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Assessing yield gap in paddy cultivation: A case study from Shivamogga district, Karnataka

M Senthilkumar[1], Sunil A[2], Maria Vinita[3] & K Poorna Teja[3]

[1]Training Division, Directorate of Extension Education, Tamil Nadu Agricultural University, Coimbatore 641 003, India

[2]Block Technical Manager (ATMA Scheme), Karnataka State Department of Agriculture, Shivamogga 577 201, India

[3]Department of Agricultural Extension and Rural Sociology, Tamil Nadu Agricultural University, Coimbatore 641 003, India

*Email: senthilmsk@tnau.ac.in

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Abstract

Paddy cultivation is a cornerstone of India's agricultural economy, with Karnataka emerging as a key contributor to this sector. Despite its significance, persistent yield gaps across various paddy varieties pose a considerable challenge to achieving optimal productivity. These yield gaps primarily stem from factors such as traditional farming practices, resource unavailability and varying environmental conditions. This study aimed to comprehensively assess the yield gap of paddy varieties specifically in the Shivamogga district of Karnataka, employing an ex-post facto research design to identify key factors influencing yield gaps. Data were systematically collected from a sample of 197 farmers using a structured interview schedule, ensuring a comprehensive analysis. The study identified four primary paddy varieties cultivated by the respondents: Jyothi, JGL-1798, MTU-1001 and MTU-1010 representing the major paddy varieties in the region. Notably, the highest yield gap was observed in the JGL-1798 variety, recording a gap of 19.33 quintals per hectare, followed closely by MTU-1010 at 18.89 q/ha, MTU-1001 at 17.50 q/ha and Jyothi at 13.42 q/ha. The Jyothi variety exhibited the lowest yield gap, highlighting its superior adaptability and market preference. This study underscores the critical need to address the underlying factors contributing to yield gaps through enhanced agricultural practices and technology dissemination, ultimately fostering increased productivity and contributing to food security and farmers' income in Karnataka.

Keywords

agricultural practices; crop management; paddy cultivation; varietal performance; yield gap; yield optimization

Introduction

Paddy is one of the most consumed cereals and a staple food of South Asian countries. These countries collectively produce 90 % of the global paddy, with India contributing 10 % to global production. Rice and rice-based foods account for 31.5 % of India's calorific intake (1).

In India, paddy is grown in varied climates and seasons due to its wide adaptability. The area under paddy cultivation in India increased from 30.5 million hectares in 1949-50 to 43.49 million hectares in 2015-16. During the same period, production rose from 23.5 million tonnes to 104.40 million tonnes and productivity improved from 771 kg/ha to 2400 kg/ha (2). India's, total paddy yield gap is approximately 10.36 %, with Karnataka contributing 17.32 % to this gap (3). Recent studies highlight a decline in rice cultivation area and production due to various factors including declining water resources and market trends (4). The lack of suitable technologies and drought-resistant varieties significantly contributes to this trend, as many available options fail to address the specific challenges of drought-prone regions. High-water-requirement hybrid rice varieties, coupled with inefficient irrigation systems such as flood irrigation, are unsuitable for water-scarce regions. Adoption of these varieties is further hindered by limited extension services, high input costs and inadequate access to quality seeds (5, 6). This is due to high costs, inadequate dissemination and limited trust in new approaches. Past failures, lack of awareness and financial constraints further contribute to farmers' hesitation in adopting these technologies. Consequently, farmers are losing interest in rice cultivation and are shifting to cash crops such as vegetables and fruits. Sustaining current food grain production while minimizing damage to natural resources requires prioritizing research and development (7). Under these circumstances, the study on profile of paddy farmers, yield gap and varietal adoption, constraints and suggestions of the farmers in rice cultivation will be of great help to analyse and to know the factors responsible for the sustenance of the crop. This study will act as a guide of information in directing the policy makers, researchers and administrators, to chalk out suitable strategies for increasing the paddy yield in the respective region. Considering the aspects mentioned above, the study was conducted with a defined set of objectives of assessing the yield gap and adoption of paddy varieties and to study the constraints in cultivation of paddy in Shivamogga district of Karnataka.

Materials and Methods

This study was specifically conducted in Shivamogga district of Karnataka. Shivamogga district is part of the Malnad region, landlocked and bordered by Haveri, Devanagari, Chikkamangaluru, Udupi and Uttara Kannada districts. Paddy is a major crop in the district, cultivated on 1.01 lakh hectares. An *Ex-post* facto research design was used, involving 197 randomly selected paddy growers from six villages - Holehonnur, Kudligere, Kasaba, Ukkunda, Saaluru and Sunnadakoppa in Shivamogga district. The data were collected from respondents using a structured and validated interview schedule and analyzed through percentage analysis, cumulative frequency, correlation and Multiple Linear Regression analysis. Independent variables viz., age, educational status, annual income, farm size, farming experience, information seeking behaviour, extension agency contact, mass media exposure, social participation, economic motivation, innovativeness, marketing decisions for paddy crop and scientific orientation. These variables were selected based on expert evaluation. The study's dependent variable yield gap, was measured using the methodology proposed by the International Rice Research Institute (IRRI), Manila, Philippines. Yield variations among crops, caused by delays in technology dissemination and disparities in farmers' adoption levels, were analysed using yield gap analysis. The study estimated three components of the yield gap: total yield gap, Yield Gap I and Yield Gap II.

