Sub-Project ID-070

Program Based Research Grant (PBRG)

Sub-project Completion Report on Economic Viability and Production Efficiency of Rice at Farm Level: A Macro Level Study in Bangladesh

Sub-project Duration

February 2018 to January 2022

Coordinating Organization

Director (Research), Bangladesh Rice Research Institute, Gazipur-1701

Project Implementation Unit

National Agricultural Technology Program-Phase II Project
Bangladesh Agricultural Research Council
Farmgate, Dhaka-1215

January 2022

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Sub-project Completion Report on

Economic Viability and Production Efficiency of Rice at Farm Level: A Macro Level Study in Bangladesh

Implementing Organization

Agricultural Economics Division
Bangladesh Rice Research Institute (BRRI)

&

Department of Agricultural Economics
Bangladesh Agricultural University (BAU)

Project Implementation Unit
National Agricultural Technology Program-Phase II Project
Bangladesh Agricultural Research Council
Farmgate, Dhaka-1215

January 2022

Citation:

Ali, M. A., Haldar, K. P., Zaman, M. K, Siddique, M. A. B., Uddin, M. T., Salam, M. A., Moniruzzaman, M., Kamruzzaman, M., 2021. Economic Viability and Production Efficiency of Rice at Farm Level: A Macro Level Study in Bangladesh, PBRG Sub-Project Completion Report.

Edited by:

Project Implementation Unit
National Agricultural Technology Program-Phase II Project (NATP-2)
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Acknowledgement

The execution of PBRG sub-project has successfully been completed by Bangladesh Rice Research Institute, Gazipur and Bangladesh Agricultural University, Mymensingh using the research fund of WB, IFAD and GoB through Ministry of Agriculture. We would like to acknowledge to the World Bank for arranging the research fund and supervising the PBRGs by BARC. It is worthwhile to mention the cooperation and quick responses of PIU-BARC, NATP-2 in respect of field implementation of the sub-project in multiple sites. Preparing the sub-project completion report required to contact a number of persons for collection of information and processing of research data. Without the help of those persons, the preparation of this document could not be made possible. All of them, who have made it possible, deserve appreciation. Our thanks are due to the Director PIU-BARC, NATP-2 and his team who given their whole hearted support to prepare this document. We hope this publication would be helpful to the agricultural scientists of the country for designing their future research projects in order to technology generation as well as increasing production and productivity for sustainable food and nutrition security in Bangladesh. It would also assist the policy makers of the agricultural sub-sectors for setting their future research directions.

Published:
January 2022

Printed by:
Sowrov Media Products
18 Babupura, Kataban Dhal, Dhaka-1205.
Cell: 01718 419001

Abbreviation and Acronyms

AWD	Alternate Wetting and Drying
BARC	Bangladesh Agricultural Research Council
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BCR	Benefit Cost Ratio
BER	Bangladesh Economic Review
BINA	Bangladesh Institute of Nuclear Agriculture
BRRI	Bangladesh Rice Research Institute
CDF	Cumulative Density Function
CSS	Component Severity Score
DAE	Department of Agricultural Extension
FGD	Focal Group Discussion
GR	Gross Return
GDP	Gross Domestic Product
GRT	Garrett Ranking Technique
HYV	High Yielding Variety
KIS	Key Informant Survey
IPM	Integrated Pest Management
LV	Local Variety
LF	Larger Farmer
MLE	Maximum Likelihood Estimation
MF	Medium Farmer
MV	Modern Variety
NR	Net Return
PBRG	Program Based Research Grant
PCR	Project Completion Report
RA	Risk Analysis
SF	Small Farmer
TC	Total Cost
TE	Technical Efficiency
TPC	Total Paid Out Cost
TIC	Total Imputed Cost
TE	Technical Efficiency
USG	Urea Super Granule
WB	World Bank
@Risk	Excel add-ins Software

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Executive Summary

Rice contributes about 80% of total food grain production (7.58% of the national GDP) in Bangladesh and covers around 72% of the total cropped areas. The country made remarkable progress in rice production through constant effort for expansion of modern technologies since 1971. Rice yield has increased more than three-folds from 1.57 ton/hectare until 1970 to-2020. Considering the national importance of rice in the economy, this sub-project has assessed input use patterns and economic viability (profitability and risks) of rice production in different seasons (*T. Aus*, *T. Aman* and *Boro*); including technical efficiency and factors responsible for variations in the level of efficiency of different farm types (small, medium and large) of different ecosystems in Bangladesh. Therefore, ensuring availability of information about profitability, risks, resource use efficiency and constraints of rice farming for the different ecosystems (e.g., saline coastal, drought prone, submergence, *haor*, hill and favorable) is critically important to undertake appropriate decision about crop choice and/or land utilization/production of combination of crops. It can be noted that the study could be generated a comprehensive set of data for the various stakeholders including policy planners for formulating the suitable policies to expedite the growth of rice production for meeting the growing demand for staple food grain of population in the future.

Goal

The goal of this study is to generate a database on input use pattern, yields, profitability, risks and constraints of rice farming in the different seasons and ecosystem of Bangladesh for the different stakeholders.

General objectives

The study will assess the economic viability of *T. Aus, T. Aman* and *Boro* rice for three farm types in the different ecosystem of Bangladesh by evaluating the profitability, risks, production efficiency and constraints of rice cultivation to generate important information for different stakeholders for boosting main staple production in future.

Specific objectives

- To assess input use pattern and economic viability (profitability and risks) of *T. Aus, T. Aman* and *Boro* rice for three farm types in the different ecosystems;
- To evaluate technical efficiency of three type of rice farmers and the factors responsible for variation in the level of efficiency among them; and
- To identify constraints of rice farming in the different seasons and ecosystems, and drivers of adoption of rice varieties in the seasons.

The fourteen administrative agricultural regions divided by Department of Agriculture Extension (DAE), are; namely, Dhaka, Mymensingh, Faridpur, Cumilla, Chattogram, Rangamati, Sylhet, Khulna, Jashore, Barishal, Rajshahi, Bogura, Rangpur and Dinajpur, respectively. Out of 14 agricultural regions, 28 districts were chosen taking 2 from each of the region. Following the terms and condition of the sub-project, BRRI component surveyed 10 regions e.g., Cumilla, Sylhet, Barishal, Dinajpur, Chattogram, Khulna, Jashore, Mymensingh, Rangpur and Rajshahi and data of the rest of four regions (Bogura, Dhaka, Faridpur and Rangamati) were collected by other

component (Bangladesh Agricultural University, Mymensingh) of the sub-project. Considering the representativeness of the ecosystems, the surveyed districts under both components of this sub-project were grouped into 8 ecosystems such as favorable, haor, coastal saline, drought prone, tidal submergence, submergence, low-lying and hill ecosystems. Purposive sampling technique was used in selecting the locations; namely, region, districts and upazilas with due consideration of different rice ecosystems (e.g., favorable, *haor*, saline coastal, drought prone, tidal submergence, submergence, and low-lying and hill). Data editing, entry, analysis and report writing was done combined by BRRI and BAU component.

A multi-stage (two stage sampling frame-work) random sampling technique was followed for selection of the villages and the households for the survey (large, medium and small farmers). A full list of farm households with operating area of the selected villages was collected from the Upazila Agricultural Office of DAE. Then stratified sampling technique was adopted to select the respondents of different farm household types (e.g., small, medium and large). Finally, twelve farmers from *T. Aus* rice growers, thirty-eight from both *T. Aman* and thirty-seven from *Boro* rice growers were interviewed from each village. Thus, in total 9,800 farm households were interviewed from 14 agricultural regions, 700 from each of the region with well-structured questionnaire. Data on constraint to rice production was collected using 5-point Likert scales.

Almost all of the farmers in all ecosystems preferred to grow *T. Aman* and *Boro* rice but a smaller portion of farmers grew *T. Aus* rice. Average household size in the surveyed areas was about 4.9 person per family, which was almost similar to the national average, of which 51% was male. On an average, two members of each household engaged in agriculture. Average age of the surveyed farmers was 46 years; indicating that they were economically active compared to national life expectancy and 59% of them were in between 26-50 years of age. Most of the farm families were male headed (97) and their literacy rate was 6% of which major portion (34%) completed secondary education. On the other hand, literacy rate of household wives was 2%. In terms of religion, most of the respondents were the Muslims (92%) followed by Hindus (8%). Most of the surveyed farmers (92%) holds agriculture as primary profession. Thirty-seven percent respondents engaged in agriculture as secondary profession, whereas 51% farmers were not engaged in any other professions except agriculture.

The highest percentage of large farmers was found in *haor* ecosystem (6%), followed by submergence (5%) and salinity ecosystem (4%). *Haor* ecosystems is also abundant with medium farmers (22%) whereas, submergence (22%) and drought ecosystems (21%) could be ranked as 2nd and 3rd, respectively. On the other hand, among the sample farmers, highest percentage of small farmers belongs to hill (92%), followed by low-lying ecosystem (89) and tidal submergence (84%) and salinity (79%). In every ecosystem, small farmers were found much more compared to large and medium. Rice based cropping pattern was found dominant in all ecosystems included *T. Aus*-*T. Aman*-*Boro*, Fallow-*T. Aman*-*Boro*, Fallow-Fallow-*Boro*, Fallow-*T. Aman*-Fallow and *T. Aus*-*T. Aman*-Vegetables, respectively.

Local variety of *T. Aman* rice is still popular (37.65%) in tidal submergence followed by favorable (16.83%) ecosystem. Swarna variety (Indian rice cultivar) have been popular among the farmers due to different traits in drought (33.46%), submergence (31.68%) and favorable (27.68%) ecosystem. Highest adoption of BRRI dhan49 was observed in drought (29.45%) followed by favorable (25.12%) ecosystem. Most popular varieties in *T. Aus* was BRRI dhan48 covering 13 to 68% *T.*

Aus areas in different ecosystems. Highest adoption of BRRI dhan48 was observed in submergence (67.52%) followed by low lying ecosystem (36.86%). Farmers also cultivated other HYVs such BR2, BR26, BRRI dhan28, BRRI dhan27, Bina dhan7, BRRI dhan56, BRRI dhan64, BRRI dhan76 and BRRI dhan82. On the other hand, major parts of rice areas are devoted to LV in tidal submergence (39.96%) ecosystem. BRRI dhan28 and BRRI dhan29 were the mega varieties in *Boro* season in Bangladesh. The adoption of BRRI dhan28 is highest in tidal submergence (32.87%) ecosystem followed by saline (32.54%) and low lying (32.45%) ecosystem. On the other hand, BRRI dhan29 was cultivated by the farmers in *haor* (48.05%) ecosystem followed by low lying (40.47%) and submergence (38.76%) ecosystem. Farmers in drought ecosystem notably (27.30%) cultivated *Zira*. Different hybrid variety were cultivated all over the country but it occupied highest area in saline ecosystem (16.35%).

As found in above section, most of the farmers under different ecosystems preferred high yielding rice varieties over the local varieties for better output in terms of yield and profit. Human labor, seed and fertilizers (Urea, TSP, MoP, Gypsum, DAP, Zinc .etc.,) were as the major inputs and power tiller, shallow tube-well, power thresher were major machineries used by the farmers for rice production in the study areas.

Benefit cost ratio (BCR), both on cash and full cost basis was more than one; implying that rice production in different seasons were economically profitable even though, it was a loss concern during recent pasts, due to lower market price but current situation of rice price seemed far better and considered to be an incentive for the growers in all seasons. Especially, BCR on cash cost basis in *Boro* season showed almost two times of investment due to high yield potential and better market price. Moreover, the net return also showed positive; meaning that net return out yielded total investment in rice production. Using Monte Carlo simulations for triangular distribution, cumulative probability distribution for risk assessment was simulated, which showed a wide range of variations among seasons and farm types. Yield was the major contributor in variation of net return in different seasons followed by market prices of rice.

The stochastic frontier production function approach was employed to estimate farm-specific technical efficiency. Human labor, fertilizer (Urea, TSP and MoP) and irrigation had significant influence on *T. Aman* and *Boro* rice production; whereas, human labour, fertilizer and insecticides had greater impact on *T. Aus* rice production. The findings of the study also revealed that experience, education, extension service, training, access to credit facilities and media had strong influence to reduce technical inefficiency in different ecosystems. In addition, medium farmers were technically more efficient in *T. Aman* and *T. Aus* rice farming; whereas, small farmers were more efficient in *Boro* rice production.

Severity ranking model was constructed to evaluate the severity of damage of rice production due to different types of risks which showed that biotic risk was the main reason for the declination of rice production in different ecosystems. Based on the Garrett's ranking technique, low price of rice, scarcity of labor, lack of short duration and high yielding rice varieties, and lack of proper training and extension service were found as the major constraints faced by the famers. The most of respondents also reported that unavailability of labor, higher wage, higher price of fertilizer and insecticides and low price of rice were major constraints to rice production at the farm level.

