.1007	2.0450	0.1786	0.1232	1.4492
β_5	Farming Experience	0.0380	0.0624	0.6091	0.2303*	0.0882	2.6109

	(Years)						
β_6	Years of Schooling	0.1024	0.0646	1.5850	0.0109	0.0175	0.6263
	R^2	0.92			0.98		
	Adjusted R^2	0.91			0.97		
	F-value	71			107		
	RTS= $\sum\beta_{1-6}$	0.98			0.94		
	Observations	40			20		

*Significant at 1% level; **Significant at 5% level; ***Significant at 10% level

Source: Authors' computation.

As presented in Table No.2 the coefficient of determination R^2 for the two groups shows that the variations explained by independent variables range from 92 to 98 per cent. R^2 for each group is tested for statistical significance by considering the corresponding F-value of each group. On testing, it is inferred that R^2 is statistically significant in each group. This indicates that the fit is good. The magnitude of elasticity coefficient associated with fertilisers is positive and significant in Group-I, negligible (insignificant)though positive in Group-II.The coefficient of seeds is significant and positive in Group-II while positive but not significant in group I. The magnitude of elasticity coefficient with respect to labour is positive and significant in both Groups I and II. With respect to Machine usage, coefficient of elasticity is positive and significant in group I while it is positive but insignificant for group II. The magnitude of elasticity coefficient associated with Farming experience is negligible though positive in Group-I and positive and significant only in Group-Il while in case of years of schooling which is positive but negligible in both the farm groups.

On the basis of these results, it is understood that the contribution of labours is highly significant in all the size-groups of farms.Thus, labourcontribute more in the output of paddy compared to other variable inputs used in paddy production.

RETURNS TO SCALE:

As presented in Table No 1 and 2, sum of production elasticity coefficients was less than unity in Group-I, indicating decreasing returns to scale. In Group-II, in case of Chandauli, sum of the elasticity coefficients is greater than unity, indicating increasing returns to scale.While in Mirzapur district its again less than unity showing the decreasing returns to scale This reveals that there is ample scope for using more inputs in Rice farms under Group-II in Chandauli district.

The sum of production elasticity coefficients was almost equal to unity for Group-I in both of the districts Chandauli and Mirzapur.While it is clearly less than unity in case of Group-II in Mirzapur. In Chandauli district it is more than unity in case of Group-II indicating increasing returns to scale,this reveals that there is ample scope for using more inputs in Rice farms under Group-II in Chandauli district.

Resource Use Efficiency

The resource use efficiency (RUE) in paddy cultivation has been calculated across different farm size categories—Marginal, Small, Semi-medium, and Medium—in both districts, as shown in Table 3 and table 4. This table presents the Marginal Value Product (MVP) to Marginal Factor Cost (MFC) ratios denoted by'r' for various inputs used in paddy cultivation. The analysis focuses on four key inputs: Seed, Fertilizer, Labor, and Machinery, to evaluate their efficiency in utilization. The RUE values indicate the allocative efficiency of these resources.

Table-3 Resource use efficiency of paddy in different farm categoriesinChandauli district

Small- Marginal Farms						
Resource	**Coefficient**	**MPP**	**MVP**	**MFC**	**MVP/MFC(r**	**Results**

s	**s**				**)**	
Seed	0.1391	57.39	1170.79	35	33.45106	Under-Utilized
Fertilizer	0.0670	1.14	23.19	17	1.363881	Under-Utilized
Labour	0.5351	35.55	725.15	250	2.90058	Under-Utilized
Machine	0.1780	139.54	2846.56	1000	2.846556	Under-Utilized
Semi Medium-Medium Farms						
Resources	**Coefficients**	**MPP**	**MVP**	**MFC**	**MVP/MFC(r)**	**Results**
Seed	0.4617	185.66	3787.38	50	75.75	Under-Utilized
Fertilizer	0.0786	2.08	42.37	20	2.12	Under-Utilized
Labour	0.4695	54.22	1106.17	250	4.42	Under-Utilized
Machine	0.0886	138.20	2819.35	1000	2.82	Under-Utilized

In case of marginal and small farms, the results show that all inputs are under-utilized, though to varying degrees. Seeds have the highest RUE of 33.45, indicating significant under-utilization and suggesting a high potential for increasing their use to boost production efficiency. Fertilizer, with an RUE of 1.36, is the least under-utilized, showing that it is closer to optimal use, but still has some room for improvement. Labor and Machinery have RUEs of 3.62 and 2.85, respectively, indicating they are under-utilized but have less potential for increased usage compared to seeds. While in case of Semi-medium to medium farms, the results reveal that all inputs in this farming operation are under-utilized. Seeds, with the highest RUE of 75.75, represent the greatest opportunity for improved efficiency, as increasing their use could significantly enhance profitability. Labor, with an RUE of 4.42, and Fertilizer, with an RUE of 2.11, also show under-utilization, though to a lesser extent.

Machinery, with an RUE of 2.81, is the least under-utilized, indicating it is closer to optimal use but still has room for improvement.