Potential yield (Yp) refers to the per-hectare yield achieved under ideal conditions at research stations, which include optimal management practices, sufficient irrigation, absence of pests and diseases and favourable climatic conditions. The term "Potential Farm Yield" or "Progressive Farmers' Yield" (Yd) indicates the highest yield recorded by a farmer within a specific farm size category. In contrast, Actual Yield (Ya) represents the per-hectare yield harvested by farmers under field conditions.

The Total Yield Gap (TYG): It is computed as the difference between the Potential Yield (Yp) and the Actual Yield (Ya). The Total Yield Gap comprises of Yield Gap I and Yield Gap II.

$$\mathbf{TYG = (Yp) - (Ya)} \qquad \text{(Eqn. 1)}$$

Yield Gap I (YG I): It is the difference between the Potential Yield and Progressive Farmers' yield.

$$\mathbf{YG\ I = (Yp) - (Yd)} \qquad \text{(Eqn. 2)}$$

Yield Gap II (YG II): It is the difference between the Potential Farm Yield and the Actual Yield.

$$\mathbf{YG\ II = (Yp) - (Ya)} \qquad \text{(Eqn. 3)}$$

Index of Yield Gap (IYG): It is the ratio of the difference between the Potential Yield and the Actual Yield to the Potential Yield expressed in percentage.

$$\mathbf{IYG = [\ (Yp) - (Ya)/\ Yp\ ] \times 100} \qquad \text{(Eqn. 4)}$$

where, (Yp) = Potential yield

(Yd) = Potential Farm Yield / Progressive farmers' yield

(Ya) = Actual Yield

Index of Realized Potential Yield (IRPY)

$$\mathbf{IRPY = [Ya/Yp] \times 100} \qquad \text{(Eqn. 5)}$$

where, (Yp) = Potential yield

(Ya) = Actual Yield

Index of Realized Potential Farm Yield (IRPFY)

$$\mathbf{IRPFY = [Ya/Yd] \times 100} \qquad \text{(Eqn. 6)}$$

where, (Ya) = Actual Yield

(Yd) = Potential Farm Yield / Progressive farmers' yield

Results and Discussion

Yield gap analysis was carried out with respect to the paddy varieties adopted by the farmers in the study area to identify key factors contributing to yield gaps. It was found that paddy varieties namely Jyothi, JGL-1798, MTU-1001 and MTU-1010 were grown by the respondents. Table 1 shows that all four varieties are old, highlighting the need to introduce and popularize region-specific high-yielding varieties to enhance productivity. The findings for the Total Yield Gap, Yield Gap I (YG I), Yield Gap II (YG II), Index of Yield Gap (IYG), Index of Realized Potential Yield (IRPY) and Index of Realized Potential Farm Yield (IRPFY) for the paddy varieties cultivated by the respondents are summarized in Table 2. As shown in Table 2, among the four varieties adopted by the respondents-Jyothi, JGL-1798, MTU-1001 and MTU-1010-the highest total yield gap was recorded for JGL-1798 (19.33 q/ha), followed by MTU-1010 (18.89 q/ha), MTU-1001 (17.50 q/ha) and Jyothi (13.42 q/ha). Table 2 and Fig. 1 show that JGL-1798 had the highest total yield gap (19.33 q/ha), while Jyothi recorded the lowest (13.42 q/ha), indicating better adaptability and performance. Besides, the market preference for Jyothi variety is also higher when compared to the other

Table 1. Details of paddy varieties grown by the respondents

S. No.	Varieties	Jyothi	JGL-1798	MTU-1010	MTU-1001
1.	Duration	115-125 days	125-130 days	120-125 days	130-135 days
2.	Released year	1977	2004	2000	2009
3.	Released by	Regional Agricultural Research Station, Pattambi, Kerala	Regional Agricultural Research Station, Jagtial, ANGRAU	ANGRAU	ANGRAU
5.	Characteristics of rice	Red and bold	Medium slender	Long and small	Bold
6.	Potential yield	55q/ha	50q/ha	50q/ha	50q/ha

Table 2. Overall yield gap of paddy varieties (n= 197)