Keywords: Ecosystem, Benefit cost ratio, Profitability, Cumulative probability, Risk and Technical efficiency

PBRG sub-project Completion Report (PCR)

A. Sub project description:

1. PBRG Sub-project title: Economic Viability and Production Efficiency of Rice at the Farm Level: A Macro Level Study in Bangladesh (070)

2. Implementing organization

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BAU component: Department of Agricultural Economics, Bangladesh Agricultural University, Mymensingh-2202

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4. Sub-project budget (Tk.):

4.1 BRRI component: Tk. 15108720/-
4.2 BAU component: Tk. 6084540/-

5. Duration of sub-project: Start date: February, 2018
End date: January, 2022

6. Background of the sub-project

Bangladesh is a densely populated agrarian country where agriculture remains the mainstay of the economy, contributing about 12.44% to the gross domestic product (GDP) and generates employment for about 47% of the total labor forces in 2015-16 (BER 2020). Rice is the main crop and staple food of people and from the view point of political and cultural heritage, rice is considered to be as synonym of 'food security' in Bangladesh. It supplies about 80% of total food grain production and covers about 72% of the total cropped area in Bangladesh (BBS, 2019). The country has made a remarkable progress in agriculture in terms of adoption of modern technologies and rice production since 1971. Rice yield has increased more than three-folds from 1.57 tons/hectare during the early 1970s to 4.46 tons/hectare in 2015-16, contributes 4.5% to the GDP (BBS 2016a). However, Bangladesh has to further enhance growth in rice productivity (at least 20% greater than the current yield) for meeting the growing demand of food of her ever-increasing population (estimated to be 173 million by 2020, Husain *et al.* 2001; Magor *et al.* 2007). This implies that rice farmers not only need to be more efficient in production activities, but also to be responsive to market indicators in utilization of scarce resources; such as, land, labour and capital for ensuring profit for the growers and rice grain supply to the non-producers of the urban people (Magor *et al.* 2007). On the other hand, a large number of studies anticipated that climate variability (e.g., increase temperature, evapotranspiration and erratic precipitation pattern) and natural calamities (e.g., floods, tropical cyclones, storm surges, and droughts) are most likely to be quite frequent and intense in future (Ahmed and Alam, 1999, Agrawala *et al.* 2003, Huq *et al.* 2004, MoEF, 2009, Yu *et al.* 2010) due to global warming led climate and environmental changes; consequently, agriculture farming would be affected extensively. In this respect, the country like Bangladesh have to face a great challenge to ensure main staple-rice security for the growing population in the latter half of the century where land use has been reached to its frontier level already (Ahmed *et al.* 1999, MoEF, 2009, WB, 2013). Thus, strategic adaptation policy needs to be included with the future economic and social development planning for ensuring food security and improving well-being of the people in a sustainable manner (WB, 2013). In addition, Bangladesh is highly ambitious to achieve the SDG's goal 1(No poverty) and 2 (Zero hunger) within the stipulated time frame by the United Nation (UN). These two goals mainly describe the targets of achieving food security and doubling the agricultural productivity within 2030. So, necessary efforts should be given in this regard also. Bangladesh Rice Research Institute (BRRI) is the pioneer in rice sector of Bangladesh in terms of varietal development and also variety related technology innovation. BRRI has so far developed more than 100 high yielding modern varieties (MVs) along with 7 hybrids (Adhunik Dhaner Chash, 2020) for different production environments which made outstanding contribution towards attainment of rice self-sufficiency in Bangladesh. But experiences revealed that all of the varieties developed and released by BRRI is not found to the farmer's field; only few mega varieties are dominating large rice areas in different seasons across the country. So,

it is an urgent issue to investigate what is the myth that leads farmers to cultivate specific variety or not. It may be due to the profitability concern to the growers, as because; economic decisions are primarily concerned with the most profitable level of input use in the production process. It's the case that governs farmers' decision to adopt a new technology or crops or rotations is most likely to be influenced by the level of profitability and risk associated with the respective crops or rotations (Dillon, 2003; Kabir *et al.* 2016). Therefore, ensuring the availability of knowledge about rice farming profitability, threats, resource use quality, and constraints in different seasons and habitats (e.g., saline coastal, drought resistant, submergence, *haor*, hillyy, and favorable) is crucial and indispensible for making appropriate crop choice and/or land utilization, price decisions etc.

It was found from the review of literature that a large number of studies have been conducted estimating costs of production and its returns (profitability) at the micro level, but they appear to be limited in scope, either in terms of data coverage or the use of practical type for econometric analyses.

Earlier studies estimated costs and return *i.e,* profitability of rice at micro level but those apparently remains narrow in their focuses either in terms of data coverage or the use of functional form for econometric analyses. None of the previous study was found to assess economic viability (profitability and risk), production efficiency and constraints to rice production in the different ecosystem using a macro-level data. Nevertheless, the country is highly divergent in terms of the soil physiographic features, climatic factors, availability of natural resources and socio-economic features. For that reason, the country has been divided into thirty agro-ecological zones, and the land use pattern in each zone is substantially influenced by the local environment (BBS 2016b). On the other hand, rice production in the country is substantially affected by frequent extreme weather events (e.g., floods, droughts, excess rain and cyclones and storm surges). Thus, an assessment of production system of rice and its profitability, resource use efficiency, risks and constraints under different ecosystems are timely demanding indispensable issues. It is expected that the present study would generate a comprehensive set of data for the various stakeholders including policy planners for formulating suitable policies to expedite the growth of rice production for meeting the growing demand of staple food in future.

In Bangladesh, the measurement of the production efficiency (technical, allocative and economic efficiency) in agricultural production is an important issue from the standpoint of agricultural development, since it gives pertinent information which is very useful for making sound management decision, resource allocations and for formulating agricultural policies and institutional improvement.

6.1 Importance of rice in Bangladesh

Rice is the foremost cereal and staple food in Bangladesh, grows in three distinct seasons round the year which occupies about 72% of the total cropped area (BBS, 2020). Rice alone constitutes 80% of the total food grains produced annually (BER, 2017). It is the principal source of agricultural GDP and livelihoods to majority of the rural population which provides about 62% of the calorie and 46% of protein of average daily intake of the consumers (HIES, 2010). It is an important parameter for determining social and political stability (Nath, 2015) and provides a sense of food security to the people. In spite of various constraints, since independence, there has been more than three-fold increase in rice production in Bangladesh, which jumped from around 10 MT in 1971-72

to about 35.06 MT in 2015-16. This has been transformed the country from so called "Bottomless Basket" to a "Full of Food Basket". In recent years, the country has not only earned self-sufficiency status in rice production, but also gradually entering into the export regime (BER, 2017). Due to the proliferation of shallow and deep tube wells and the development of high-yielding seeds for different seasons, rice yields have increased dramatically and the share of dry-season rice has increased substantially (Hossain, 2009).

The major achievement of rice research in Bangladesh, as in other Asian countries might be recognized as to development of high yielding modern varieties. By 2020, Bangladesh Rice Research Institute (BRRI) developed and released more than 100 rice varieties for different agro-ecological condition, while the Bangladesh Institute of Nuclear Agriculture (BINA) and Bangladesh Agricultural University (BAU), released about twenty rice varieties. The varieties were, however, developed and released following a top-down breeding and evaluation process. But only a few improved varieties have, however, remained popular to the farmers. In the 1970s the most popular varieties in the *Boro* and *Aus* seasons were IR8, Purbachi and BR3. During 2015-16, BRRI dhan28 and BRRI dhan29 were the most popular rice varieties in *Boro* season covering by 64% of total *Boro* area. In *Aus* season area coverage of BRRI dhan28 was the highest (15%) followed by BRRI dhan48 (11%) and BR26 (7%). For the *Aman* season, the most popular varieties in the 1970s were Pajam and IR20, which have been gradually replaced by BRRI dhan49 (10%) and BR11 (9%) as of 2015. Among BRRI varieties, BRRI dhan29 was the top yielder in *Boro* (6.44 t/ha) season followed by BR16 (5.90 t/ha). In *T. Aman* season, BRRI dhan49 ranked the top position in terms of per unit yield (5.02 t/ha) followed by BR11 (4.91 t/ha). In *Aus* season, BRRI dhan48 produced higher yield (4.52 t/ha) followed by BRRI dhan28 (4.51 t/ha) (BRRI, 2015). The key drivers of adoption popular varieties in the different seasons were included higher yield potential, environmental suitability, market demand and price as well as preferred grain quality.

7. Sub-project objectives

7.1. Goal

To generate a database on input use pattern, yields, profitability, risks and constrains of rice farming in the different seasons and ecosystem of Bangladesh for the different stakeholders.

7.2. General objective

The study was designed to assess the economic viability of rice production in different seasons in different regions along with farm specific efficiency, risks and constraints of rice farming in Bangladesh. The information generated from the study are expected to be helpful for different stakeholders of the rice sector and policy planners for formulating future guidelines.

7.3. Specific objectives

i) assess input use pattern and economic viability (profitability and risks) of *T. Aus, T. Aman* and *Boro* rice production for different farm types (e.g small, medium & large) in different ecosystems;

ii) evaluate technical efficiency and identify factors responsible for variation in the level of efficiency among different farm types; and

iii) identify the constrains of rice farming in different seasons, ecosystems and drivers of adoption of rice varieties at the farm level.

7.4 Literature review

Review of literature of any research work is essential as it might provide new dimensions for reviewing the stock of knowledge and information about the proposed study. This knowledge gives guidelines in shaping and furnishing the future research problem and validating the existing findings.

Research works relating to various aspects of farm level efficiency, sustainability, yield gap and growth performance of rice production carried out all over the world including Bangladesh are overviewed here. This chapter identifies the methodology used in the previous studies, findings and also makes justification of conducting the present study in Bangladesh. Thus, it will be helpful to identify that what ought to be done more on this subject that means the existing research gap will be identified. With this end in view, literature and research works in the line with the present study were searched in the relevant libraries, research institutes, offices and websites. The important studies which were conducted in the recent past related to the present study are discussed below:

7.4.1 Bangladesh perspective

Hossain and Jaim (2012) showed that farmers adopted rice varieties with nutritional traits only if there is no yield penalty, could mature earlier and have better eating quality. Findings of the study also revealed that millers, however, go for more polishing for targeting high-income consumers and the urban market that pay premium prices for polished rice. It was also suggested that information campaigns must be strengthened and the seed distribution system must be improved for fast-tracking the diffusion of a new rice variety. The potential yield of rice varieties should be increased focusing on environmental stress, particularly with the threat of climate change to rice farming. Government organizations should play active role in developing varieties suitable for growing under stress conditions or unfavorable ecological conditions.

Findings of the 2005 IRRI survey showed that considerable diversity still exists for rice varieties at the farm level in Bangladesh. However, the diversity is higher in the *Aman* and *Aus* seasons than in the *Boro* season (Hossain and Jaim, 2012). The survey also showed that a few varieties dominate the landscape; often, three to five varieties account for over half of the total land area.

Many farmers keep traditional varieties of their choice for the special traits that they value in that variety. The survey also indicated that there is large regional variation in the choice and concentration of improved varieties. Some Indian varieties with special traits are popular in areas near the Indian border. It was found that high yield is the predominant trait that farmers want in a new variety. However, they also prefer shorter maturity for more intensive land use and good quality for premium prices. The findings also showed that hybrids are becoming popular despite the high seed cost because of their 1.0 to 1.5 t/ha yield advantage. Findings in relation to the process of adoption and diffusion of new varieties showed that extension officials are the dominant source of first information about a new variety, but the extension contact is biased in favor of large farmers. For small and marginal farmers, enterprising farmers are the major source of information about an improved variety.

Banik (1994) applied Cobb-Douglas stochastic frontier production function for assessing technical efficiency of irrigated *Boro* rice farms in Dhamrai Upazila of Bangladesh. The results showed that average technical efficiency for the entire sample was 78%, implying that there was considerable

scope for increasing the efficiency of the sample farms as a group. Through categorizing the sample farms by farm size groups, the study further revealed that the average technical efficiency of small farms was much higher than that of large and medium farms. Likewise, Owner cum tenant farms was technically more efficient than owner farms.

BRRI (2009) estimated profitability of MV *Aus*, *T. Aman* and *Boro* rice production in the 10 agricultural regions in Bangladesh using cross section data of 60, 66 and 68 farm households, respectively during 2009-09. Per kilogram production cost of MV *Aus*, *T. Aman* and *Boro* rice was BDT 13, 13.3 and 12.72, respectively. The MV *Boro* growers received higher gross margin (Tk.38,971/ha) than MV *T. Aman* (Tk. 22,821/ha) and MV *Aus* (Tk. 14,523/ha) due to higher yield.

Bala, *et al.* (2010) estimated technical inefficiencies of rice, wheat and maize production in Bangladesh from a sample of 944 farmers, fitting the Cobb-Douglas type stochastic frontier model. The result showed that the productivity of LV *Aman*, HYV *Boro* and hybrid *Boro* could be increased by the provision of quality seed. Also, there was a scope for increasing the productivity of *Boro* hybrid by increasing human lobour supply. Besides, increased level of irrigation in LV *Aman* and *Boro* hybrid rice could increase the yield. The model also showed that the productivity of wheat and maize could be raised by increasing the farm size and labour and investing more on irrigation. The findings of the study also revealed that there was a scope for increasing production in *Aus* (HYV), *Aman* (LV & HYV) and *Boro* (HYV & hybrid) rice, wheat (HYV) and maize (HYV & hybrid) on an average by 24%, (17% & 24%), (20% & 16%), 26% and (3% & 14%), respectively.

BRRI (2011) estimated profitability of MV *Aus*, *T. Aman* and *Boro* rice production in the 10 agricultural regions in Bangladesh using cross section data of 60 farm households in each season. Per kilogram production cost of MV *Aus*, *T. Aman* and *Boro* rice was BDT 19.29, 17.79 and 18.80, respectively. The MV *T. Aman* growers received higher gross margin (Tk. 26,594/ha) than MV *Boro* (Tk. 9,639/ha) and MV *Aus* (Tk. 3,168/ha) due to higher market rice price and lower production cost of their product.

BRRI (2012) estimated profitability of MV *Aus*, *T. Aman* and *Boro* rice production in the 10 agricultural regions in Bangladesh using cross section data of 60 farm households in each season during 2010-2011. Per kilogram production cost of MV *Aus*, *T. Aman* and *Boro* rice was BDT 19.35,16.47 and 18.20, respectively. The MV *T. Aman* growers received higher gross margin (Tk. 23,466/ha) than MV *Boro* (Tk. 21,516/ha) and MV *Aus* (Tk. 12,013/ha) due to lower production cost and higher rice price.

BRRI (2013) estimated profitability of MV *Aus*, *T. Aman* and *Boro* rice production in the 10 agricultural regions in Bangladesh using cross section data of 120 farm households in each season during 2011/12. Per kilogram production cost of MV *Aus*, *T. Aman* and *Boro* rice was BDT 19.87,17.38 and 18.89, respectively. The MV *T. Aman* growers received higher gross margin (Tk.34,029/ha) than MV *Boro* (Tk. 23,154/ha) and MV *Aus* (Tk. 11,746/ha) due to lower production cost and higher rice price.

BRRI (2014) estimated profitability of MV *Aus*, *T. Aman* and *Boro* rice production in the 10 agricultural regions in Bangladesh using cross section data of 120 farm households in each season during 2012/13. Per kilogram production cost of MV *Aus*, *T. Aman* and *Boro* rice was BDT 18.64, 17.61 and 18.65, respectively. The MV *T. Aman* growers received higher gross margin (Tk. 18,392/

ha) than MV *Boro* (Tk. 12,101/ha) and MV *Aus* (Tk. 2,404/ha) due to lower production cost and higher market price. The net return of rice was negative in the all three seasons.

BRRI (2015) estimated profitability of MV *Aus, T. Aman* and *Boro* rice production in the 10 agricultural regions in Bangladesh using cross section data of 60 farm households in each season during 2013/14. Per kilogram production cost of MV *Aus*, *T. Aman* and *Boro* rice was BDT 18.37, 17.83 and 20.07, respectively. The MV *T. Aman* growers received higher gross margin (Tk. 24,770/ha) than MV *Aus* (Tk. 3,919/ha) and MV *Boro* (Tk. 3,621/ha) season due to higher rice price and lower production cost; while the net return of *Aus* and *Boro* seasons were negative on full cost basis

Mottaleb and Mohanty (2015) estimated profitability of rice farming using household income and expenditure survey data for 2000 and 2010. The study found that the loss in profitability is generally larger for small farms than large farms, as small farms use more labor and other inputs compered to large farm households. It was also found that per acre profitability of rice cultivation in Bangladesh declined in 2010 than 2000, the rate of reduction the number of small farm households was higher than for large farm households.

