

2

An Impact of Farmers Producer Organisation to Produce Climate Resilient Paddy Seed in the North-Eastern State Tripura

Kiran Bhowmik* & Srijan Debnath**

Abstract

The rainfall patterns have been erratic, and spatial and temporal distribution has been noticed in the last few years due to a gradual and adverse change in climate in Tripura. Climate change has adversely affected paddy area coverage, production, and productivity during the Aush and Aman seasons. To combat the climate change situation, the Indian Council of Agricultural Research (ICAR) in Tripura has released varieties of rice viz., Gomati Dhan, Tripura Hakuchuk-2, Tripura Nirog, and Tripura Chikan Dhan, which have constituted more than seventy-three percent of the total breeder seed indent from the Government of Tripura. To increase climate change-resilient seed production for paddy in the state of Tripura, the National Bank for Agriculture and Rural Development (NABARD)-sponsored FPO has positively impacted paddy seed productivity for the varieties of rice Gomati Dhan and Tripura Nirog. NABARD's intervention has significantly increased farmers' income, highlighting its effectiveness in enhancing agricultural profitability and rural livelihoods. The estimated results of

* Research Scholar of Department of Economics and Research Associate, Study on Evaluation of Finances of State of Tripura, Tripura University (A Central University), Suryamaninagar, West Tripura

** Reaserch Assistant, Study on Evaluation of Finances of State of Tripura, Department of Economics, Tripura University (A Central University), Suryamaninagar, West Tripura

the Cobb-Douglas Production Function for Paddy Seed Productivity have suggested that the inputs provided by FPO viz., manure and nitrogen have positively influenced yield or productivity of paddy; therefore, farmers should be encouraged to use balanced organic and chemical fertilisers to sustain soil fertility. Soil testing and precision nutrient management have been promoted. It is also important to enhance labour efficiency through hands-on training with the help of ICAR scientists by FPO because labour input has significantly contributed to productivity. The positive impact of Integrated Pest Management (IPM) suggests that integrated pest control strategies should be expanded, reducing dependency on chemical pesticides and improving sustainability. The seed certification process has needs to be shortened in order to optimise farmers' profits and expedite approvals. For more storage and processing facilities, post-harvest infrastructure has to be strengthened in order to preserve seed quality and minimise losses. In order to guarantee farmers, receive higher rates for their certified seeds, the FPO has helped them establish direct market linkages.

Keywords: Climate Change, Seed, Productivity, FPO and Income.

Introduction

The state has become a surplus producer of certified HYV paddy and mustard seeds. The seed replacement rate (SRR) of HYV-certified paddy has been maintained at the optimum level of 33 per cent for the last few years. In the case of mustard, the SRR has reached 50 per cent. Steps have been taken to achieve self-sufficiency in HYV pulses, groundnuts, and sesamum seeds. The HYV paddy seed replacement rate has been recorded at 39 per cent. The production of HYV-certified paddy seeds reached 1435.30 MT during 2022-23.

The farm sector has played a key role in strengthening the economy, improving inclusive growth, ensuring sustainable development, and addressing climate change. Poverty reduction has occurred with investment in agriculture, focusing on improved agricultural practices. These practices have included improving the efficacy of farmland by halting and reversing deteriorating

soil health, encouraging crop diversification, promoting the usage of certified seeds, practising sustainable water management with rainwater harvesting and preservation of rainwater, developing local agricultural marketing, and using technology.

A special initiative has been taken to make the state self-sufficient in HYV seed production. Now, the state has produced a surplus quantity of HYV seeds of paddy and mustard. The surplus production has been marketed to the North Eastern States through the National Seed Corporation (NSC).

Fig. 1 presents the month-wise variation of high temperatures from 2001 to 2023. Each month has recorded different high temperatures over this period, reflecting seasonal changes and climate patterns.

January has recorded a high temperature of 3.35 square degree Celsius, while February has slightly decreased, reaching 2.75 square degree Celsius. March has witnessed a rise, with a high of 3.59 square degree Celsius, and April has continued this trend, recording 4.05 square degree Celsius. May has experienced a decline in temperature, with a recorded high of 1.90 square degree Celsius. June also showed a slight decrease, reaching 1.70 square degree Celsius. However, July recorded the highest temperature at 6.11 square degree Celsius, marking a significant peak.

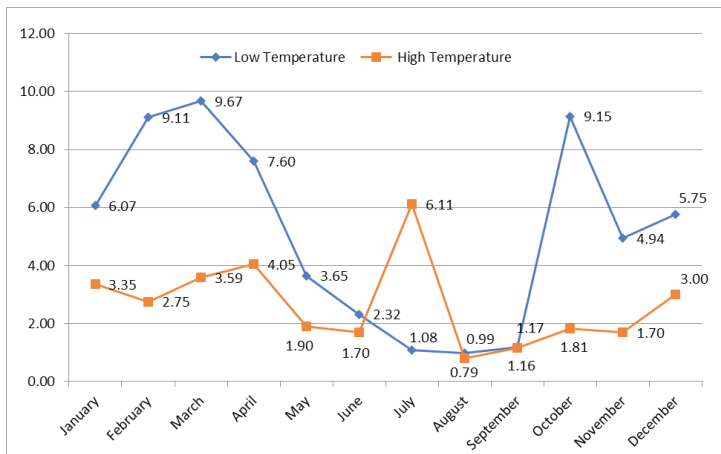
August saw a drop in temperature, with a high of 0.79 square degree Celsius, while September saw a slight increase, reaching 1.16 square degree Celsius. October has shown a further rise, with a high temperature of 1.81 square degree Celsius. November has maintained a similar trend, recording a high of 1.70 square degree Celsius. Finally, December has increased again, with a high temperature of 3.00 square degree Celsius.