S.No.	Variety	Number	Actual yield	YG I (q/ha)	YG II (q/ha)	TYG (q/ha)	IRPY (%)	IRPFY (%)	IYG (%)
1.	Jyothi	105	41.58	5.00	8.42	13.42	75.61	83.17	24.39
2.	JGL-1798	30	42.83	12.17	7.17	19.33	77.88	85.67	22.12
3.	MTU-1001	35	40.00	10.00	7.50	17.50	80.00	84.21	20.00
4.	MTU-1010	27	38.05	11.94	6.94	18.89	76.11	84.57	20.00

Note : YG I - Yield gap I; YG II - Yield gap II, TYG - Total Yield Gap; IYG - Index of Yield gap; IRPY - Index of Realized Potential Yield; IRPFY - Index of Realized Potential Farm Yield

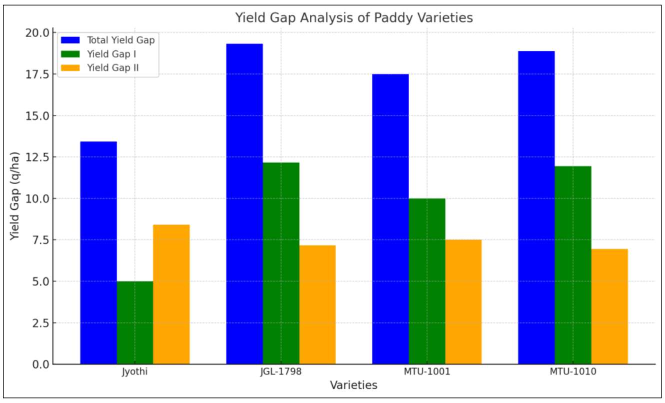

Fig. 1. Yield gap analysis of paddy varieties in Shivamogga district.

three varieties.

As shown in Table 2, the Index of Realized Potential Farm Yield (IRPFY) indicates that JGL-1798 achieved the highest farm-level performance among the varieties, followed closely by MTU-1010 and MTU-1001, with Jyothi showing slightly lower performance. These values reflect the degree to which farmers can realize the potential yields of these varieties under their current farming practices. Similarly, the Index of Realized Potential Yield (IRPY) highlights notable performance gaps across all varieties, suggesting significant room for improvement. Addressing constraints such as delayed transplanting, improper nutrient management and pest control could help farmers achieve closer to the varieties' potential yields. The results indicate that there exists potential to the tune of 14.33 % to 23.89 % to increase the yield in paddy varieties by adopting improved production technologies by the respondents. Respondents identified several reasons for the yield gap, including delayed transplanting of aged seedlings, improper management of fertilizers and micro-nutrients and indiscriminate use of plant protection chemicals. Limited labour availability during the peak seasons and lack of knowledge on improved production practices were also significant factors

Level of influence of independent variables on yield gap

Thirteen independent variables were considered for the study: age, educational status, annual income, farm size, farming experience, information-seeking behaviour, extension agency contact, mass media exposure, social participation, scientific orientation, economic motivation, innovativeness and marketing decision for the paddy crop. These variables were analyzed to determine their influence on the yield gap. Multiple regression analysis was used to identify the relationship between the independent variables and the yield gap of selected paddy varieties. Table 3 shows the correlation and regression results, highlighting the significant variables affecting the yield gap.

Table 3 reveals that the multiple regression analysis of the thirteen variables resulted in an R^2 (Coefficient of Multiple Determination) value of 0.734, indicating that these variables explain 73.40 % of the variation in the yield gap. Additionally, the F-value of 38.94 demonstrated statistical significance at the 1 % significance level, indicating that the regression model is robust and the variables collectively contribute to explaining the yield gap.

The independent variable, age (X_1), contributed positively and significantly to the yield gap at the 1 % significance level. This indicates that as the age of farmers increases, the yield gap tends to widen. Older farmers may be less inclined to adopt advanced agricultural practices and technologies, which can

Table 3. Correlation and multiple regression analysis of the selected independent variables

S.No.	Variables	'r' Value	Regression co-efficient	't' value
1.	Age	**0.630****	0.152	**2.468****
2.	Educational status	-0.015	-0.010	-0.468
3	Annual income	0.069	-0.020	-0.388
4.	Farm size	0.045	-0.027	-0.774
5.	Farming experience	-0.049	-0.014	-0.247
6.	Information seeking behaviour	0.113	0.006	0.131
7.	Extension agency contact	-0.041	0.022	0.288
8	Mass media exposure	-0.016	0.017	0.331
9.	Social participation	0.118	0.006	0.109
10.	Scientific orientation	**-0.141***	0.051	-0.862
11.	Economic motivation	**-0.390****	-0.337	**-5.028****
12.	Innovativeness	**-0.818****	-0.704	**-12.651****
13	Marketing decision for paddy crop	**-0.160***	-0.070	-1.311

R^2 = 0.734   * * = significant at 1 % level

F = 38.942   * = significant at 5 % level result in lower productivity and larger yield gaps compared to younger, more innovative farmers. Innovativeness (X_7) and Economic motivation (X_{10}) had shown a negative and significant association with yield gap at a 1 % significance level, indicating that farmers who are more innovative and economically motivated experience lower yield gaps due to their proactive adoption of improved technologies and practices. Whereas, Scientific orientation (X_{11}) and Marketing decision (X_{13}) showed a negative significance at 5 % significance level. This suggests that farmers with higher scientific orientation and better marketing strategies are able to minimize yield gaps. The prediction equation fitted for the yield gap of paddy farmers is given below.