Tama *et al.* (2015) assessed the financial profitability of aromatic rice production in Dinajpur using cross section data of 45 farm households. It was found that gross margin for aromatic rice was estimated at Tk. 59,999 per hectare. Thus, the net return was estimated at Tk. 49,797 for aromatic rice production. The undiscounted Benefit Cost Ratio on the basis of total cost was 1.77, implying that the aromatic rice production was highly profitable.

Kabir *et al.* (2016) evaluated the relative profitability and riskiness of the major cropping systems, using data from two coastal villages in Khulna District. The budgeting results showed that with current management practices, the rice/shrimp system is economically more viable (higher returns to land and labour and less risky) than the rice/non-rice system. However, the economic viability is affected by seasonal fluctuation of yield and price of crops because of seasonal weather variation and market uncertainty.

Islam *et al.* (2017) conducted a study to assess the profitability, constraints and factors affecting rice production in coastal district Satkhaira in Bangladesh. The study found that the small farmers (Tk. 10293/ha) got higher net returns than the medium (Tk. 6894/ha) and large (Tk. 4799/ha) farmers per hectare, respectively. It is found that the coefficient of seed, fertilizer, power tiller, irrigation cost and human labor have significantly impact on gross return. Lack of saline tolerable good quality seeds, high price of inputs, low price of outputs and natural calamity were the major problems for rice farming in the study area though rice farming was a profitable enterprise.

Sujan *et al.* (2017) analysed the profitability and resource use efficiency of boro rice cultivation in Bogra district of Bangladesh using cross sectional data of 103 farm households. It was found that per hectare gross return, gross margin, and net return were BDT 86,548, BDT 28,965 and BDT 15,340, respectively. Cobb-Douglas production function analysis showed that the key production factors, that is, human labour, irrigation, insecticide, seed and fertilizer had statistically significant effect on yield. MVP and MFC ratio analysis showed that growers allocated most of their resources in the rational stage of production.

Alam *et al.* (2017) studed profitability of four cropping systems/establishment methods in Jessore to evaluate cropping system intensification with varying degrees of tillage and rice residue retention. It was found that system productivity (rice equivalent yield, REY) of all wheat-mungbean-*Aman* systems was significantly higher than that of the *T. Aman –Boro* system in the first and fourth years and when averaged over the four years (by 10% or 1.3 tonne/ha) The wheat-mungbean-*Aman* systems were also economically superior to the *T. Aman-Boro* system in terms of higher gross margin (by 26%), net return (double) and benefit cost ratio (1.1 vs 1.0) due to both higher returns and lower cost of production.

Kabir *et al.* (2017) analysed farmers' profitability and risks of major cropping system in the drought- prone areas in Bangladesh. It was found that emerging cropping systems like maize/ cucumber and maize/stem amaranth/rice were economically more viable (more profitable and less risky) than the traditional rice/rice and rice/maize systems. Despite some uncertainties (profitability has been affected by seasonal variation of yield and prices of crops), farming was preferred to off-farm work, generating higher returns to labour for all cropping systems. Lack of access to stress-tolerant varieties, extension services and affordable agricultural credit, combined with high production costs, variability in crop yields and output prices, are the main barriers to adapta-tion. Stronger agricultural research and support services, affordable credit, community-focussed farming education and training are critically important for effective adaptation to climate change.

Mortuja and Uddin (2019) studied the impact of climatic variables on major field crops in *char* areas of Mymensingh district. The study aimed at climatic variables impacts on seasonal productivity of *Boro*, Jute and Wheat production. The authors pointed out that production of all the three crops were found as increasing. They revealed that humidity has influence on seasonal *Boro* production whereas temperature and rainfall didn't influence the production. The study concluded that climatic information should be used for all aspects of crop production and it could affect the productivity of crop. It also mentioned that productivity of crop increased in most of the areas but seasonal variability of climatic parameters could vary by the types of crops.

Rahman *et al.* (2018) conducted a study on economic investigation of BRRI dhan29 and hybrid rice production in Bangladesh: The case of *Haor* area. They focused on productivity, profitability, resource use efficiency and farmers' perception of growing of BRRI dhan29 and hybrid rice production. The authors revealed that farmers preferred BRRI dhan29 than hybrid variety though there is no significant variation of total cost of production. But on the basis of income share, farmers get higher net return for cultivating BRRI dhan29 and negative net return for hybrid rice production.

Rasha *et al.* (2018) conducted a study on financial profitability and resource use efficiency of *Boro* rice production in some selected areas of Mymensingh district in Bangladesh. They found that *Boro* rice production was profitable and quantity of seed, animal labor, power tiller cost, number of human labor, quantity of fertilizer and cost of irrigation had a positive and significant effect on the gross yield of *Boro* rice production, except for cost of manure and cost of pesticides had an insignificant effect on the gross yield of rice production.

Uddin and Dhar (2018) assessed government input support on Aus rice production in Bangladesh: impact on farmers's food security and poverty situation. The study aimed at boosting *Aus* rice (UFSHI and NERICA variety) production through government input (both cash and kind) support. The authors found that cropping intensity as well as profitability and productivity of supported

farmers was increased compared to non-supported farmers. Poverty in terms of deprivation of health education, employment, housing, mobility and income was decreased, and overall livelihood circumstances were improved through government input support on *Aus* rice production.

Islam *et al.* (2017) conducted a study on profitability and productivity of rice production in coastal distrct Satkhaira in Bangladesh. They found that the small farmers got higher net return than that of medium and large farmers. The study mentioned that the coefficient of seed, fertilizer, power tiller, irrigation cost and human labor have significantly impact on gross return. The authors observed that lack of saline tolerable good quality seeds, high price of inputs, low price of outputs and natural calamity were the major problems for rice farming in the study area though rice farming was a profitable enterprise.

Samarpitha (2016) attempted a study to estimate the technical, economic and allocative efficiencies of rice farms using stochastic frontier approach. The author revealed that 63 and 76 percent of technical and economic inefficiencies respectively were largely within the control of individual farmers. Human labour considered the major determinant of rice productivity. The author mentioned that education level of a farmer, experience in rice cultivation, membership in cooperative society and accesses to institutional credit were the most influential determinants of technical efficiency.

Hasnain *et al.* (2015) analyzed the technical efficiency of *Boro* rice producing farmers of Meherpur district in Bangladesh. They found that technical efficiency of *Boro* rice farms was 89.5%. Furthermore, labor, fertilizer and pesticide, seed and irrigation are the significant factors that affect the level of technical efficiency while farm size and ploughing cost are found insignificant in affecting technical efficiency. They concluded that farmers could increase their production through increasing the use of labor, seed and irrigation inputs and also by using proper doses of fertilizer and pesticide.

Devi and Singh (2014) conducted a study on resource use and technical efficiency of rice production in Manipur. The study aimed at assessing technical efficiency of individual farms through stochastic production function analysis. They found that total cost of cultivation on small farms was much higher than the large farms. Imputed rental value for owned land was the major cost items for all the farms. The study showed that on an average majority (40%) of the rice growing farmers were operating at the technical efficiency level of (99-100) % in relation to frontier output level.

Nasrin and Uddin (2013) conducted a study on financial profitability of aromatic rice production and its impact on farmers' livelihood in selected areas of Tangail district. They found that aromatic rice production helped the farmers to get higher income and better livelihood.

Rahman *et al.* (2013) conducted a study on assessment of the technical efficiency of *T. Aman* rice growers in a coastal empoldered area of Bangladesh. They revealed that *T. Aman* rice production was profitable as benefit cost ratio (BCR) was 1.75 on full cost basis. The study showed that the average level of technical efficiency of the sample farmers was about 75%, implying that given the existing technology and level of inputs, the output could be increased by 25%.

Bala *et al.* (2010) estimated the technical inefficiencies of rice, wheat and maize production in Bangladesh. The authors pointed out that the productivity of LV *Aman*, HYV *Boro* and hybrid *Boro* could be increased by the provision of quality seed. Also, there was a scope for increasing the productivity of *Boro* hybrid by increasing human lobour supply. Besides, increased level of irrigation in LV *Aman* and *Boro* hybrid rice could increase the yield.

Shahabuddin and Dorosh (2002) conducted a study on comparative advantage of international trade through measuring net economic profitability and the domestic resource cost ratio. They demonstrated that Bangladesh has a comparative advantage in domestic production of rice for import substitution. However, at the export parity price, economic profitability of rice was generally less than economic profitability of many non-rice crops, implying that Bangladesh has more profitable options other than production of rice for export.

Banik (1994) applied Cobb-Douglas stochastic frontier production function for assessing technical efficiency of irrigated Boro rice farms in Dhamrai Upazila of Bangladesh. The author showed that average technical efficiency for the entire sample was 78%, implying that there was considerable scope for increasing the efficiency of the sample farms as a group. Through categorizing the sample farms by farm size groups, the study further revealed that the average technical efficiency of small farms was much higher than that of large and medium farms. Likewise, Owner cum tenant farms was technically more efficient than owner farms.

The above review indicates that most of the studies estimated the profitability of rice and technical efficiency of rice production using a small-scale household survey data in Bangladesh. However, none of the studies found to assess the profitably, risk, constraints and production efficiency of rice using a macro level survey data of the different ecosystems while the production decision is substantially influenced by the profitability and risk. Thus, a study using macro level data for assessing the profitably, risk, production constraints and production efficiency of rice in the different ecosystem is timely justified for formulating the site-specific policy to enhance rice production for meeting the growing demand.

7.4.2. Other countries perspectives

Battese and Coelli (1992) applied stochastic panel data model incorporating time- varying farm effects in the analysis of unbalanced data for 15 rice farmers in an Indian village for ten years. They found that the stochastic frontier production function with the time trend was not significantly different from the average function technical efficiencies could be considered absent from the model. This result indicated a probable correspondence between technical change and improvement in technical efficiency, especially when the period of analysis is not very long and there is a rationale for using OLS estimates with time trend to represent improvement in technical efficiency.

Sasmal (1993) applied stochastic production function for assessing risks of cultivating high yielding varieties of rice in Midnapore, West Bengal, India. It concluded that the marginal effects of inputs on mean output and variance of output were independent. This implied that the input which had a positive effect on mean output did not necessarily have similar effect on risk of productivity. It also observed that fertilizer, pesticide, labour, and seeds positively related to output mean, but not to variability.

Islam *et al.* (2004) applied both Cobb-Douglas and Translog stochastic frontier production functions to estimate the technical efficiency of total 638 coarse and aromatic rice farm households in Bangladesh. The mean efficiency of aromatic, fine and coarse varieties were 97%, 98% and 85% respectively. They suggested that by better management practice, coarse rice producers can increase the efficiency.

Reddy (2015) conducted a study for assing the regional disparities in profitability of rice production in 12 states of India. He foulnd that there was a widening gap between bottom 25% and top 25% (based on farm size) of the farmers in terms of yields, gross returns and profitability. The findings of the study revelaed that the condition of tenant-SFs was more precarious due to high land rents (50% of total cost). The share of loss-making farms is 17% among bottom 25% of the farmers compared to only 3% among top 25% of the farmers. The distress of small farms is aggravated by higher risk in profitability. Most of the farmers in states like Punjab, Haryana, Andhra Pradesh, Tamil Nadu and Gujarat are getting reasonable profits, while farmers of Maharashtra, Jharkhand, Assam, Bihar and Orissa are earning meagre profits. Use of modern inputs (farm machinery and fertilizer) helped in increasing profitability, while use of traditional inputs (animal labour and manure) were associated with losses.

Subedi *et al.* (2020) conducted research from January to June, 2020 to determine the profitability and resource use efficiency of rice production in Jhapa district of Nepal. The primary information was collected from 100 rice growing farmers, randomly selected from the sampling frame, using the pre-tested semi-structured interview schedule; moreover, two Key Informant Surveys were also done. In addition, the secondary information was collected from the review of related literatures. Descriptive statistics, Cobb-Douglas production function were used for data analysis. The gross margin (NRs. 53,531/ha) and benefit cost ratio (2.05) indicated that rice production was profitable with the productivity of 4.5 mt/ha. The return to scale of rice production was calculated 0.86 which indicated that the production function exhibited a decreasing return to scale. The allocative efficiency indices revealed that for optimum allocation of resources, cost on seed, chemical fertilizers and irrigation cum pesticides/herbicides need to be increased by 73.8, 78.4 and 93.9 percent respectively; while cost on human labor and tractor power should be decreased by 53.8 and 51.5 percent respectively.

Bagchi *et. al.* (2012) showed that rice is cultivated mostly on medium land (73% of the rice area) having a favorable environment for rice production in about half of the area (54% of the rice area) where farming is mostly dominated by small/marginal farmers in West Bengal of India. The study revealed that irrigation facilities in West Bengal were found to be inadequate; only about 31% of the rice area had access to irrigation. The study identified 226 distinct rice varieties grown by the sample farmers of the selected blocks during 2006-07. The number of varieties grown in the wet/*Aman* season of 2006 was 166. Although large numbers of varieties were grown in the *Aman* season, only 18 were grown on more than 1% of the rice area. Among all the varieties grown in the *Aman* season, the most popular variety was Lal Swarna (MTU 7029), which alone covered 45% of the rice area. The number of rice varieties planted by the sample farmers during the dry/boro season was limited (60 varieties) compared with the *Aman* season. The most popular dry-season rice was IR36, covering 26% of the dry-season rice area. Other popular varieties according to importance were *Satabdi, Khitish*, CR-1010, Sankar, etc., and the top five varieties covered about 68% of the total dry-season rice area.

Behura *et. al.,* (2012) A survey covering all the districts of Orissa, state of India identified poor landholding status of the farmers as having adverse environmental characteristics, which do not seem to be at all favorable for rice production in general. Ecosystems having characteristics of either flood-prone or drought-prone or both covered about 76% of the study area. Only about 24% of the rice area had access to irrigation and canals were the major source of irrigation, which became

useless during drought years due to poor storage capacity of the reservoirs. High yield was the most important trait in selecting a rice variety. The second most important trait in selecting the most popular variety (such as Swarna) was good taste of the cooked rice, followed by lodging resistance, shorter duration, high-quality grain, higher milling recovery, etc. The overall findings of the survey revealed that a large number of traditional varieties still exist in Orissa and the adoption of modern varieties is seriously constrained by reliable sources of irrigation, an adequate supply of quality seeds, information about new technologies, etc. Potential yield of both traditional and modern varieties should be increased by focusing on environmental stresses. Therefore, more attention/ support is needed from government and nongovernment organizations in developing rice varieties suitable for growing under stress conditions or in unfavorable ecological conditions.