The data has indicated significant fluctuations in low temperatures throughout the year, highlighting seasonal variations and long-term climate trends over the analysed period from the year 2001 to 2023. Each month has recorded different low temperatures over this period, reflecting seasonal changes and climatic patterns.

January has recorded a low temperature of 6.07 square degree Celsius. February has increased, reaching 9.11 square degree Celsius, while March has witnessed a further rise, recording 9.67 square degree Celsius. April has experienced a slight decrease, with a low temperature of 7.60 square degree Celsius.

May has recorded a significant drop in temperature, reaching 3.65 square degree Celsius. June has continued this trend, with a low temperature of 2.32 square degree Celsius. July has witnessed the lowest temperature of the year at 1.08 square degree Celsius, indicating the coldest month.

Fig. 1. Month-wise variation of temperature during the year 2001 to 2023 (in degree Celsius)



Source: Insert based on data collected from <https://www.indiastat.com/>

August has maintained a similar trend, recording a low temperature of 0.99 square degree Celsius, while September has slightly increased, reaching 1.17 square degree Celsius. October has shown a sharp rise, with a low temperature of 9.15 square degree Celsius. November has declined, with a low temperature of 4.94 square degree Celsius, while December has witnessed a slight increase, reaching 5.75 square degree Celsius.

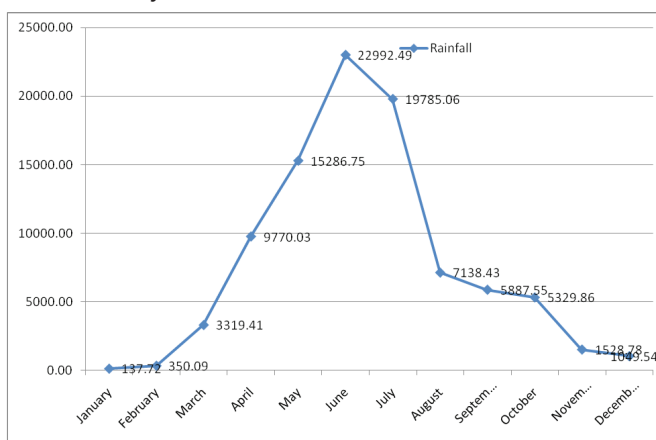
Fig. 2 clearly shows a distinct seasonal variation in rainfall, with the highest levels having occurred between May and July. This trend has been crucial for understanding water resource management, agricultural planning, and climate patterns. Such data analysis has helped prepare for droughts, floods, and water conservation strategies, ensuring sustainable environmental and economic development.

Rainfall has played a crucial role in maintaining ecological balance and supporting agriculture, water resources, and

biodiversity. The given data has presents a month-wise variation in rainfall recorded over a period of 22 years, from 2001 to 2023. This information has provided insights into seasonal patterns and trends in precipitation across different months of the year.

January has received 137.72 square mm of rainfall, marking a relatively dry start to the year. February has recorded a slight increase, reaching 350.09 square mm. However, March has witnessed a notable rise, with rainfall reaching 3319.41 square mm, signalling the transition to a wetter season. April has seen further growth in rainfall, recording 9770.03 square mm. The trend continued in May, which experienced 15286.75 square mm, reflecting the onset of monsoon activity.

Fig. 2. Month-wise variation of rainfall during the year 2001 to 2023 (in millimetre)



Source: Insert on the basis of data collected from <https://www.indiastat.com/>

June has recorded the highest rainfall, reaching an impressive 22992.49 square mm. July has followed closely with 19785.06 square mm, highlighting the peak of the monsoon season. These months have contributed significantly to annual water availability. August has recorded a decrease in rainfall, measuring 7138.43 square mm. The declining trend has continued in September, which has received 5887.55 square mm, and October, which has recorded 5329.86 square mm. This period has marked the gradual retreat of monsoon rains.

The dry season began to take effect in November, with rainfall reduced having reduced to 1528.78 square mm. By December, the precipitation has further decreased to 1049.54 square mm, marking the end of the rainy period for the year.