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$Y = \text{constant} + 0.152\,(X_1) - 0.010\,(X_2) - 0.027(X_3) - 0.014\,(X_4) - 0.020\,(X_5) + 0.006\,(X_6) - 0.704\,(X_7) + 0.022\,(X_8) + 0.006\,(X_9) - 0.337\,(X_{10}) + 0.051\,(X_{11}) + 0.017\,(X_{12}) - 0.070\,(X_{13})$.

Age (X_1) was identified as having a positive and highly significant relationship at the 1 % significance level. Ceteris paribus, a one-unit rise in age would lead to a 0.152-unit increase in the yield gap of paddy farmers. It indicates that as age increases the yield gap also gets increased as the old farmers may not take interest in adopting improved practices.

The variables innovativeness and economic motivation were negatively correlated and found to be statistically significant at the 1 % significance level. This indicates that a unit increase in innovativeness and economic motivation, *ceteris paribus*, would decrease the yield gap of paddy farmers by 12.651 and 5.028 units respectively. It indicates that the paddy growers who are innovative and economically motivated are experiencing a lower yield gap than others.

The results show that the majority of the respondents are young and middle-aged and they are eagerly practicing newly introduced practices on their farms without much hesitation, which results in a low yield gap (8). The yield gap trends observed align with national data, as Karnataka exhibits a higher -than-average yield gap, echoing systemic challenges faced in other states like Uttar Pradesh and Tamil Nadu (9). On a global scale, these findings align with studies from Bangladesh, which emphasize similar barriers to technology adoption (6). Addressing these gaps through region-specific strategies could significantly enhance rice productivity and farmer incomes.

Other variables such as educational status (X_2), farm size (X_3), farming experience (X_4), annual income (X_5), social participation (X_6), extension agency contact (X_8), information seeking behaviour (X_9), decision making behaviour (X_{11}), mass media exposure (X_{12}) and marketing behaviour (X_{13}) were found to be non-significant.

Constraints encountered in paddy cultivation

Constraints faced by the respondents in paddy cultivation were assessed using open-ended questions and responses were categorized into thematic groups as shown in Table 4.

Table 4 shows that the majority of respondents (82.74 %) faced challenges related to poor soil health and difficulty in obtaining farmyard manure (FYM), categorized under "other constraints." Non-availability of labour during peak planting and intercultural operations was reported by 76.14 % of respondents, making it the second most significant issue. Additionally, 75.63% of farmers highlighted the need for high-yielding varieties, while 70.05 % struggled with pest and disease management. Lack of knowledge about recommended rice cultivation practices was noted by 57.36 % of respondents and 38.07 % cited a lack of credit facilities as a constraint.

Conclusion

Yield gap is one of the major determinants that impact food production, productivity and income of the farmers. It was evident from the study that there exists a yield gap in all the paddy varieties cultivated by the respondents due to various constraints that include non-availability of high-yielding varieties and need for adoption of improved crop production practices, labour shortage and credit needs. The findings highlight the need to introduce and demonstrate high-yielding paddy varieties and improved crop production technologies. Capacity building of farmers, promotion of farm mechanization and access to credit are facilities to reduce the yield gap and improve farmers' livelihood. This is evident that similar yield gap studies on major crops have to be taken up periodically in various locations to give directions to researchers and extension workers for deploying strategies to increase the productivity of crops.

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Table 4. Constraints in paddy cultivation

S. No.	Constraints	Number	Percentage	Rank
1.	Need for high yielding varieties	149	75.63	III
2.	Non-availability of labour on time	150	76.14	II
3.	Difficulty in management of Pest & diseases	138	70.05	IV
4.	Lack of credit facilities	75	38.07	VI
5.	Lack of knowledge on recommended rice cultivation practices	113	57.36	V
6.	Other constraints (Poor soil health, difficulty in getting FYM)	163	82.74	I

* Multiple responses

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Authors' contributions

SM conceived the study, participated in its design and coordination and drafted the manuscript. SA carried out the formal analysis, investigation and data curation. MV and KPT contributed to the writing, review and editing of the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: The authors declare that they have no competing interests regarding the work presented in this manuscript.

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