Heriqbaldi1 *et al.* (2015) conducted a study to estimate technical efficiency in rice production and to assess the effect of farm-specific socio-economic factors on the technical efficiency in Indonesia during 2008. Stochastic frontier production function model was used to estimate the technical efficiency of rice farms in each province of Indonesia which showed that there was sizeable degree of variation of inefficiency between different provinces. It also finds that factors like land size, income and source of funding are the influential determinants of technical efficiency. In terms of age, it also indicated that younger farmers tend to be more efficient. Expanding the agricultural area, especially outside Java and Sumatera Islands, improving farmers' income and giving an incentive to young people to work in the agricultural sector will enhance technical efficiency and thus productivity, as well as the overall rice output.

Wabbi *et al.* (2013) conducted a study to investigate the profitability of potato and pineapple enterprises and the technical efficiency and drivers of efficiency among potato farmers, chosen purposively within IAR4D project sites in southwestern Uganda. For enterprise profitability, a non-parametric net crop revenue analysis was used, while a stochastic frontier parametric approach was used to analyse technical efficiency. Both potato and pineapple enterprises were found to be profitable, although returns from pineapples were lower. Seasonality impacted on the gross returns of both enterprises. Pineapple prices were lower than for potatoes during the peak seasons, but off-peak prices rose 350% above the peak price, resulting in substantial increases in gross incomes. All potato farms were inefficient. However, female farmers were relatively more efficient than male farmers. Education was positively and significantly associated with efficiency, indicating that public investments in education have complementary and synergistic effects on IAR4D development outcomes in Uganda.

Ali *et al.* (1991) reviewed conceptual and methodological issues and empirical results of studies aimed at measuring technical efficiency. The estimation of technical efficiency using a production frontier would include technical efficiency of all inputs as conventionally defined, as well as allocative within the aggregate category of purchased inputs. Economic inefficiency estimated by this specification was likely to arise from managerial variables such as education and technical knowledge. They concluded that agriculture, technical inefficiency was likely to be overestimated by inadequate specification of environment variables. This problem can be reduced by giving attention to soil type, rainfall and pest problems in farm level surveys. A synthesis of the results strongly suggested the existence of sizeable inefficiency, which in most cases can be traced to human capital and management variables.

Battese *et al.* (1989) used Cobb-Douglas frontier model in the analysis of farm level data from ICRISAT's village level studies. Results showed that family and hired labour were homogeneous, given the model considered for labour services. Frontier production function considered in the analyses had the property that the variance of production was proportional to the square of the mean of production. The analyses indicated some of the possibilities associated with an application of frontier production function model to empirical data on agricultural production of individual farms. A basic component of frontier production function research was the prediction of technical efficiencies of individual farm operators and the identification of factors which contributes significantly to higher levels of technical efficiencies.

Coelli and Battese (1996) revealed that age and level of education of the Indian farmers, as well as farm size and year of observation had significant influence upon the size of the inefficiencies of farmers in two of the villages under the study. Farm size and year of observation were estimated to be inversely related to the level of technical inefficiency in all villages. In two of the three villages, the effect of age and education of farmers were found to be negatively related to the inefficiency effects.

Bravo-Ureta and Pinheiro (1997) studied technical, economic and allocative efficiency in peasant farming in the Dominican Republic using maximum likelihood techniques to estimate a Cobb-Douglas production frontier. They estimated average levels of technical, allocative and economic efficiency equals to 70, 44 and 31 percent, respectively. These results suggested that substantial gains in output and/or decreases in cost could be attained given existing technology. They found younger and more educated farmers exhibited higher levels of technical efficiency. In addition, it was found that contract farming, medium size farms and being an agrarian reform beneficiary have a statistically positive association with economic and allocative efficiency.

Kebede (2001) used econometric frontiers under the specification of the Cobb-Douglas production function model with four (Half- Normal, Truncated-Normal, Exponential and Gamma) inefficiency effects. The study demonstrated a method of estimating the Normal- gamma stochastic frontier model specification. Among the four different stochastic frontier model specifications, the Half-Normal stochastic frontier model was selected because it provides moderator results in comparison to the other models. The model was then used to measure technical efficiency levels.

Overall, rice production in Bangladesh seemed profitable thoroughly; and has a comparative advantage in domestic production than that of import substitution. However, the profitability of rice farming has been declined in 2010 compared to 2000 and it also varied from season to season largely due to seasonal variation of yield and in terms of product prices. At the same time, average technical efficiency of rice farmers in Bangladesh varied from 50% to 78%, indicated that there is a large scope for boosting up rice production through increasing the level of efficiency of the farmers.

Hossain and Jaim (2012) showed that it is also the case that farmers level of education, farming experiences and farm size and/or farm income could increase the technical efficiency of farmers. On the other hand, lack of access to stress-tolerant varieties, extension services, agricultural credit, high production costs are the major problem of rice production in the country. Thus, adopting improved agronomic practice and stress tolerant modern rice varieties, and increasing education both the formal and informal education of farmers and ensuring access to soft credit may help to increase rice production.

In short, on average rice production was profitable and Bangladesh has a comparative advantage in domestic production of rice than that for import substitution. However, the profitability of rice farming has declined in 2010 than that for in 2000 and the profitability of rice has largely varied from season to season due to seasonal variation of yield and price of rice in the country. On the other hand, average technical efficiency of rice farmers in Bangladesh varied ranges between 50-78%, indicated that there is a large scope for increasing *T. Aus*, *T. Aman* and *Boro* rice production. It was also the case that farmers level of education, farming experience and farm size and/or farm income had increased the technical efficiency of farmers. On the other hand, lack of access to stress-tolerant varieties, extension services, agricultural credit, high production costs are the major problem of rice production in the country. Thus, adopting improved agronomic practice and stress tolerant modern rice varieties, and increasing education both the formal and informal education of farmers and ensuring access to soft credit may help to increase rice production. A large number of studies estimated the profitability of rice and technical efficiency of rice production using a small-scale household survey data in Bangladesh. However, none of the studies found to assess the profitably, risk, production constraints and production efficiency of rice using a macro level survey data of the different production ecosystem while the production decision is substantially influenced by the profitability and risk. Thus, a study using macro level data for assessing the profitably, risk, production constraints and production efficiency of rice in the different ecosystem is timely for formulating the site-specific policy to enhance rice production for meeting the growing demand.

8. Methodology

8.1 Study locations

Department of Agricultural Extension (DAE) divided the whole country into fourteen Agriculture Regions. These fourteen agricultural regions are; namely, Dhaka, Mymensingh, Faridpur, Cumilla, Chattogram, Rangamati, Sylhet, Khulna, Jashore, Barishal, Rajshahi, Bogura, Rangpur and Dinajpur, respectively. Out of 14 agricultural regions, 28 districts were chosen taking 2 from each of the region. Following the terms and condition of the sub-project, BRRI component surveyed 10 regions e.g., Cumilla, Sylhet, Barishal, Dinajpur, Chattogram, Khulna, Jashore, Mymensingh, Rangpur and Rajshahi and data of the rest of four regions (Bogura, Dhaka, Faridpur and Rangamati) were collected by other component (Bangladesh Agricultural University, Mymensingh) of the sub-project. Considering the presentiveness of the ecosystems, all surveyed districts were grouped into 8 ecosystems such as favorable, *haor*, coastal saline, drought prone, tidal submergence, submergence, low-lying and hilly ecosystems. Purposive sampling technique was used in selecting the locations; namely, region, districts and upazilas with due consideration of different rice ecosystems (e.g., favorable, *haor*, saline coastal, drought prone, tidal submergence, submergence, and low-lying and hilly).

Table 8.1: Locations of the study

Component	Region	District	Upazila	Ecosystems	Households (no.)
BRRI	Dinajpur	Panchagor	Buda	Favorable	175
			Ponchogor sadar	Favorable	175
		Dinajpur	Parbatipur	Favorable	175
			Phulbari	Favorable	175
	Mymensingh	Mymensingh	Muktagacha	Favorable	175
			Fulbaria	Favorable	175
BAU	Dhaka	Tangail	Ghatail	Favorable	175
			Nagorpur	Favorable	175
	Bogura	Bogura	Sherpur	Favorable	175
BAU	Bogura	Bogura	Sariakandi	Favorable	175
BRRI	Sylhet	Sunamgonj	Sunamgonj Sadar	Haor	175
			Bishwambarpur	Haor	175
		Habigonj	Habigang Sador	Haor	175
			Madhobpur	Haor	175
BAU	Dhaka	Kishoreganj	Mithamoin	Haor	175
			Hossainpur	Haor	175
BRRI	Chattogram	Feni	Sonagazi	Salinity	175
			Feni sadar	Salinity	175
		Cox's Bazar	Ramu	Salinity	175
			Chokriya	Salinity	175
	Khulna	Khulna	Dumuria	Salinity	175
			Rupsha	Salinity	175
		Satkhira	Sadar Satkhira	Salinity	175
			Shyamnagar	Salinity	175
	Jeshore	Jessore	Jessore Sadar	Drought	175
			Monirumpur	Drought	175
		Kushtia	Mirpur	Drought	175
			Khustia Sador	Drought	175
	Rajshahi	Rajshahi	Gudagari	Drought	175
			Poba	Drought	175
		Naogaon	Dhamhat	Drought	175
			Manda	Drought	175
	Barisal	Barisal	Bakergonj	Tidal submergence	175
			Barisal Sadar	Tidal submergence	175
		Patuakhali	Patuakhali sadar	Tidal submergence	175
			Golachipa	Tidal submergence	175
	Mymensingh	Jamalpur	Islampur	Submergence	175
			Mathargonj	Submergence	175
BAU	Bogura	Sirajganj	Tarash	Submergence	175
			Rayganj	Submergence	175

Component	Region	District	Upazila	Ecosystems	Households (no.)
BRRI	Rangpur	Gaibandha	Sundorganj	Submergence	175
			Fulchori	Submergence	175
		Kurigram	Rajarhat	Submergence	175
			Kurigram	Submergence	175
BAU	Faridpur	Faridpur	Sadar	Low lying	175
			Bhanga	Low lying	175
		Gopaganj	Kasiani	Low lying	175
BAU	Gopaganj	Kasiani	Moksudpur	Low lying	175
BRRI	Cumilla	Cumilla	Borura	Low lying	175
			Debiddar	Low lying	175
		Bramonbariya	Sarail	Low lying	175
			Ashugonj	Low lying	175
BAU	Rangamati	Bandarban	Naikhongchhari	Hilly	175
			Lama	Hilly	175
		Khagrachhari	Matiranga	Hilly	175
			Sadar	Hilly	175
Total		28	56	8	9800

Source: Field survey, 2019-2020.

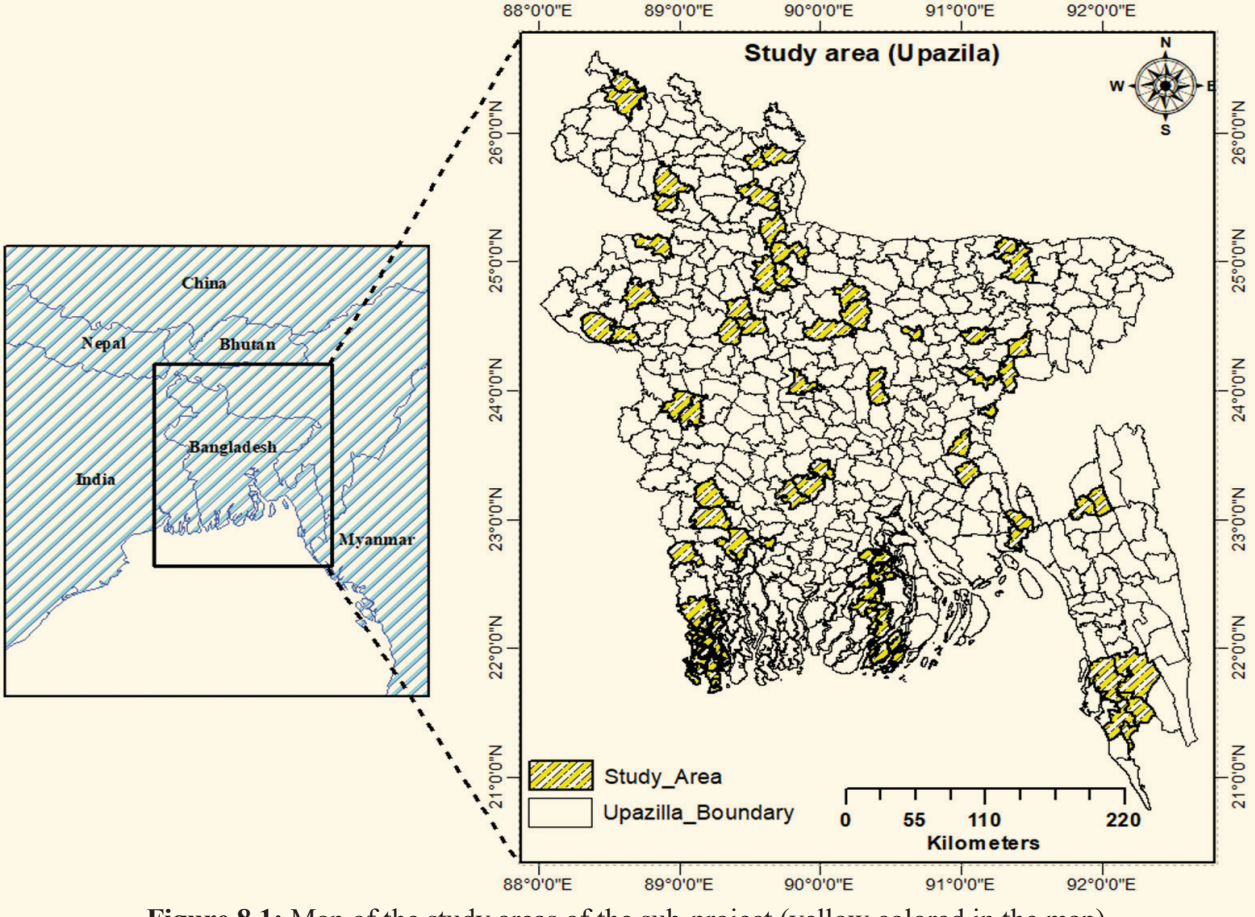


Figure 8.1: Map of the study areas of the sub-project (yellow colored in the map)

8.2. Sampling technique and sample size

In order to ensure that the study is nationally representative, a multi-stage (two stage sampling frame-work) random sampling technique was followed for selection of the villages and purposive sampling was used to choose the households for the survey (large, medium and small farmers). A full list of farm households with operating area of the selected villages was collected from the Upazila Agricultural Office of DAE which have been used as a sampling frame for selecting the respondents. Then purposive stratified sampling technique was adopted to select the respondents of different farm household types (e.g., small, medium and large). Based on the farm household distribution report of Agricultural Census 2019 in Bangladesh, sample framing was structured but number of surveyed households were not exactly matched with pre structured sampling frame during survey. In many cases, Aus rice growers and large farmers were not much available. Then, based on the field experience, the sampling frame were restructured to apply stratified random sampling method across the seasons and types of famers. Table 8.1 presents the chosen distribution of sample for all agricultural regions. Finally, Therteen farmers from *T. Aus*, thirty-eight from *T. Aman* and thirty-seven from *Boro* rice growers were interviewed from each village. Thus, in total 9,800 farm households were interviewed from 14 agricultural regions, 700 from each of the region with well-structured pre-tested questionnaire.