Literature Reviews

There has been a significant decline in rice productivity due to climate change. Adopting Direct Seeded Rice (DSR) options has significantly improved rice productivity and resilience, providing the additional benefit of advancing the seeding of succeeding crops by 15 days compared to the mechanically transplanted rice system. The DSR option has sustained food security and crop resilience under adverse climatic conditions (Jat et al., 2022). In order to meet future rice demands, it is now crucial to breed climate-robust rice types. In the upcoming years, rice output has had to be maintained because of the crop's heightened vulnerability to severe biotic and abiotic problems, including unexpected drought and submergence brought on by shifting climatic conditions. Inland salinity, seawater intrusions, and increased drought and submersion events have all presented significant risks to rice production. Along with modern breeding methods for climate-resilient rice, it has become necessary to address the impending challenges to long-term sustainable rice production in the face of global climate change (Suresh et al., 2024). It has been important to follow technological, infrastructural, and policy-level suggestions to increase productivity, profitability, climate resilience, and sustainability of rice production through research and re-orientation with farmers' participatory approach (Pathak et al., 2018). Systems genetics is a new field that can speed up the identification of novel alleles to create rice varieties with better grain quality and resistance to environmental factors (Sreenivasulu et al., 2015). With the help of Climate Change-Resilient Rice Production Technology (CRRPT), rice seedlings can now be kept in the seedbed for a longer time to coincide with the arrival of monsoon rains. Moreover, it has been profitable, water-efficient, climate change-resistant, and simple for farmers to implement (Biswas et al., 2019). Adopting resilient rice production systems has improved rice productivity and yield potential, especially in rice-growing areas where water scarcity has already prevailed. The successful transition from the traditional flooded system to

improved resilient rice production has been necessary to increase production. Resilient rice production systems, such as aerobic rice, SRI, GCRPS, AWD system, DSR, and drum-seeded rice, have been found to be very effective in water-stressed areas and for resource-poor farmers (Yadav et al., 2015). Climate-resilient cultivars can guarantee increased productivity and climate risk adaptation if they are widely introduced and popularised in Bangladesh (Nayak et al., 2022). The seed dormancy of local landraces has exhibited variation, and high-dormancy genotypes, such as Bari Mota and Tulsimala, have been cultivated in disaster-prone coastal areas of Bangladesh (Bristy et al., 2025). In eastern India, rice fields have been inundated by recent cyclonic storms with heavy rainfall during the October–November grain maturity period, which has had a major impact on rice yield. The market worth of produce has decreased due to viviparous germination, which has compromised the food quality of rain-soaked seeds. The introduction of wild seed dormant traits into high-yielding, non-dormant rice varieties has helped maintain rice production's stability in light of the growing frequency of these calamities (Mohapatra & Kariali, 2016). Improved production techniques, including crop establishment techniques, water and weed control, nutrient management, and the use of microbial resources that increase cropping systems' resistance to extreme weather events, have been followed, and the effects of climate change on rice crops have been understood. Using climate-resilient production technology has improved the resilience of rice production systems (Shahid., 2021).

In light of climate change, the study's emphasis on how Farmers' Producer Organizations (FPOs) may increase the yield of climate-resilient rice cultivars like Gomati Dhan and Tripura Nirog is essential. Significant obstacles to agriculture are presented by climate change, such as a rise in the frequency of extreme weather events, changes in rainfall patterns, and increased susceptibility to diseases and pests. To lessen these difficulties and guarantee food security, it is crucial to develop and promote rice varieties that are climate resilient. Successful adoption of climate-resilient techniques can be facilitated and hindered by examining the variables that affect changes in agricultural productivity among farmers connected to FPOs. Knowing this information is

essential for creating focused interventions that tackle the unique difficulties faced by farmers in the northeastern Indian state and other comparable areas.

Objectives of the Study:

The present study mainly focuses on two aspects: the impact of Farmers' Producer Organizations (FPOs) on increasing the productivity of climate-resilient rice seeds, viz. Gomati Dhan and Tripura Nirog. The objective of the study also focused on the change in farmers' income in Tripura because of climate-resilient rice seed production in the North Eastern state of India. One more objective is to study the factors that influence changes in agricultural productivity among farmers associated with FPOs. These farmers benefit from modern technology and various support from the NABARD-sponsored project under the Farm Sector Promotion Fund (FSPF) to improve their agricultural activities for climate-resilient rice seed production.

This study is significant because it examines how economic consequences, agricultural innovation, and community organisation interact with climate change. Its conclusions can help create plans to strengthen rice farming systems' resilience, guaranteeing food security and long-term livelihoods in areas that are at risk.

Methodology of the Study:

This study uses two types of methodology: data collection and data analysis, followed by policy decisions to benefit the farming community in Tripura, a northeastern agrarian state of India. The data comes from farmers who receive benefits from the National Bank for Agriculture and Rural Development (NABARD) sponsored FPO, Bagma Agri Producer Company Limited (BAPCL), located in Bagma Village under Tepania Rural Development Block in Gomati District, Tripura. The beneficiary list has been taken from BAPCL, an FPO that benefits farmers under a sponsored project by Seed Village.

The primary data has been collected from farmers with the help of scheduled questionnaires designed for the study in accordance with the study's objectives. The data was collected from eighty-three farmers who received benefits from the NABARD-sponsored

project. The NABARD project has been funded under the Farm Sector Promotion Fund (FSPF) to enhance the productivity of agriculture and allied sectors and create market sectors.

Primary data were collected using purposive sampling from the beneficiaries in West Khupilong and Dakshin Bagma Gram Panchayat. To know about the impact of the NABARD-sponsored project, apart from the field survey, a focus group discussion was held at the village level in the presence of beneficiaries.