Table-4 Resource use efficiency of paddy in different farm categoriesin Mirzapur district

Small-Marginal						
Resources	**Coefficients**	**MPP**	**MVP**	**MFC**	**MVP/MFC(r)**	**Results**
Seed	0.0082	3.01	61.49	40	1.54	Under-Utilized
Fertilizer	0.1730	3.43	70.05	18	3.90	Under-Utilized
Labour	0.4636	24.71	504.02	250	2.02	Under-Utilized
Machine	0.2059	121.78	2484.24	1050	2.37	Under-Utilized
Semi Medium-Medium						
Resources	**Coefficients**	**MPP**	**MVP**	**MFC**	**MVP/MFC(r)**	**Results**
Seed	0.1158	42.16	859.98	75	11.47	Under-Utilized
Fertilizer	0.1382	1.67	34.17	21	1.63	Under-Utilized
Labour	0.2676	12.44	253.87	250	1.02	Optimal-utilized
Machine	0.1786	166.13	3389.15	1000	3.39	Under-Utilized

Table 4 reveals thatIn the Small-Marginal category of farms,seeds show a slight over-utilization with an RUE of 1.54, indicating that the current input level is close to optimal but could be slightly reduced to enhance efficiency. Fertilizer, on the other hand, has a high RUE of 3.89, signalling significant under-utilization and suggesting that increasing fertilizer use could boost productivity. Labor is moderately under-utilized, with an RUE of 2.02, showing that while labour contributes substantially to production, there is potential for optimization. Machinery is also under-utilized, as indicated by an RUE of 2.37, highlighting the opportunity to increase its use for improved productivity.

In the Semi Medium-Medium category of farms, seeds are highly under-utilized, with an RUE of 11.47, suggesting substantial potential for increased usage to improve efficiency. Fertilizer is also under-utilized, with an RUE of 1.63, indicating room for enhanced use to achieve better productivity. Labor in this category is being used optimally, as reflected by an RUE of 1.02, meaning no significant adjustments are necessary. However, machinery, with an RUE of 3.39, remains under-utilized, suggesting that increasing its use could lead to better efficiency and higher output.

Conclusion

The findings reveal a general trend of under-utilization of key inputs like seeds, fertilizers, and machinery, with varying degrees of efficiency observed between the two districts.This suggests that there is still potential to increase production while maintaining a focus on sustainability.Chandauli exhibits higher efficiency in machinery use, while Mirzapur shows potential in optimizing labour and fertilizer usage, emphasizing the need for targeted interventions to enhance input utilization, particularly through improved access to technology and better agronomic practices. Policymakers and agricultural stakeholders should focus on promoting balanced resource use to boost productivity and sustainability in these regions.In summary, This analysis underscores the significant potential to enhance the utilization of underutilized resources. State agricultural machinery, KVKs, and scientists can play a crucial role in this effort. For instance, adopting the direct seeding method could increase seed consumption, while greater use of machinery in harvesting and straw management could help minimize waste and improve soil fertility. Additionally, providing soil health cards could guide farmers in applying the appropriate amount of fertilizers. These steps will surely assist farmers in augmenting their income.

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References

Bouman, B. A., Humphreys, E., Tuong, T. P., & Barker, R. (2007). Rice and water. *Advances in agronomy*, *92*, 187-237.

Bruinsma, J. (2017). *World agriculture: towards 2015/2030: an FAO study*. Routledge.

Fairhurst, T., Witt, C., Buresh, R., Dobermann, A., & Fairhurst, T. (2007). *Rice: A practical guide to nutrient management*. Int. Rice Res. Inst.

Hafeez, M., Khan, S., & Mushtaq, S. (2007). Re-use and cyclic use of water saving in rice cultivation in gravity irrigation system of Phillippines. In *International Congress on Modelling and Simulation (MODSIM)* (pp. 177-183). The Modelling and Simulation Society of Australia.

Hafeez, M., Bundschuh, J., & Mushtaq, S. (2014). Exploring synergies and tradeoffs: Energy, water, and economic implications of water reuse in rice-based irrigation systems. *Applied energy*, *114*, 889-900.

MOHANTY, B. B. (2013). Potential and Possibilities for Livelihood of the Poor. *State of India's Livelihoods Report 2012*, 157.

Norton, G. W., Alwang, J., & Masters, W. A. (2021). *Economics of agricultural development: world food systems and resource use*. Routledge.

Pingali, P. L. (2012). Green revolution: impacts, limits, and the path ahead. *Proceedings of the national academy of sciences*, *109*(31), 12302-12308.

Pretty, J. (2008). Agricultural sustainability: concepts, principles and evidence. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *363*(1491), 447-465.

Seck, P. A., Diagne, A., Mohanty, S., &Wopereis, M. C. (2012). Crops that feed the world 7: Rice. *Food security*, *4*, 7-24.

Singh, A., & Thakur, R. K. (2022). Profitability, resource use efficiency and technical efficiency of organic crops in Himachal Pradesh, India. *International Journal of EnvironmentalStudies*, *80*(5), 1248–1258. https://doi.org/10.1080/00207233.2022.2037337

Singh, J. P. (1975). Resource use, Farmsize and Returns to Scale in a Backward Agriculture. *Indian Journal of Agricultural Economics*, *30*(2), 32-46.

Tilman, D., Balzer, C., Hill, J., & Befort, B. L. (2011). Global food demand and the sustainable intensification of agriculture. *Proceedings of the national academy of sciences*, *108*(50), 20260-20264.

Government of Uttar Pradesh. (2024). Area, Production & Productivity of Paddy in 2021-22. Agriculture Directorate, Krishi Bhawan, Lucknow, Uttar Pradesh. https://upagripardarshi.gov.in/StaticPages/ASP.aspx