Table 8.2: Sample distribution under the selected agricultural regions

Regions	No of district	No of upazila	No of villages	Farm size	No. of Sample by season			Total
					T. Aus	*T. Aman*	*Boro*	
14	28	56	112	Small (0.22-1.00 ha)	944	3070	2840	6854
				Medium (1.1-3ha)	354	929	1007	2290
				Large (Above 3 ha)	97	240	319	656
				Total	1395	4239	4166	9800

Source: Field survey, 2019-2020.

8.3 Survey team

A survey team was formed with scientists and trained enumerators to collect primary data with the assistance of DAE personel. The Coordinator and Principal investigator monitored data collection activities on a regular basis.



Picture 1: Survey team with farmers and DAE personnel

8.4 Questionnaire preparation

A semi-structured questionnaire was developed for collecting the basic socio-demographic features and agricultural statistics of farm households, including input, labour use pattern and yields of rice grown in the different seasons (*T. Aus, T. Aman* and *Boro*), prices of inputs and outputs, constraints of rice production and their suggestions for eradicating those problems. The developed questionnaire was pretested through collecting data from Mymensingh and Dinajpur areas and then the actual and practical experiences assembled from pre-testing. Besides, a checklist for conducting FGD and KIS schedule for expert panel was also prepared.

8.5 Period of Study

Both survey and reporting were carried out in three phases. The first phase was 14 February, 2018 to 13 February 2019, the second phase was 14 February, 2019 to 13 February, 2020 and the third phase was 14 February, 2021 to 31 January, 2022. Under three phases of data collection and reporting, respectively four, three and six selected agricultural regions, were surveyed; necessary data collection from the sample farm households and reporting had been accomplished during the aforementioned study periods.

8.6 Method of data collection

Household survey was conducted using the semi-structured questionnaire. All necessary data had been collected following face-to-face interview method. A checklist was developed for collecting the cross-check information on input use pattern, yields, price of inputs and outputs, seasonal variability in inputs and yields, criteria and constraints of adopted rice varieties, overall problem of rice cultivation and their suggestions to mitigate the problems. In total, 14 FGDs were conducted for this study in fourteen regions.




Picture 2: Focus group discussion with farmers and key informants

8.7 Data Entry and Data Management

The collected data were carefully checked and cleaned by each enumerator before submitting to data entry operator for developing a master sheet. Data were then scrutinized, classified, cleaned and coded after entering into MS Excel sheet for developing a reliable and realistic database which consists of a wealth of updated region-specific rice production information. The accounting calculation and econometric model were employed, as needed. Mostly, descriptive statistics were used for analyzing the collected data. The data was analyzed using Rstudio, STATA16 and @RISK software programme version 8.2.

8.8 Analytical Techniques

The following major analytical tools were used for analyzing the generated data.

8.8.1 Descriptive statistics

Descriptive Statistics was used to get the simple measures like average, percentage and ratio. It included socio-economic profiles of rice farmers, production practices and input use, costs and returns of rice farming of different regions.

8.8.2 Profitability status

To determine per hectare profitability in rice production for each farm of the selected rice farming following algebraic equation:

$$\prod = \sum Q_y.P_y + \sum Q_b.P_b - \sum_{i=1}^{n}(X_i.P_{xi}) - TFC \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where,

$\prod$= Net profit (Tk/ha);

Q_y = Total quantity of (rice) outputs (ton/ha);

P_y = Per unit prices of the rice (Tk/ton);

Q_b = Total quantity of the concerned by-product (Kg/ha);

P_b = Per unit price of the relevant by-product (Tk/kg);

X_i = Quantity of the concerned i^{th} inputs;

P_x = Per unit price of the relevant i^{th} inputs;

TFC = Total fixed cost involved in production per hectare; and

$i = 1,2,3,...,n$ (Number of inputs).

8.8.3 Technical Efficiency

Technical efficiency refers to the productive input mix. In that sense, a producer is said to be technically efficient when considering a set of factors and inputs, it is impossible to increase the quantity of a product without increasing the factor aspect or decrease the quantity of another product. For the same level of production, the most technically efficient producer is the one that uses less input. The technical efficiency of the individual farm can be defined as

$$\text{Tecnical efficiency} = \frac{\text{(Observed output by a given set of inputs)}}{\text{(Frontier output at the same level of input)}}$$

A stochastic frontier production function has been employed to determine the production efficiency of rice farmers of different regions. The stochastic frontier production function model for cross sectional data is as follows:

$$Y_i = f(xi, \beta i)e^{\epsilon} i \quad \ldots\ldots\ldots\

Where,

Y_i represents rice yield of ith farmers (ton/ha)

In X_1 represents logarithomic form of rice area (RA) of ith farmers (in decimal);

In X_2 is the logarithomic form of the labour of ith farmers (in man-days/ha)

In X_3 is the logarithomic form of the seed of ith farmers (in kg/ha);

In X_4 is the logarithomic form of the NPK (Urea, TSP and MoP) of ith farmers (in kg/ha);

In X_5 is the logarithmic form of the land preparation cost (LPC) ith farmers of (in taka/ha);

In X_6 is the logarithomic form of irrigation cost of ith farmers (in taka/ha);

In X_1 In X_1 is the form of log(RA)*log(RA);

In X_2 In X_2 is the form of log(labour)*log(labour);

In X_3 In X_3 is the form of log(seed)*log(seed);

In X_4 In X_4 is the form of log(NPK)*log(NPK);

In X_5 In X_5 is the form of log(LPC)*log(LPC);

In X_6 In X_6 is the form of log(irrigation cost)*log(irrigation cost);

In X_1 In X_2 is the form of log(RA)*log(labour);

In X_1 In X_3 is the form of log(RA)*log(seed);

In X_1 In X_4 is the form of log(RA)*log(NPK);

In X_1 In X_5 is the form of log(RA)*log(LPC);

In X_1 In X_6 is the form of log(RA)*log(irrigation cost);

In X_2 In X_3 is the form of log(labour)*log(seed);

In X_2 In X_4 is the form of log(labour)*log(NPK);

In X_2 In X_5 is the form of log(labour)*log(LP);

In X_2 In X_6 is the form of log(labour)*log(irrigation cost);

In X_3 In X_4 is the form of log(seed)*log(NPK);

In X_3 In X_5 is the form of log(seed)*log(LPC);

In X_3 In X_6 is the form of log(seed)*log(irrigation cost);

In X_4 In X_5 is the form of log(NPK)*log(LPC);

In X_4 In X_6 is the form of log(NPK)*log(irrigation cost);

In X_5 In X_6 is the form of log(LPC)*log(irrigation cost);

v_i is the random variables associated with disturbance in production;

u_i is the farm specific characteristics to production efficiency; and

β_0, β_j's and β_{jk}'s are the parameters to be estimated; j = 1, 2, ... 6 and k = 1, 2, ...6 .

u_i are non-negative random variables, associated with technical inefficiency of farmers, assumed to be independently distributed, such that the technical inefficiency effect for the i^{th} farmer growing rice. It is assumed that the technical inefficiency effects are linearly related to the farmers' characteristics as follows:

$$u_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \delta_6 Z_{6i} + \delta_7 Z_{7i} + w_i \quad \text{..... (4)}$$

Where,

Z_1 = Age of i^{th} farmers (in years);

Z_2 = Experience of i^{th} farmers (in years);

Z_3 = Education of i^{th} farmers (in years of schooling);

Z_4 = Extension dummy of i^{th} farmers, 1 if extension service received, otherwise 0;

Z_5 = Training dummy of i^{th} farmers, 1 if Training received, otherwise 0;

Z_6 = Credit dummy of i^{th} farmers, 1 if credit received, otherwise 0;

Z_7 = Access to media dummy of i^{th} farmers, 1 if access to mass media, otherwise 0;

δ_0..... δ_7 are unknown parameters to be estimated; and

w_i's are random error that are defined by the truncation of the normal distribution with zero mean and variance, σ_w^2 such that the point of truncation is $-Z_i\delta$, *i.e.,* $w_i > - Z_i\delta$.

8.8.4. Risk analysis

Financial analysis is an average estimate of turnover performance, which never considers causes of variation in yields and prices due to respective events such as weather and market distortion. Sensitivity is switching the value of the variable and only establishes priorities and identify the most important factors which lead to great improvements in output factors (Khoshroo *et al.* 2018). Therefore, sensitivity analysis could not dig out the insight of synergic variability of financial performance and the likelihood of particular effect (Lien 2003). Hence, risk analysis is the product of threat, vulnerability and consequences that could be quantified by stochastic budgeting method and probability distribution of conditional outcome (Xu, 2009). Farmers were asked to estimate the most likely/average, maximum, and minimum yields and market prices for crop enterprise. The maximum yield could be produced in best weather that is expected to exist across growing season and minimum yield is always not expected but happened under erratic weather. Extreme event is not considered in hypothesis in risk analysis since occurrence of extreme events such as cyclone, drought and flood lead to total loss of farm investment. The program @RISK Versions 8.2 was employed which adds in software in Excel to calibrate cumulative probability distributions for gross income and net-income. Triangular distribution is three-point estimate of probability distributions meaning that it requires three parameters with the lower limit defined as worse case, the moderate as the perceived most likely outcome, and the maximum limit as the best case (Anderson and Dillion, 1992; Hardaker *et al.* 2004).

A Monte Carlo simulation was run for assessing the relative risks of *Aus*, *Aman* and *Boro* rice cultivation in the different ecosystems such as saline coastal, drought prone, submergence, *haor*, char, hillyy and favorable. Farmers' decision to adopt a new technology or crops or rotations is most likely to be influenced by the level of profitability and risk associated with the respective crops or rotations. In this respect, the stochastic dominance is a tool for measuring comparative probability of relative risks involved with the outcomes of the alternative choices through cumulative probability distributions or to evaluate risk-return trade-offs. For instance, net return is stochastic due to involvement of uncertainty wherein a producer can reduce risks by receiving reduced profits (Dillon, 2003).

The stochastic budgeting will be developed through Monte Carlo simulation software in the study for assessing the risks of rice crops grown in the different seasons and ecosystems. There are a wide variety of standard probability distributions (e.g., the normal, beta, gamma, and triangular or rectangular) which can be estimated by using specialist software add-ins such as @Risk (Palisade, 2012) with Excel spread-sheet (Dillon and Hardaker, 1993) but triangular distribution was applied in the study due to availability of data to fit into the distribution.

Monte Carlo simulation was applied by 10000 iterations to compute the cumulative probability and inputs ranks for risk assessment. Stochastic efficiency analysis was carried out to evaluate the risk-return trade-offs by comparing the cumulative probability distributions of the alternative enterprise choices (Dillon and Hardaker 1993).

8.8.5 Severity Ranking Model (SRM)

The severity of damage of rice production due to risk in different ecosystems was estimated by using severity ranking model (SRM) (Uddin *et al.* 2018). The major consequence of the model was identified as risk. The sub-component of risk was biotic risk, abiotic risk and natural calamities. Biotic risk of rice farming connected with: i) insects; ii) diseases and iii) rats; abiotic risk included: i) drought, ii) water logged and iii) submergence; natural calamities included: i) flash flood, ii) rainfall and iii) hailstorm. The severity of damage was characterized as extreme (severity point = 4), high (severity point = 3), medium (severity point = 2) and low (severity point = 1). The component severity score (CSS) of each stress of the model was estimated using the following formula:

$$CSS = (N_E \times SP_E) + (N_H \times SP_H) + (N_M \times SP_M) + (N_L \times SP_L)$$

Where,

CSS = Component severity score in case of biotic risk, abiotic risk and natural calamities;

N_E = Number of farmers in extreme damage level; SP_E = Severity point of extreme damage level; N_H = Number of farmers in high damage level; SP_H = Severity point of high damage level; N_M = Number of farmers in medium damage level; SP_M = Severity point of medium damage level; N_L= Number of farmers in low damage level; and SP_L = Severity point of low damage level.

8.8.6 Garrett's Ranking Technique (GRT)

Information regarding the constraints faced by the farmers in rice cultivation under different ecosystems was procured using garrett's ranking technique (GRT). Constraints were identified in consultation with the respondents by asking to rank the problems proposed to them. Garrett's ranking technique provides the change of orders of constraints and advantages into numerical scores (Jimjel *et al.* 2015). The prime advantage of this technique over simple frequency distribution is that the constraints are arranged based on their severity from the point of view of respondents. Hence, the same number of respondents on two or more constraints may have been given different rank and these ranks were entered into percent position using the formula as follows:

$$\text{Percent Position} = \frac{100 \times (R_{ij} - 0.5)}{N_j}$$

Where,

R_{ij}= Ranking given to the i^{th} constraints by the j^{th} individual and = Number of constraints ranked by the j^{th} individual.

The percent position was determined from the scores referring by Garrett and Woodworth (1969) which is represented in Table 3 as follows:

Table 8.3: Percentage positions and their corresponding Garrett table values

Rank	Percent position		Garrett table value
1	100(1-0.5)/6	8.3	77
2	100(2-0.5)/6	25.0	63
3	100(3-0.5)/6	41.7	54
4	100(4-0.5)/6	58.3	46
5	100(5-0.5)/6	75.0	37
6	100(6-0.5)/6	91.7	23

Source: Garrett and Woodworth, 1969.

9. Results and discussion

9.1 Demographic profile of the farmers

Table 9.1 showed the socio-demographic profile of the respondents in the surveyed regions under respective ecosystem. It revealed from the analysis that average household size in the study areas was about 5 persons per family, of which 51% was male and it was in line with the national average (4.11, HIES 2017). On an average, three person per household were engaged in agriculture by profession. Most (56%) of the farmer's age ranged between 26-50 and it is to be noted that a large portion (36%) of the farmer's age were between 51-70 years. Most of the farm families (95) were male headed while it was 99% in some cases. In case of educational status, most of the respondents (61%) were done with primary and secondary schooling but it is to be noted that on an average 28% farmers were found as illiterate. In terms of religion, most of the respondents were Islam followers (86%) followed by Hinduism and Buddhism (7%). Most of the surveyed farmers (92%) occupied agriculture as their primary profession from last 27 years, on an average. In terms of experience, most of the farmers (52%) were engaged in agriculture for 21-40 years. A large portion (34%) of the farmers have 20 or below 20 years of farming experience all over the country.