Table 1. Sampling design in accordance with the category of the beneficiaries

Name of the Patches	Name of the Villages under Tepania R.D Block of Gomati District in Tripura	Varieties of Rice Seed Produced	Beneficiaries among Farmers [in Nos.]
Patch-I	Dakshin Bagma	Gomati Dhan	16
Patch-II	Dakshin Bagma		13
Patch-III	Dakshin Bagma		11
Patch-IV	Dakshin Bagma		12
Patch-V	West Khupilong	Tripura Nirog	31
Total	2 Nos. Villages		83

Source: Bagma Agri Producer Company Limited (BAPCL)

The total sampling design is shown in Table 1.1. The respondents are selected similarly to beneficiaries from Dakshin Bagma and West Khupilong villages under the Udaipur Subdivision of Gomati District. The beneficiaries are selected for the paddy seed production under the Seed Village project of NABARD, which BAPCL implements in two different village areas with five patches. The beneficiaries in Dakshin Bagma village are Patch-I (16), Patch-II (13), Patch-III (11), Patch-IV (12), and in West Khupilong, Patch-V (31). A total of 83 beneficiaries responded with their observations during data collection.

Methodology for Data Analysis:

In the case of data analysis, advanced statistical and econometric techniques were used. To examine the impact of the project

sponsored by NABARD under the farm sector promotion fund in view of enhancing the productivity of agriculture and allied sectors and creating market access, the paired t-test is used. The hypotheses are constructed for the present study in accordance with the following:

Null Hypothesis: $H_0: \mu_1 - \mu_2 = 0$, there is no difference in the average productivity of paddy and farmers' income before and after receiving the benefit of the NABARD-sponsored project with the help of the FPO-based company Bagma Agri Producer Company Limited (BAPCL).

Alternative Hypothesis: $H_1: \mu_1 - \mu_2 \neq 0$, there is a difference in the average productivity of paddy and farmers' income before and after receiving the benefit of the Seed Village Project under the NABARD Farm Sector Promotion Fund with the help of the FPO-based company BAPCL in Tripura.

Where, μ_1 and μ_2 are the average productivity of paddy and farmers' income before and after receiving the benefit of the Seed Village Project under the NABARD.

In this case, the test statistic is written with the help of the following structure;

$$t = \frac{(\bar{X}_1 - \bar{X}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{s_1^2}{n} + \frac{s_2^2}{n}}} \sim t_{(n-1)+(n-1)}$$

Where, $s_j^2 = \frac{\sum_{i=1}^n (X_i - \bar{X}_j)^2}{(n-1)}$, for all $j=1$ and 2 in case of two samples and for all $i=1, 2, 3, \dots, n$

In the case of the present discussion, $\bar{X}_1$ and $\bar{X}_2$ are the average sample parameters of the productivity of paddy and the average income of the beneficiaries before and after getting benefits from the sponsored scheme by BAPCL.

Where, s_1^2 and s_2^2 are the sample variance of paddy productivity and the beneficiaries' average income before and after receiving the benefits in the NABARD-sponsored project.

In this case, the decision to be taken with the direction is that, if the observed value of the paired t-test exceeds the table value of the t-distribution with $(2n-2)$ degrees of freedom, then the null hypothesis is rejected, which means the test is significant. The test is significant, which means there is a difference in productivity and average annual income before and after receiving the benefits of NABARD sponsored project. If the observed value is less than the table value of the t-distribution $(2n-2)$ degrees of freedom, the null hypothesis is accepted, and the test is insignificant.

Factors like seed, labour, manure, and fertiliser are important for the productivity of paddy among farmers associated with FPOs. These factors influence changes in agricultural productivity among these farmers. They benefit from modern technology and various supports from the NABARD-sponsored project under the Farm Sector Promotion Fund (FSPF) to improve their agricultural activities.

To identify the determinants of paddy productivity under the NABARD-sponsored project with the financial outlay of the Farm Sector Promotion Fund (FSPF), the study analyses the dependence of the dependent variable on the independent variables. It aims to predict the elasticity for a one per cent change in independent variables and uses the expected value of dependent variables. The factors considered important for paddy productivity are mentioned in Table 2.

Table 2. Details of the study variables used for the analysis

Variables	Code	Unit	Description
Paddy Productivity	Inyield	Kg/ Kani	Average paddy production
Labour	Inlabour	Person	Paddy production is still labour-intensive in the state Tripura
Seed	Inseed	Kg	ICAR quality seeds used by farmers in the Seed Village project

Manures	lnmanures	Kg	Manures used are important for paddy productivity.
Nitrogen	lnnitrogen	Kg	Proper nitrogen application improves grain quality and overall crop productivity.
Phosphorus	lnphosphorus	Kg	Phosphorus also plays a key role in energy transfer and nutrient uptake, which improves flowering, grain formation, and overall yield.
Potassium	lnpotassium	Kg	Potassium is important for increasing paddy productivity because it helps strengthen plant cells, improve drought resistance, and enhance disease resistance.
Integrated Pest Management (IPM)	lnipm	ml	IPM is important for paddy productivity because it helps control pest populations in an environmentally sustainable way.

Source: Author's Estimation

Table 2 shows various variables related to paddy productivity. The variables $\ln\text{yield}$, $\ln\text{labour}$, $\ln\text{seed}$, $\ln\text{manures}$, $\ln\text{nitrogen}$, $\ln\text{phosphorus}$, $\ln\text{potassium}$ and $\ln\text{ipm}$ are variable that likely represent logarithm of paddy productivity ($\ln\text{yield}$), logarithm of labour ($\ln\text{labour}$), logarithm of seed ($\ln\text{seed}$), logarithm of manures ($\ln\text{manures}$), logarithm of nitrogen ($\ln\text{nitrogen}$), logarithm of phosphorus ($\ln\text{phosphorus}$), logarithm of potassium ($\ln\text{potassium}$) and logarithm of integrated pest management ($\ln\text{ipm}$).