Table 9.1: Demographic profile of the farmers

Categories	Ecosystem								Average
	Favorable	*Haor*	Salinity	Drought	Tidal submergence	Submergence	Low lying	Hill	
Household size (no)	5	6	5	4	5	5	6	6	5
Male (%)	50	53	52	50	51	50	52	50	51
Female (%)	50	47	48	50	49	50	48	50	49
Engaged in ag. (no)	3	7	2	2	2	2	2	6	3
Average farm size (dec)	201	233	202	253	209	324	167	125	214
Age distribution (years) (% of farmers)									
below 25	6	3	3	4	3	2	3	6	4
between 26-50	61	52	54	66	49	60	52	63	56
between 51-70	30	41	40	28	44	36	42	28	36
above 70	4	5	4	2	5	3	5	3	4
Female headed family	2	2	4	3	1	7	3	22	5
Male headed	98	98	96	97	99	94	97	78	95
Educational status (% of farmers)									
Primary	25	37	24	20	40	26	31	36	30
Secondary	25	23	35	41	33	36	33	19	31
Above secondary	12	4	10	22	8	19	7	7	11
Illiterate	36	35	30	18	18	20	31	38	28
Religious distribution (% of farmers)									
Islam	89	82	88	4	98	98	90	44	86
Hindu	11	18	10	1	2	2	10	2	7
Christian	0	0	0	1	0	0	0	0	0
Buddha	0	0	2	0	0	0	0	54	7
Occupational status (% of farmers)									
Agriculture	89	97	95	88	89	95	94	86	92
Business	5	1	3	7	3	2	2	8	4
Service	2	1	1	3	4	1	2	4	2
Others	5	1	2	2	4	2	2	2	3
Experience status (years) (% of farmers)									
Below 20	34	32	24	38	26	26	31	60	34
Between 21-40	53	51	60	55	57	56	52	28	52
Above 40	12	18	16	7	20	19	19	12	14

Source : Field survey, 2019-2021

9.2 Scenario of land tenancy pattern in different ecosystems

Data in Table 9.2 depict the structure of the farm size and land tenancy status of sample farms in different ecosystems of the country. The highest percentage of large farmers was found in *haor* ecosystem (6%) followed by submergence (5%) and saline (4%) ecosystem. *Haor* ecosystem is also abundant with medium farmers as 26% and it was 22% in submergence ecosystem and 21% in drought ecosystem. On the other hand, among the sample farmers, highest percentage of small farmers belonged to hilly ecosystem (92%) followed by low lying (89%) and tidal submergence (84%) ecosystem. However, the average percentage of large, medium and small farmers were 3%, 18% and 79%, respectively among all the ecosystems. Highest large farm size was observed in hilly (1275 decimal) followed by drought (1241 decimal) and low lying (1237 decimal) ecosystem. Largest medium farms were found in tidal submergence (466 decimal) followed by drought (431 decimal) and low lying (382 decimal) ecosystem. Largest small farm was recorded in hilly (92 decimal) followed by low lying (89 decimal) and tidal submergence (84 decimal) ecosystem. Farmers in drought ecosystem reported to have more own cultivated land (895 decimal) among all the ecosystems while farmers in Hilly (62 decimal) ecosystem mentioned to have the lowest amount of own cultivated land. Results also revealed that farmers in Low lying ecosystem likely to have more (533 decimal) land which are rented or leased in while farmers in hilly ecosystem were found at top (645 decimal) in case of amount of land rented/leased out. On average, the amount of rented/leased in land were 246, 85 and 40 decimal for large, medium and small farmers while the amount of land rented or leased out were 350, 86 and 7 decimal for large, medium and small farmers, respectively in all the studied ecosystems.

Table 9.2: Structure of farm size and tenancy status of sample farmers under different ecosystems

Particulars	Land tenancy arrangement (Decimal)					
	Farmers	% Farmers	Av. farm size	Own cultivated	Rent/leased in	Rent/leased out
Favorable ecosystem						
Large	62	3	953	464	87	366
Medium	395	19	364	276	59	68
Small	1643	78	134	107	26	6
***Haor* ecosystem**						
Large	66	6	976	667	94	393
Medium	274	26	378	260	52	88
Small	710	68	146	138	22	14
Salinity ecosystem						
Large	56	4	1035	443	351	273
Medium	239	17	335	172	163	29
Small	1105	79	140	94	68	3

Particulars	Land tenancy arrangement (Decimal)					
	Farmers	% Farmers	Av. farm size	Own cultivated	Rent/leased in	Rent/leased out
Drought ecosystem						
Large	44	3	1241	895	162	210
Medium	290	21	431	374	75	26
Small	1066	76	151	143	35	4
Tidal submergence ecosystem						
Large	12	2	947	509	210	237
Medium	100	14	466	313	101	11
Small	588	84	164	128	51	4
Submergence ecosystem						
Large	55	5	954	587	76	358
Medium	234	22	345	194	37	79
Small	761	72	146	114	28	6
Low lying ecosystem						
Large	17	1	1237	380	533	316
Medium	142	10	382	157	67	163
Small	1241	89	119	102	34	11
Hilly ecosystem						
Large	2	0	1275	178	454	645
Medium	57	8	356	91	124	225
Small	641	92	84	62	56	11
Grand total						
Large	314	3	1077	515	246	350
Medium	1731	18	382	230	85	86
Small	7755	79	136	111	40	7

Source : Field survey, 2019-2021
Note: Large farmers (>=750 dec); Medium farmers (250-749 dec); Small farmers (50-249 dec)

9.3 Land topography and soil types in different ecosystems

The percentage area of land topography and soil types has been presented in Table 9.3. Most of the farmers preferred to cultivate HYV rice in medium high (MH) and medium low (ML) land during all the three seasons in all the ecosystems. It is to be noted that, farmers in *Haor* ecosystem cultivated their rice mostly in medium to low land compare to other ecosystem. Moreover, most of the farmers cultivated rice on sandy loamy and loamy soil followed by clay loamy by considering all the ecosystems as a whole. Most of the high to medium high land in all the ecosystems were used in *T. Aus* season, where drought ecosystem topped the type. Again, farmers all over the country mainly use loamy and sandy loamy soil for HYV rice cultivation.

Table 9.3: Percentage of area under land topography and soil types in different ecosystems

Land/soil type	Percent area under different land topography and soil type								
	Favorable	*Haor*	Salinity	Drought	Tidal submergence	Submergence	Low lying	Hilly	Average
Land type									
T. Aus									
High land	7	13	4	27	11	3	11	22	12
Medium high	32	20	32	33	43	34	35	38	33
Medium low	32	18	31	15	24	28	20	15	23
Medium	21	41	28	16	13	26	22	18	23
Low	8	7	5	8	9	9	13	7	8
T. Aman									
High land	5	8	6	18	10	4	12	21	11
Medium high	24	20	31	30	41	23	44	39	31
Medium low	29	17	32	22	30	33	23	19	26
Medium	28	47	24	25	11	28	11	16	24
Low	14	8	7	6	8	11	11	5	9
Boro									
High land	12	8	4	20	4	11	13	20	12
Medium high	25	25	20	36	27	13	36	28	27
T. Aus									
Medium low	32	14	44	18	48	27	20	21	28
Medium	20	32	21	17	12	39	17	23	22
Low	10	20	11	9	9	10	14	7	11

Land/soil type	Percent area under different land topography and soil type								
	Favorable	*Haor*	Salinity	Drought	Tidal submergence	Submergence	Low lying	Hilly	Average
Soil type									
T. Aus									
Sandy loam	35	44	17	37	10	76	46	26	36
Loamy	30	29	44	41	64	23	35	66	41
Clay loamy	30	25	39	22	25	0	19	7	21
Others	5	2	0	0	1	0	0	1	1
T.Aman									
Sandy loam	31	40	51	33	15	82	41	36	41
Loamy	34	30	27	38	61	15	36	43	35
Clay loamy	35	29	22	28	24	1	21	18	22
Others	1	1	0	1	0	2	2	3	1
Boro									
Sandy loam	39	49	36	23	10	85	33	13	36
Loamy	26	35	25	48	59	14	40	63	39
Clay loamy	33	16	39	29	30	1	27	23	25
Others	2	0	0	1	0	0	0	1	1

Source : Field survey, 2019-2021.

9.4 Area coverage (%) under different crops varieties in different seasons

There are many modern rice varieties and plenty of local varieties which are being cultivated in Bangladesh in different region under diverse agro-ecological condition. Due to strong extension network and dissemination of modern cultivar, modern rice varieties continuously replacing the local varieties to improve the farmers' productivity. The season-wise area coverage under rice varieties in different ecosystems has been presented in Table 9.4-9.6.

Among HYVs, most popular varieties in *T. Aus* season was BRRI dhan48 covering 13 to 68% areas in different ecosystems. Highest adoption of BRRI dhan48 was observed in submergence (67.52%) ecosystem followed by low lying ecosystem (36.86%) region. In this season, farmers also cultivated other HYVs; such BR2, BR26, BRRI dhan28, BRRI dhan27, Bina dhan7, BRRI dhan56, BRRI dhan64, BRRI dhan76 and BRRI dhan82. On the other hand, major parts of rice areas are devoted to LV_s in tidal submergence (39.96%) ecosystem in this season. It is to be noticed that there was a large amount of land of which remains fallow during *T. Aus* season.

Table 9.4: Percent area coverage by rice varieties in *T. Aus* season in different ecosystems

Ecosystem	Varieties	% of rice area	Ecosystem	Varieties	% of rice area
Favorable ecosystem	BRRI dhan48	32.96	***Haor* ecosystem**	Bina dhan7	3.62
	BRRI dhan82	14.20		BRRI dhan82	4.04
	Hybrid	2.27		BRRI dhan48	35.74
	Vegetables	3.47		BAU63	2.71
	Fallow	23.69		BRRIdhan46	4.26
	Others	24.56		Fallow	23.98
Tidal submergence ecosystem	BAU63	2.71		Others	26.12
	BRRI dhan27	5.73	**Submergence ecosystem**	BRRI dhan48	67.52
	BRRI dhan48	13.74		BRRI dhan82	7.89
	Local	39.96		Vegetables	3.02
	Vegetables	4.54		Fallow	17.61
	Fallow	29.06		Others	3.98
	Others	4.27	**Salinity ecosystem**	BRRI dhan28	8.48
Drought ecosystem	BRRI dhan28	5.36		BRRI dhan48	24.87
	BRRI dhan48	23.98		BRRI dhan52	6.05
	BRRI dhan56	18.03		BRRI dhan75	9.41
	BRRI dhan76	16.70		BRRI dhan64	6.41
	Minikit	11.28		BRRI dhan74	5.13
	Jute	7.45		BRRI dhan78	12.82
	Fruit orchard	6.32		Pajam	6.41
	Vegetables	4.40		Fish	15.26
	Fallow	6.78		Fallow	5.64
Low lying ecosystem	BR2	32.63	**Hilly ecosystem**	BRRI dhan58	15.65
	BR26	4.03		BRRI dhan48	21.49
	BRRI dhan28	3.27		BRRI dhan20	7.50
	BRRI dhan48	36.86		Suri	10.75
	Local	7.52		Local	12.25
	Vegetables	3.20		Hybrid	4.47
				Vegetables	8.92
	Fallow	12.52		Tobacco	13.46
				Others	6.28

Source : Field survey, 2019-2021





Picture 3: *T. Aus* rice in the farmers' field

In *T. Aman* season, Local variety is still popular rice cultivars (37.65%) in tidal submergence ecosystem followed by favorable ecosystem (16.83%). Swarna (an Indian variety) is very popular among the farmers due to different traits in drought (33.46%), submergence (31.68%) and favorable (27.68%) ecosystem. Farmers grew BR22 in 29.44% areas in *haor* ecosystem followed by 27.89% in Low lying ecosystem. Highest adoption of BRRI dhan49 was observed in drought ecosystem (29.45%) followed by favorable (25.12%) ecosystem. On the other hand, highest amount of lands remains fallow during in *T. Aman* season in saline (14.19%) ecosystem followed by the *haor* (13.47%) ecosystem (Table 9.4).

Table 9.5: Percent area coverage by rice varieties in *T. Aman* season in different ecosystems

Ecosystem	Varieties	% of rice area	Ecosystem	Varieties	% of rice area
Favorable ecosystem	BRRI dhan49	25.12	**Tidal submergence ecosystem**	BR22	24.73
	BRRI dhan11	6.07		BR23	4.10
	BRRI dhan22	4.05		BRRI dhan49	5.62
	BRRI dhan32	2.73		BRRI dhan52	3.07
	Swarna	27.68		Local	37.65
	Horidhan	8.70		Vegetables	5.33
	Local	16.83		Fallow	5.71
	Hybrid	4.27		Others	16.88
	Vegetables	5.16	**Submergence ecosystem**	BR11	6.71
***Haor* ecosystem**	BR22	29.44		BRRI dhan49	12.47
	BRRI dhan32	2.91		BRRI dhan39	20.66
	BRRI dhan46	26.73		BRRI dhan52	4.64
	BRRI dhan49	5.26		Swarna	31.68
	Local	7.86		Ranjit	7.19
	Fallow	13.47		Horinga	6.12
	Others	14.34		Local	7.58
Salinity ecosystem	BR10	15.75		Fallow	3.04
	BR23	8.72	**Low lying ecosystem**	BR22	27.89
	BRRI dhan30	12.20		BRRI dhan46	10.68
	BRRI dhan49	13.90		BRRI dhan49	23.56
	Swarna	10.03		Bina dhan7	14.28
	BRRI dhan46	7.49		R parina	7.52
	BRRI dhan52	6.64		Debobuni	3.98
	Pajam	3.92		BRRI dhan33	6.24
	Fallow	14.19		Local	6.18
	Others	7.20		Bina-7	23.64
Drought ecosystem	BRRI dhan49	29.45	**Hilly ecosystem**	Cokkapanja	1.70
	BRRI dhan87	3.78		Sonali pajam	7.96
	Swarna	33.46		Sylheti pajam	12.72
	Local	8.85		BRRI dhan11	16.34
	Hybrid	6.12		BRRI dhan49	16.58
	Vegetables	3.12		BRRI dhan33	1.42
	Fruit orchard	3.51		Indian pajam	3.32
	Fallow	5.26		Hori	13.40
	Others	7.32		ACI-7006	3.39

Source : Field survey, 2019-2021.