The data is collected from eighty-three beneficiaries through a survey, and Table 3 presents descriptive statistics for the selected variables in the study. The study focuses on understanding the

factors influencing paddy productivity and the impact of various inputs on farmers' output. It examines labour, seed quality, manures, fertilisers, and pest management practices. The results help analyse the relationship between these factors and paddy production, providing insights into ways to improve agricultural productivity in the region.

The descriptive statistics of the collected data have provided valuable insights into various agricultural factors. The mean values have shown that the average yield has been 395.94 units, while labour usage has averaged 24. The mean seed usage has been 4 Kg, and manure application has reached 976 Kg. The application of nitrogen, phosphorus, and potassium has averaged 25.02 Kg, 31.42 Kg, and 8.64 Kg, respectively. Integrated Pest Management (IPM) implementation has an average value of 337.83 ml.

Table 3. Descriptive statistics of the various agricultural factors, including productivity

Descriptive Statistics	Yield	Labour	Seed	Manures	Nitrogen	Phosphorus	Potassium	IPM
Mean	395.94	23.602	4.23	976.39	25.02	31.42	8.64	337.83
Median	400	20	3	1000	22.5	25	7.5	300
Maximum	545	72	15	486.96	60	80	20	800
Minimum	50	5	1	110	3	6	2.5	80
Std. Dev	84.45	14.36	3.17	2000	15.17	17.7	4.2	184.7
Skewness	-0.671	1.279	1.243	0.504	0.801	0.927	0.884	0.83
Kurtosis	4.741	4.656	4.33	2.18	2.762	2.965	2.872	2.68
Observations	83	83	83	83	83	83	83	83

Source: Calculated from the data collected by field survey

The maximum recorded values have shown a peak yield of 545, a labour usage of 72, and a maximum seed usage of 15. The highest manure application has reached 486.96, while the maximum application of nitrogen, phosphorus, and potassium has been 60, 80, and 20, respectively. The adoption of IPM has reached a maximum of 800.

Conversely, the minimum values have indicated that some farms have had a yield as low as 50, with labour usage as low as five and seed application at only one. The minimum manure application has been 110, and the lowest nitrogen, phosphorus, and potassium application levels have been recorded at 3, 6, and 2.5, respectively. The adoption of IPM has been as low as 80 in some cases.

The standard deviation has highlighted variations across different parameters, with yield deviating by 84.45, labour usage by 14.36, and seed application by 3.17. The manure application has shown a high deviation of 2000, while nitrogen, phosphorus, and potassium application levels have deviated by 15.17, 17.7, and 4.2, respectively. IPM adoption has varied by 184.7 units.

The skewness values have revealed that yield has been negatively skewed. At the same time, other variables such as labour, seed usage, and nutrient applications have exhibited positive skewness, indicating a tendency for higher values in the distribution. The kurtosis values have suggested that most distributions have been moderately peaked, with yield and labour usage exhibiting higher kurtosis than other variables.

The study has analysed 83 observations for each parameter, ensuring a comprehensive understanding of agricultural inputs and their distribution across the surveyed farms.

Econometric Modelling:

This study used the log-log model to determine the change in independent variables labour, seed, manures, nitrogen, phosphorus, potassium, integrated pest management, and the expected change in paddy productivity.

The functional form of the model is given below;

$$Yield_i = A Labour_i^{\beta_1} Seed_i^{\beta_2} Manures_i^{\beta_3} Nitrogen_i^{\beta_4} Phosphorus_i^{\beta_5} Potassium_i^{\beta_6} IPM_i^{\beta_7}$$

The log-log regression equation can be rewritten by taking the log on both sides with the following technique;

$$\ln \text{yield}_i = \beta_0 + \beta_1 \ln \text{labour}_1 + \beta_2 \ln \text{seed}_2 + \beta_3 \ln \text{manures}_3 + \beta_4 \ln \text{nitrogen}_4 \\ + \beta_5 \ln \text{phosphorus}_5 + \beta_6 \ln \text{potassium}_6 + \beta_7 \ln \text{ipm}_7 + \varepsilon_i$$

where, $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6$ and β_7 are the coefficients in the log-log regression equation mode, and $\log A = \beta_0$ intercept. The error term in the model is ε_i .

Results and Discussions

The table has shows that the NABARD-sponsored FPO has positively impacted paddy productivity across all patches. The improvements have been statistically significant, as indicated by the t-test and probability values. Across all patches, the mean productivity has risen from 1039.16 kg to 1181.69 kg. The overall t-test value (10.097) and p-value (0.000) confirm a significant positive impact of the NABARD-sponsored FPO intervention.