Picture 4: *T. Aman* rice at the farmers' field

It is very worth mentioning that *Boro* season in Bangladesh is mainly driven by the two HYV mega variety, namely, BRRI dhan28 and BRRI dhan29. The adoption of BRRI dhan28 is highest in tidal submergence (32.87%) ecosystem followed by saline (32.54%) and Low lying (32.45%) ecosystem. On the other hand, BRRI dhan29 was mostly cultivated by the farmers in mono crop areas like; *haor* (48.05%) ecosystem followed by low lying (40.47%) and submergence (38.76%) ecosystem. Farmers in drought ecosystem notably (27.30%) cultivated Zira another Indian variety. Although, different hybrid varieties were cultivated in this season all over the country but it occupied highest area in saline ecosystem (16.35%).

Table 9.6: Percent area coverage by rice varieties in *Boro* season in different ecosystems

Ecosystem	Varieties	% of rice area	Ecosystem	Varieties	% of rice area
Favorable ecosystem	BRRI dhan28	18.73	**Tidal submergence ecosystem**	BRRI dhan28	32.87
	BRRI dhan29	29.21		BRRI dhan29	13.1
	BR19	2.58		BRRI dhan47	5.46
	Hira	7.48		Pulse	10.13
	Miniket	10.58		Vegetables	8.85
	Subolota	8.88		Fallow	16.1
	Pea nut	5.82		Others	13.5
	Hybrid	7.54	**Submergence ecosystem**	BRRI dhan28	27.46
	Vegetables	9.27		BRRI dhan29	38.76
***Haor* ecosystem**	BRRI dhan28	28.66		Hira	20.28
	BRRI dhan29	48.05		Miniket	8.28
	Hira	10.18		Vegetables	3.33
	Lota*Boro*	5.47		Fallow	1.89
	Vegetables	3.27	**Low lying ecosystem**	BRRI dhan28	32.45
	Fallow	4.37		BRRI dhan29	40.47
Salinity ecosystem	BRRI dhan28	32.54		BRRI dhan48	6.26
	BRRI dhan29	11.41		BRRI dhan58	5.49
	BRRI dhan63	7.45		Hybrid	4.74
	BRRI dhan81	5.27		Kali*Boro*	6.85
	BRRI dhan33	11.1		Others	3.78
	Hybrid	16.35	**Hilly ecosystem**	BRRI dhan28	30.05
	Vegetables	8.64		BRRI dhan78	9.69
	Fallow	2.68		BRRI dhan29	8.76
	Others	4.56		Bina12	8.68
Drought ecosystem	BRRI dhan28	28.695		Hira	12.92
	BRRI dhan81	2.15		ACI	5.32
	BRRI dhan50	8.12		Aloron	2.43
	Kataribhog	7.94		Gol IRRI	5.91
	Zira	27.305		Cokkapanja	1.44
	Miniket	16.55		Tia	4.34
	Pulse	2.29		Supershera	3.18
	Vegetables	1.93		1203	3.3
	Varieties	% of rice area		Varieties	% of rice area
	Fallow	3.34		Agomoni	1.84
	Others	1.68		Others	2.14

Source : Field survey, 2019-2021



Picture 5: *Boro* rice in the farmers' field

9.5 Major cropping patterns in different ecosystems

Cropping pattern simply refers to the proportion of land under cultivation of various crops at different points of time, indicating arrangement of crops in a particular acreage which has the potential advantages of increasing yield, reducing the crop risks, etc. Cropping pattern/system or crop rotation may be one of the means to augment the total production of agriculture sector. There are more than 300 cropping patterns in the country. Highlighting this issue, the cropping pattern of the surveyed areas are presented in Table 9.7 according to ecosystem.

Favorable ecosystem: Fallow-*T. Aman-Boro* is the principal cropping pattern (36.88%) followed by Fallow-*T. Aman*-Fallow (10.23%), *T. Aus*-Fallow-*Boro* (10.05%), *T. Aman*- Potato-*Boro* (8.39%), *T. Aus-T. Aman-Boro* (7.19%), Fallow-*T. Aman*-Vegetables (6.88%), Fallow-Fallow-*Boro* (3.38%) and Peanut-*T. Aman-Boro* (3.06%).

Drought ecosystem: Fallow-*T. Aman-Boro* (49.37%) is the major cropping pattern followed by *T. Aus-T. Aman-Boro* (18.56%), *T. Aus*-Fallow-*Boro* (6.84%), *T. Aus-T. Aman*-Fallow (4.36%) cropping pattern, respectively and Fallow- *T. Aman*-Fallow (4.27%).

***Haor* ecosystem:** Fallow-Fallow-*Boro* (61.50%) is the major cropping pattern followed by Fallow-*T. Aman*-Fallow (15.80%), *T. Aus-T. Aman-Fallow* (12.85%) and *T. Aus*-Fallow-*Boro* (9.86%), respectively.

Salinity ecosystem: Dominant cropping pattern is Fallow-*T. Aman-Boro* (31.15%) followed by Fish-Fish-*Boro* (10.57%), Fallow-Fallow-Vegetables (8.47%), Fallow-Fallow-*Boro* (7.88%), *T. Aus-T. Aman-Boro* (7.33%) and *T. Aus-T. Aman-Fallow* (6.51%), respectively.

Tidal submergence ecosystem: Dominant cropping patterns are- Fallow-*T. Aman-Boro*, which covered about 24% of the net cropped areas (NCA) in this region, followed by Fallow-Fallow-*Boro* (15.35%), Fallow-*T. Aman*-Fallow (13.48%).

Submergence ecosystem: About 87% cropped area is under Fallow-*T. Aman-Boro* followed by Fallow-*T. Aman*-Vegetables (3.67%) and Fallow-Fallow-*Boro* (3.06%), respectively.

Low-lying ecosystem: Leading cropping patterns are- Fallow-Fallow-*Boro* (26.64%) followed by *T. Aus-T. Aman -Boro* (24.61%), Jute-*T. Aman*-Fallow (16.47%), *T. Aman-Boro* (16.18%), and *T. Aus*-Fallow-Fallow (3.06%), respectively (Table 8).

Hilly **ecosystem:** Dominant cropping pattern of this ecosystem are Fallow-*T. Aman-Boro* (78.71%), *T. Aus*-Fallow-Tobacco (10.28%), Fallow-*Aman*-Vegetables (6.1%) and Fallow-*T. Aman*-Fallow (3.46), respectively.

Table 9.7: Major cropping patterns under different ecosystems

Ecosystem	Cropping pattern	% of area	Ecosystem	Cropping pattern	% of area
Favorable	Fallow-T. Aman-Boro	36.88	**Drought**	Fallow-Mustard-Boro	1.27
	Fallow-T. Aman-Fallow	10.23		Fallow-T. Aman-Fallow	4.27
	T. Aus-T. Aman-Boro	7.19		Fallow-T Aman-Mustard	2.04
	Fallow-Fallow-Boro	3.38		Fallow-T. Aman-Potato	1.38
	Fallow-Peanut-Fallow	2.98		Fallow-T. Aman-Boro	49.37
	Fallow-T. Aman-Vegetables	6.88		Fallow-T. Aman-Vegetables	1.79
	Maize-T. Aman-Boro	2.93		Fallow-Vegetable-fallow	1.46
	Peanut-T. Aman-Boro	3.06		Fallow-Mustard-Boro	1.12
	T. Aman-Potato-Boro	8.39		T. Aus-Fallow-Fallow	2.22
	Vegetables-T. Aman-Boro	1.34		T. Aus-Fallow-Mustard	1.22
	T.Aman-Jute-Boro	3.38		T. Aus-Fallow-Boro	6.84
	Fallow-Mustard-Boro	3.59		T. Aus-T. AMan-Fallow	4.36
	Fallow-T. Aman-Vegetables	0.34		T. Aus-T. Aman-Boro	18.56
Haor	T. Aus-Fallow-Boro	10.05		T. Aus-Vegetables-Boro	1.55
	Fallow-Fallow-Boro	61.50		Jute-T. Aman-Boro	1.41
	Fallow-T. Aman-Fallow	15.80		Vegetables-Vegetables-Boro	1.15
	T. Aus-Fallow-Boro	9.86		Fallow-Fallow-Boro	15.35
	T. Aus-T. Aman-Fallow	12.85		Fallow-T. Aman-Fallow	13.48
	T. Aus-Fallow-Boro	4.32		Fallow-T. Aman-Jute	5.18
	T. Aus-T. Aman-Fallow	6.51		Fallow-T. Aman-Pulse	13.34
Salinity	Fallow-Fallow-Boro	7.88	**Tidal submergence**	Fallow-T. Aman-Boro	24.14
	Fallow-Fish-Boro	4.19		Fallow-T. Aman-Vegetables	6.68
	Fallow-T. Aman-Fallow	7.05		Jute-T. Aman-Boro	1.44
	Fallow-T. Aman-Boro	31.15		T.Aus-Fallow-Fallow	1.19

Ecosystem	Cropping pattern	% of area	Ecosystem	Cropping pattern	% of area
	Fish-Fish-Fish	3.37		T. Aus-T. Aman-Pulse	8.13
	Fish-Fish-Boro	10.57		T. Aus-T. Aman-Boro	5.93
	T. Aus-Fallow-Boro	1.23		T. Aus-T. Aman-Vegetables	3.60
	T. Aus-T. Aman-Boro	7.33		Vegetables-Vegetables-Vegetables	1.56
	Fallow-Fallow-Vegetables	8.47		Fallow-Fallow-Boro	26.64
	Fallow-T. Aman-Vegetables	3.89		Fallow-T. Aman-Fallow	2.12
Submergence	Fallow-Vegetables-Vegetables	4.64	**Low lying**	Fallow-T. Aman-Boro	16.18
	Fallow-Fallow-Boro	3.06		Jute- Fallow-Boro	7.19
	Fallow-Fish-Boro	1.45		T. Aus-Fallow-Fallow	3.06
	Fallow-T. Aman-Fallow	2.65		T. Aus-T. Aman-Fallow	2.46
	Fallow-T. Aman-Boro	86.76		T. Aus-T. Aman-Mustard	1.32
	Fallow-T. Aman-Vegetables	3.67		T. Aus-T. Aman-Boro	24.61
	Vegetables-Vegetables-Potato	2.41		Jute- Aman-Fallow	16.47
	Fallow-T. Aman-Boro	78.71			
	Fallow-T. Aman-Fallow	3.46			
Hilly	Fallow- Aman-Vegetables	6.1			
	T. Aus-Fallow-Tobacco	10.28			
	Fallow-Fallow-Boro	1.47			

Source : Field survey, 2019-2021

9.6 Salient features of some modern *T. Aus* and *Boro* rice varieties

BAU63 is a high yielding fine grain quality variety. It is also a good straw yielder which has no lodging and shattering problems.

Bina dhan5 is a high yielding variety, which has no lodging and shattering problems. Bina dhan7 is early maturing high yielding variety. Its grain size is medium bold and good tasted to eat; so, it has better market demand. Its grain and straw yields are better and free of lodging and shattering problems. Bina dhan7 is some extent insect-pest and stem borer resistant, requires less amount of fertilizers and irrigation cost which rendering lower cost of production; eventually, generates more economic return. Bina dhan8 is an insect-pests resistant high yielding good grain quality variety. It requires lower inputs, involes low costs of production; hence, generates higher profit.

Bina dhan10 is an insect-pests resistant high yielding good grain quality variety. Eating quality of cooked rice of this variety is good, so it has good market demand. Weed infestation is low in this variety and requires lower inputs, confirms low costs of production; hence, generates higher profit. Bina dhan17 is a high yielding early matured variety. Insect-pests infestation is low in this variety and has more tillering capacity. Bina dhan18 is an insect-pests resistant high yielding good grain quality variety. Eating quality of cooked rice of this variety is good, so it has good market demand.

BR1 is the first successful outcome of BRRI in the field of varietal development a early maturing variety which local name is 'Chandina'. Its grain size is short bold but good tasted to eat. So, it has a good market reputation. It requires low inputs cost. It is resistant to insect-pests like BPH, stem borer etc. It has no lodging or shattering problems. It is a lower input required variety, so, incurs lower costs of production; that generates higher economic return.

Basically, BR7 was recommended for *Boro* and *Aus* season but the growers cultivate it in *Aman* season also for its earliness, fine grain and good eating quality. Its popular name is 'BRRI-Balam'. 'Balam' is popular brand name in the rice market of Bangladesh with fine, long slender grain size traditional rice variety. BRRI-Balam' is almost similar to traditional 'balam' but higher yielder. So, most of the farmers preferred this variety for its earliness which help them to cultivate the next crop, higher yield performance and better market price. In addition, this variety is resistant to stem borer and it registered lower irrigation cost also.

Though, **BR10** is a typical *Aman* variety with medium fine grain size, but farmers cultivate it in *Boro* season for its higher yield performances. It was released in 1980 mainly for low land but it was adopted by nationwide for its better yield performance, good eating quality and higher market demand. It is also popular to the growers for straw which is very useful to them for cattle feed. In addition, BR10 is some extent insect-pest and stem borer resistant and required lesser number of fertilizers.

BR14 was released in 1983 for *Boro* and *Aus* season. Its grain size is medium bold and color is white. The specialty of this variety is; its spikelet is awned and tightly attached with the sheaf; so it could persist even under heavy rainfall or hailstorm. Besides, insect-pest infestation is less in this variety and incurred lower irrigation cost; consequently, cost of production remains lower. **BR16** is a long duration (160 days) higher yield potential (6.0 t/ha) *Boro* variety was released in 1983. Its local name is 'Shahibalam'. 'Balam' is popular brand name of traditional rice variety in the rice market of Bangladesh with fine, long slender grain size. BRRI-Balam' is almost similar to

traditional 'balam' but higher yielder. It's a low GI indexed variety which is beneficial for diabetic patients. Its grain size is long slender and white which attract the attention of the consumers and realized a good market demand. Besides, it's a low input required variety, incurs comparatively low production costs. **BR17** is a medium duration (155 days) higher yield potential (6.0 t/ha) variety, suitable for *Haor* areas, was released in 1985. Its local name is 'Hashi'. Its grain size is medium bold with good eating quality. Its straw yield is also good. BR18 is a long duration (170 days) higher yield potential (6.0 t/ha) variety, suitable for *Haor* areas, was released in 1985. Its local name is 'Shahajalal'. Its grain size is medium bold with good eating quality. It's also a good straw yielder and incurs lower costs of production. **BR19** is a long duration (170 days) higher yield potential (6.0 t/ha) variety, suitable for *Haor* areas, was released in 1985. Its local name is 'Monghal'. Its grain size is medium bold with good eating quality and has a good market demand. BR19 is some extent rice pests' resistant. It's also a good straw yielder and incurs lower costs of production.