Table 4. Patch-wise and overall impact of NABARD sponsored FPO on paddy productivity

Name of the Patches	Name of the Villages	Mean Productivity of Paddy before (in kg)	Mean Productivity of Paddy after (in kg)	t-test	Prob.
Patch-I	Dakshin Bagma	825	983.75	9.116	0.000
Patch-II		1384.62	1590	7.287	0.000
Patch-III		1363.64	1575.46	8.168	0.000
Patch-IV		837.5	938.33	7.623	0.000
Patch-V	West Khupilong	967.741	1067.097	3.23	0.001
Overall		1039.16	1181.69	10.097	0.000

Source: Calculated from the data collected by field survey

Table 4 presents the impact of the NABARD-sponsored Farmers Producer Organizations (FPOs) on paddy productivity in different patches (regions). The data compares the mean productivity of paddy (in kg) before and after the intervention. The t-test values and probability (p-values) indicate the statistical significance of the changes.

In Patch-I under Dakshin Bagma village, the mean of paddy productivity has increased from 825 kg to 983.75 kg, with a t-test value of 9.116 and a p-value of 0.000, showing a significant impact. A t-test value of 7.287 and a p-value of 0.000 confirm a significant improvement in mean productivity, which rises from 1384.62 kg to 1590 kg in the case of Patch-II. The paddy yield increases from 1363.64 kg to 1575.46 kg in Patch-III, indicating a statistically significant influence with a t-test value of 8.168 and a p-value of 0.000. There is a significant change as the productivity increases from 837.5 kg to 938.33 kg, with a t-test value of 7.623 and a p-value of 0.000 in Patch-IV. There is a statistically significant increase in rice productivity from 967.741 kg to 1067.097 kg in Patch-V under West Khupilong, as indicated by a t-test value of 3.23 and a p-value of 0.001.

Table 5 presents a structured timeline of activities implemented by the NABARD-sponsored FPO to support paddy cultivation and seed certification. The process has been systematically designed to ensure high-quality seed production and efficient farm management.

Table 5. Structured Timeline of Activities Implemented by the NABARD-Sponsored FPO

Sl. No.	Activities	Duration from Trans Plantation
1	Pre-Season Training	Before Plantation
2	Demo-cum-Training at the time of planting sowing	20 to 25 Days
3	Organising visits by technical experts during the programme from KVK/ICAR/ Department of Agriculture	26 to 40 Days
4	Demo-cum-Training on Plan Protection	41 to 50 Days

5	Inspection by Seed Certification Officer from Seed Register Office (SRO)	51 to 70 Days
6	Demo-cum-Training at the time of rouging	71 to 90 Days
7	Extension materials include an information brochure, field display boards, etc.	91 to 130 Days
8	Visit of Seed Certification Officer	131 to 150 Days
9	Demo-cum-Training at the time of harvest, post-harvest handling and processing by ICAR, KVK and agriculture expert	151 to 160 Days
10	Harvesting by Farmers	161 to 170 Days
11	Sending a sample of seed to get approval for seed certification by farmers from SRO	171 to 185 Days
12	Certification received by farmers from SRO	186 to 210 Days
13	Selling seeds to government authority at Rs. 24 Per Kg	211 to 220 Days
14	Received money from government authority as a return	221 to 310 Days

Source: BAPCL Office at Bagma under Gomati District in Tripura

Training on pre-seasonal activities has been conducted before the plantation to equip farmers with essential knowledge. At this stage, plants have established themselves, and farmers need practical guidance on nutrient management, irrigation, and pest control. Farmers have learned firsthand about proper techniques for weeding, fertiliser application, and disease management. Farmers have been introduced to new technologies, such as bio-fertilisers, mulching, and precision farming tools. Demo-Cum Training 20–25 days after transplantation has ensured that farmers have received timely, practical, and hands-on guidance to enhance crop productivity, reduce losses, and adopt sustainable farming practices. The visits by technical experts from Krishi Vigyan Kendra (KVK), the Indian Council of Agricultural Research (ICAR) and the Agriculture Department have been organised between 26 to 40 days, providing farmers with expert insights on

crop management. Demo-cum training on plant protection has been conducted over 41 to 50 days, ensuring farmers adopt the best pest and disease control measures.

Inspection by the Seed Certification Officer from the Seed Register Office (SRO) has occurred between 51 to 70 days, verifying the quality of crops. A demo-cum training during rouging has been carried out from 71 to 90 days, helping farmers remove undesirable plants to maintain seed purity. The extension materials like leaflets, brochures, and field display boards have been distributed between 91 to 130 days, providing farmers with additional learning resources. A second visit by the Seed Certification Officer has been scheduled between 131 to 150 days to assess seed quality further. The demo-cum training during harvest and post-harvest handling has been organised from 151 to 160 days, ensuring proper storage and processing.

Farmers have started harvesting the crops between 161 to 170 days, completing the primary cultivation phase. Seed samples were sent for certification approval from the SRO between 171 and 185 days. Farmers have received seed certification from the SRO within 186 to 210 days, marking the official recognition of seed quality. Certified seeds have been sold to the government authority at Rs. 24 per kg from 211 to 220 days. Farmers have received payments from the government authority between 221 to 310 days, ensuring financial returns from their certified seed production.

As pre-season and ongoing training have played a crucial role, more specialised training programs should be introduced to improve farmers' technical knowledge. Efforts should be made to reduce the seed certification timeline, allowing farmers to receive approvals faster and maximise their earnings. The FPO should facilitate direct market connections to ensure farmers get better prices for their certified seeds. It is important to strengthen post-harvest infrastructure for more storage and processing facilities to maintain seed quality and prevent losses.

Table 6 presents the patch-wise and overall impact of the NABARD-sponsored Farmer Producer Organisation (FPO) on increasing farmers' income. It has shown the mean income of farmers before and after the programme's implementation across different patches and villages.

Table 6. Patch-wise and overall impact of NABARD-Sponsored FPO to increase farmers' income

Name of the Patches	Name of the Villages	Mean income of farmers before (in Rs.)	Mean income of farmers after (in Rs)	t-test	Prob.
Patch-I	Dakshin Bagma	15675	23610	9.345	0.000
Patch-II		26307.69	38160	8.010	0.000
Patch-III		25909	37810.91	8.124	0.000
Patch-IV		15912	22520	8.959	0.000
Patch-V	West Khupilong	18387	25610	7.584	0.000
Overall		19744	28360	15.751	0.000

Source: Calculated from the data collected by field survey

According to the table, NABARD's intervention has significantly increased farmers' income in all patches. For instance, in Patch-I (Dakshin Bagma), the mean income has risen from Rs. 15,675 to Rs. 23,610, while in Patch-V (West Khupilong), it has increased from Rs. 18,387 to Rs. 25,610.

Similarly, Patch-II, Patch-III, and Patch-IV have also witnessed substantial growth in farmers' earnings, as reflected in their t-test values, which indicate statistically significant improvements. The probability (Prob.) values of 0.000 have confirmed that the changes in income are highly significant.

The NABARD-sponsored FPO initiative has boosted farmers' income from Rs. 19,744 to Rs. 28,360, highlighting the program's effectiveness in enhancing agricultural profitability and rural livelihoods.

The Cobb-Douglas production function estimation for paddy productivity is shown in Table 7, which also illustrates how different inputs affect yield. The findings have shown that some factors have significantly impacted paddy productivity, including labour, manure, nitrogen, phosphorus, and integrated pest management (IPM).

Table 7. Estimation of the Cobb-Douglas Production Function for Paddy Productivity

Inyield	Coef.	Std. Err.	t	P> t
lnlabour	0.24222*	0.07451	3.25	0.002
lnseed	0.0652***	0.03828	1.7	0.093
lnmanures	0.11399*	0.04074	2.8	0.007
lnnitrogen	0.18337*	0.05225	3.51	0.001
lnphosphorus	0.24335*	0.05803	4.19	0.000
lnpotassium	-0.9608*	0.08874	-10.83	0.000
lnipm	0.33893*	0.12034	2.82	0.006
Constant	3.0677*	0.38262	8.02	0.000

Source: Calculated from the Data through Field Survey

Note: The symbols *, ** and *** have been used to denote the level of significance at 1%, 5% and 10% level respectively.

The labour (lnlabour) coefficient has been estimated at 0.24222, indicating a positive and statistically significant impact at the one per cent level. This suggests that increasing labour input has contributed to higher productivity. Similarly, the use of manures (lnmanures) and nitrogen (lnnitrogen) has also shown a significant positive effect, with coefficients of 0.11399 and 0.18337, respectively.

Phosphorus (lnphosphorus) has emerged as the most influential nutrient, with a coefficient of 0.24335, which suggests that its application has strongly enhanced paddy yield. The impact of integrated pest management (lnipm) has also been significant, showing a positive relationship with productivity.

However, potassium (lnpotassium) has a negative coefficient of -0.9608, indicating that its excessive application has reduced productivity. This suggests that farmers may have been overusing potassium, potentially leading to nutrient imbalances affecting crop growth.

The estimated results of the Cobb-Douglas production function have provided valuable insights into the key determinants of paddy productivity, enabling policymakers and farmers to make informed decisions for sustainable agricultural growth.

It is important to concentrate on the use of chemical fertiliser because potassium has shown a negative impact on yield. Farmers have been advised to reassess and optimise its application to prevent overuse. Soil testing and precision nutrient management should be promoted.

As manure and nitrogen have positively influenced yield, farmers should be encouraged to use balanced organic and chemical fertilisers to sustain soil fertility. The positive impact of IPM suggests that integrated pest control strategies should be expanded, reducing dependency on chemical pesticides and improving sustainability.

It is important to enhance labour efficiency because labour input has significantly contributed to productivity; efforts should be made to train farmers in efficient labour utilisation and mechanization to maximise output. The combined effects of nitrogen, phosphorus, and potassium should be carefully managed through customised fertiliser recommendations based on soil and crop needs.

Table 8 presents the ANOVA results of the Cobb-Douglas production function estimation for paddy productivity, showing the model's overall significance and explanatory power.

Table 8. ANOVA Results of the Cobb-Douglas Production Function estimation for paddy

Source	SS	df	MS	Number of obs. =	83
				F (7, 75) =	75.7
				Prob > F=	0.000
Model	6.331	7	0.9045	R-squared=	0.876
Residual	0.896	75	0.0119	Adj R-squared=	0.8644
Total	7.227	82	0.08814	Root MSE=	0.10931

Source: Calculated from the data through field survey

The F-statistic value of 75.7 indicates that the model is highly significant, as confirmed by the p-value of 0.000, which suggests that the independent variables included in the regression have jointly explained a substantial portion of the variation in paddy yield.

The R-squared value of 0.876 shows that the model has explained 87.6 per cent of the variation in paddy productivity. Additionally, the Adjusted R-squared value of 0.8644 has confirmed the strong explanatory power of the model even after adjusting for the number of predictors.

The model's Mean Square (MS) value has been estimated at 0.9045. At the same time, the Residual Mean Square has remained low at 0.0119, suggesting that the model has achieved a good fit with minimal unexplained variation. Furthermore, the Root Mean Squared Error (RMSE) of 0.10931 indicates that the model's predictions have been reasonably accurate.

The ANOVA results have confirmed that the Cobb-Douglas production function has been an effective model for assessing paddy productivity, providing valuable insights for farmers and policymakers in optimising agricultural practices.

Conclusion with Suggestions:

Effective community-based approaches to agricultural adaptation are revealed by the study's analysis of the effects of FPOs on the uptake and yield of these resilient rice seeds. FPOs can help farmers better handle climatic stressors by creating support networks, facilitating access to improved seed types, and sharing best practices. A better understanding of FPOs' function in this setting can help develop programs and policies that increase agricultural resilience.

The NABARD-sponsored FPO has positively impacted paddy productivity in the state of Tripura. NABARD's intervention has significantly increased farmers' income, highlighting its effectiveness in enhancing agricultural profitability and rural livelihoods.

As manure and nitrogen have positively influenced yield, farmers should be encouraged to use balanced organic and chemical fertilisers to sustain soil fertility. Soil testing and precision

nutrient management should be promoted. It is important to enhance labour efficiency because labour input has significantly contributed to productivity; efforts should be made to train farmers in efficient labour utilisation and mechanization to maximise output. The positive impact of IPM suggests that integrated pest control strategies should be expanded, reducing dependency on chemical pesticides and improving sustainability.

More specialised training programs are necessary to enhance farmers' technical expertise, as pre-season and continuous training have been essential. The seed certification process should be shortened to optimise farmers' profits and expedite approvals. To guarantee farmers receive higher rates for certified seeds, the FPO should help them establish direct market linkages. Post-harvest infrastructure must be strengthened for more storage and processing facilities to preserve seed quality and minimise losses.

References

- Biswas, B., Timsina, J., Patra, S. R., De, D., Mishra, B., Chakraborti, R., & Ray, B. R. (2019). Climate change-resilient rice production technology: A high yielding, water efficient and remunerative option for south Asian farmers. *Global Journal of Agricultural and Allied Sciences*, 1(1), 20-29. DOI: <https://doi.org/10.35251/gjaas.2019.003>
- Bristy, S. Y., Tahura, S., Khan, M. R., Ghosh, A., Hossain, M. S., Mia, S., & Jindo, K. (2025). Seed Dormancy and Germination Potential of Coastal Rice Landraces in Bangladesh: Implications for Climate-Resilient Cultivation. *Sustainability*, 17(2), 625. <https://doi.org/10.3390/su17020625>
- Jat, R. K., Meena, V. S., Kumar, M., Jakkula, V. S., Reddy, I. R., & Pandey, A. C. (2022). Direct seeded rice: strategies to improve crop resilience and food security under adverse climatic conditions. *Land*, 11(3), 382. DOI: <https://doi.org/10.3390/land11030382>
- Mohapatra, P. K., & Kariali, E. (2016). Management of viviparous germination in rice: a strategy for development of climate resilient rice cultivation. *ORYZA-An International Journal on Rice*, 53(3), 235-239.
- Nayak, S., Habib, M. A., Das, K., Islam, S., Hossain, S. M., Karmakar, B., Fritsche Neto, R., Bhosale, S., Bhardwaj, H., Singh, S., Islam, M. R., Singh, V. K., Kohli, A., Singh, U. S., & Hassan, L. (2022). Adoption Trend of Climate-Resilient Rice Varieties in Bangladesh. *Sustainability*, 14(9), 5156. DOI: <https://doi.org/10.3390/su14095156>

- Pathak, H. P. M. H., Samal, P., & Shahid, M. (2018). Revitalizing rice-systems for enhancing productivity, profitability and climate resilience. Rice research for enhancing productivity, profitability and climate resilience. ICAR-National Rice Research Institute, Cuttack, Odisha, 1-17.
- Shahid, M., Munda, S., Khanam, R., Chatterjee, D., Kumar, U., Satapathy, B. S., & Nayak, A. K. (2021). Climate resilient rice production system: Natural resources management approach. *Oryza*, 58, 143-167.
- Sreenivasulu, N., Butardo Jr, V. M., Misra, G., Cuevas, R. P., Anacleto, R., & Kavi Kishor, P. B. (2015). Designing climate-resilient rice with ideal grain quality suited for high-temperature stress. *Journal of Experimental Botany*, 66(7), 1737-1748. DOI: <https://doi.org/10.1093/jxb/eru544>.
- Suresh, R., Shanmugam, A., Viswabharathy, S., Antony, J.B., Samuthirapandi, S., Manonmani, S. (2024). Climate Change Impact on Rice Production and Breeding for Climate Resilient Rice. In: Singh, A., Singh, S.K., Shrestha, J. (eds) *Climate-Smart Rice Breeding*. Springer, Singapore, 1-14. DOI: https://doi.org/10.1007/978-981-97-7098-4_1.
- Yadav, G. S., Datta, M., Babu, S., Singh, R., Devi, H. L., Debnath, C., & Saha, P. (2015). Climate resilient rice production systems. *Popular Kheti*, 3(3), 14-19.