BRRI dhan28 was released in 1994; like BR11, it is by far the most popular high yielding (5.5-6.0 t/ha) *Boro* variety. This mega variety is now being cultivated in other countries also like, India, Nepal and few African countries. It's an early maturing variety which life span (140 days) is about three weeks shorter than the popular BRRI dhan29, suitable for low laying flood prone areas, requires less amount of water. It required low fertilizer, low irrigation cost, Indigent farmers who want to harvest in advance prefer this variety. Its grain size is medium slender and good taste to eat, so market demand and price is high.

BRRI dhan29 is a long duration *Boro* variety which has significant contribution in achieving food security in the country. This most popular (mega) variety was approved for commercial cultivation in 1994. It is the best inbred modern variety in terms of grain (7.5 t/ha) and straw yield, quality of grain and its taste of eating and coverage of adoption also. Its grain size is medium slender and good taste to eat, so market demand and price is high. It has more tillering ability which is an essential component of higher yield compared to other inbred varieties. It is resistant to sheath blight, bacterial blight, stem borer and also moderate resistant to lodging and shattering problems. Following the aforementioned traits and features this variety is very popular to the growers at the field level.

BRRI dhan45 is a short duration (137 days) higher yield potential (6.5 t/ha) *Boro* variety was introduced in 2005. Its grain size is long slender and white which is good tasted to eat. BRRI dhan46 is a late maturing, submergence tolerant variety, suitable for flood prone low land areas. Though, its plant height is tall but not susceptible to lodging and shattering so, it produces good quality bulky amount of straw for cattle feed. BRRI dhan46 requires less amount of fertilizer and less irrigation cost; so, the cost of production of this variety is comparatively lower. Insect-pest and stem borer infestation is lower in this variety. Its grain size is medium bold and milling outturn is higher and have good eating quality. So, the economic return of this variety is higher than other varieties. BRRI dhan47 is a saline tolerant high yielding (6.0 t/ha) *Boro* variety, was introduced in 2007 for saline prone coastal region of Bangladesh. It can tolerate 12-14 dS/m salinity in seedling stage and up to 6 dS/m in rest of the life cycle. Its grain size is medium bold and have good quality of eating, so its market demand and price are high.

BRRI dhan48 is an early maturing high yielding (5.5 t/ha) popular *Aus* variety was released in 2008. It has more tillering ability which induced higher yield. Its plant height is tall and stem is strong, but has no lodging and shattering problems. So, it harvests a good grain and straw yields

also. The good tasted grain size of BRRI dhan48 is medium slender and cooked rice is crispy, for that reason it captures higher market demand and price also. It can suppress the insect-pest infestation and stem borer attack, side by side fertilizer and irrigation costs of this mega variety is lower which persuades lower cost of production.

BRRI dhan50 is a long slender, slightly fragranced, premium quality white grain rice. Its popular name is 'Banglamoti' which is almost similar to the world famous 'Bashmoti' brand in shape and size. BRRI dhan50 is some extent insect-pest and stem borer resistant. It is suitable in low laying land for its tall plant but resistant to lodging and shattering problems. So, its grain and straw yields are better. Its grain size is medium slender and have good eating quality thus, ensures good market demand and price. Side by side, it requires less fertilizer and irrigation cost which induces cost of production low; thus, the growers can earn more benefit.

BRRI dhan57 is a drought-resistant, high-yielding (5.0 t/ha), short-duration variety that can withstand rainless conditions for 10-14 days during the reproductive stage without losing substantial yield. It has an excellent market demand because its grain size is long and slender, and the taste of cooked rice is good, thus it has a good market demand, which results in higher prices. **BRRI dhan58** is a long duration high yielding (7.2 t/ha) *Boro* variety. Its shape, size and taste are almost like mega variety-BRRI dhan29 but it is about 5 days earlier than BRRI dhan29. It was developed through tissue culture method. One of the remarkable features of this variety is that its flowering stage being completed within 8 to 10 days, and all the grain in the sheaf ripens at a time. This scenario is very stimulating to see the whole field at a glance as the sheaf of the ripen rice located on the top of the dig leaves. Its straw yield is also higher and has no lodging problems. Its grain size is medium bold which eating taste is good. It is some extent insect-pest and stem borer resistant, requires less fertilizer and irrigation cost which induces cost of production a bit lower; thus, the growers get more economic benefit from cultivating this variety.

BRRI dhan59 is a short duration (147 days) higher yield (7.1 t/ha) potential *Boro* variety. Its grain size is medium bold and good tasted to eat. So, it has a good market demand and absorbed higher prices also. BRRI dhan59 is some extent rice pests, lodging and shattering problems resistant and BRRI **dhan62** is a zinc enriched (19.8 mg/kg) early maturing short duration (100 days), drought escaping, high yielding (4.5 t/ha) variety, which white grain is long slender and taste of eating quality is good. So, its market demand and price are high. It is about 10-12 days earlier than popular 'BRRI dhan33'. Farmers can easily cultivate potato or other rabi crops after harvesting BRRI dhan62. It is also lodging tolerant and has no shattering problems.

BRRI dhan63 is a premium quality, high yielding (6.5 t/ha) *Boro* variety, commonly known as 'Saru Balam.' The shape and size of this 'Balam' type variety is almost similar to world famous 'Bashmoti' brand. The grain size of this variety is very slim and thin (8.1 mm long and 1.9 mm wide) and cooked rice is crispy (amylose 25%), which taste is very good. The market demand and price are high. It has no shattering problem and straw yield also is better which is good feed for the cattle. BRRI dhan63 is some extent insect-pest and stem borer resistant, requires less amount of fertilizers and irrigation cost which renders the cost of production a bit lower; eventually, generates more economic return.

BRRI dhan67 is a salt tolerant high yielding (6.0 t/ha) *Boro* variety which can tolerate up to 12-14 dS/m salinity at seedling stage and 8 dS/m salinity level rest of the life span. It contains less unfilled

grains and has no lodging and shattering problems. Its grain size is medium slender and cooked rice is crispy which tasted good to eating, so its market demand is high. BRRI dhan68 is a medium duration (149 days) very higher yield (7.3 t/ha) potential variety which dig leaves remain green even at the harvesting period. The grain size is medium bold and good tasted to eat which capture better market demand. This variety is stem borer, lodging and shattering problem free.

BRRI dhan84 is a comparatively short duration (141 days), high yielding (6.5 t/ha) zinc (27.6 mg/kg) and also iron and protein enriched *Boro* variety which is about 5 days earlier than popular mega variety-BRRI dhan28. The plant size is almost like BRRI dhan28 and color of the outer side of grain of this variety is red. Cooked rice crispy and taste is very good, so it has better market demand. BRRI dhan86 is a comparatively short duration (140 days), high yielding (6.5 t/ha) *Boro* variety was released to replace the BRRI dhan28. Its grain size is long slender and good tasted. Its plant is dwarf type which does not tilt. It contains 25% amylose and 10.1% protein, cooked rice is crispy which taste is good to eat, so its market demand is high.

BRRI dhan88 is about 4-5 days earlier than the popular mega variety-BRRI dhan28. Its grain size is medium bold and white. Its cooked rice is crispy and good tasted so, its market demand is high. BRRI dhan89 is a long duration (156 days), very high yield potential (8.0 t/ha) variety, was released in 2018 for *Boro* season. BRRI dhan89 contains very high amylose (28.5%), which grain size is medium bold and white. Its cooked rice is crispy and good tasted so, its market demand is high. BRRI dhan88 is a short duration (142 days), high yielding (7.0 t/ha) variety, was released in 2018 for '*Haor*' areas in *Boro* season.

9.7 Salient features of some modern *T. Aman* rice varieties

BR11 is a mega rice variety for *Aman* season in Bangladesh, was released in 1980. It is widely adopted throughout the country. Its grain size is medium bold with average research station yield 6.0t/ha. It's a good tasted higher market demand-oriented variety, required lower amount of fertilizers and irrigation cost; eventually, reduce the cost of production. It is also insect-pest, lodging and shattering tolerant variety which straw is a good feed for the cattle. Some of the growers cultivate it in *Boro* season also.

BR21 is suitable for direct seeding and rainfed areas in Aus season.

BR22 is a late maturing photoperiod sensitive high yielding *Aman* variety, suitable for low laying areas which have more tillering ability. It is drought tolerant and some extent resistant to insect-pest and stem borer. It needs less fertilizer and irrigation costs also. Its grain size is fine which tasted good to eat so, its market demand is high. Side by side its plant height is tall which ensures good harvest of straw.

BR23 is a long slender late maturing photoperiod sensitive high yielding (5.05t/ha) *Aman* variety. It is submergence tolerant and some extent resistant to insect-pest, stem borer and lodging and shattering. It needs lower fertilizer and irrigation costs also. Its grain size is long slender which tasted good to eat. For those above-mentioned reasons, its market demand and price remains high. **BR25** was released in 1992 for *Aman* season. The popular name of this high yielding variety is 'Nayapajam'. The grain size of this variety is very similar to Pajama but 5-6 days earlier compared to pajam. It is suitable for direct seeding and has low glycemic acid index which is beneficial for

diabetic patients. Though, its grain size is short bold but the respondents opined that the taste of eating of this variety is good; so, its market demand and price is high.

BR26 is a long slender intermediate amylose enriched variety. Initially, it was recommended for *Aus* and *Boro* season but farmers cultivate it in *Aman* season also for higher yielding performance and requirement of fertilizer is less. **BRRI dhan27** is medium bold, higher yielder, good tasted variety, requires less fertilizer so, the growers cultivate it in *Aman* season also.

BRRI dhan30 is a long duration (140 days), weakly photoperiod sensitive *Aman* variety. It's a high yielding (5.0 t/ha) variety which grain size is medium slender, milling outturn is higher and color is white; so its market demand and price is also high. Its straw yield is higher and quality is good. This variety has some extent capacity to resist insect-pest infestation and also lodging and shattering problems.

BRRI dhan 32 is a medium duration (130 days), high yielding lower input required variety, so its cost of production is low. The grain is white, medium bold and good taste to eat. Its straw is also a good feed for the cattle. As such, its market demand and price are high.

BRRI dhan33 is a short duration (118 days), high yielding *Aman* variety. It's has blackish spot-on rice but there is a white spot on the belly of the short bolded milled rice which is good tasted to eat. BRRI dhan33 has a significant contribution to mitigate the 'Mongha' a seasonal scarcity of food in the north-western Bangladesh. For its earliness, growers can cultivate the next crop easily in time, which create opportunities for employment and earnings of the poor and landless farmers when they suffer from the lack of job in off time.

BRRI dhan34 is a high yielding aromatic rice variety. Its grain size is short, bold and highly protein and anti-oxidant enriched. Its yield is higher (3.5 t/ha) compared to other niche aromatic varieties (1.5-2.5 t/ha). For higher yield and good taste its market demand and price are higher. Its straw yield is also notable and good feed to the cattle. Thus, the farmers are getting economic benefit from cultivating this variety.

BRRI dhan36 is a cold tolerant, high protein enriched variety. Though, it was released in 1998 for *Boro* season but farmers cultivate it in *Aman* season also for its long slender grain which ensure better market prices to them. BRRI dhan39 is an early maturing, medium slender grain variety which eating taste is good. So, it secures higher market demand and price also. Its plant height is tall but has no lodging tendency and shattering problems, which produces good quality straw yield. Less insect-pest infestation is seen in this variety, including lower irrigation cost also, so it's cost of production is also lower.

BRRI dhan40 is a moderately salt tolerant *Aman* variety which is suitable for coastal region. It's a high yielding (5.0 t/ha) variety which grain size is medium bold, good eating quality, so its market demand and price are high. Its straw yield is also higher and qualitative. It is some extent insect-pest, stem borer, lodging and shattering problem resistant. It can suppress the weed infestation and require lower irrigation. So, its production cost is lower.

BRRI dhan41 is a moderately salt tolerant *Aman* variety, suitable for low laying and coastal region of Bangladesh. The grain size of this high yielding (5.0 t/ha) variety is long slender and good taste to eat, so its market demand and price are high. Its straw yield is also higher, qualitative, which is

good feed of the cattle. It is some extent insect-pest, stem borer, lodging and shattering problem resistant. It requires lower fertilizer and irrigation costs, which eventually induced lower cost of production.

BRRI dhan42 is a drought tolerant, short duration (100 days) variety suitable for rainfed and drought prone areas. Its grain size is long slender and white in color which attracts the consumers' attention. For its good grain quality and taste of eating market demand is high. BRRI dhan44 is a high yielding (5.5 t/ha) long duration (145 days) *Aman* variety, suitable for coastal non-saline tidal prone areas. It requires less fertilizer, less irrigation cost; so, cost of production of this variety is comparatively lower. Unfilled grain is comparatively less in this variety. Though, the plant height is tall but it has no lodging and shattering problems. Its grain size is medium bold, amylose content is high (27.5%) and good taste in eating which ensures better market demand.

BRRI dhan49 is an early maturing ''**Nizersail**' type high yielding (5.5 t/ha) *Aman* variety which matures 7 days earlier than the popular mega variety BR11. It has more tillering ability and less unfilled grain which inducing higher yield. BRRI dhan49 is some extent insect-pest and stem borer resistant It is suitable in low laying land for its tall plant but has no lodging and shattering problems. For this reason, it harvests good grain and straw yields. Its grain size is medium slender and have good eating quality, thus market demand and price are high. On the other hand, it requires less fertilizer and irrigation cost which induces low cost of production; consequently, economic return remains higher.

BRRI dhan51 is a submergence and lodging tolerant high yielding variety, which could survive up to 14 days under submerged condition. It's a good rice and straw yielder. Its grain size is medium slender and white in color. The taste of cooked rice is good, so market demand and price is higher. It requires less amount of fertilizer and irrigation cost; so, involves low production cost

BRRI dhan52 is a submergence and lodging tolerant high yielding (5.5 t/ha) variety, which could survive up to 14 days under submerged condition. It is a late planting variety with tall plant height and resistant to lodging and shattering. It is some extent resistant to insect and pests also. Its grain size is medium bold and quality of cooked rice is good, so its market demand is high.

BRRI dhan53 is a salt tolerant early maturing variety, which can tolerate up to 8 dS/m salinity at the seedling and reproductive stages of life cycle. Its grain size is medium slender and good taste to eat; so, its market price is high. BRRI dhan54 is also another salt tolerant early maturing variety, which can tolerate up to 8 dS/m salinity at the seedling and reproductive stages. Its grain size is medium slender and good taste to eat; leading to high its market price.

BRRI dhan55 is a multi-stress tolerant high yielding (7.0 t/ha) early maturing variety which is moderately tolerant to salt, drought and cold. Its grain size is long slender which attracts the attention of the consumers easily, so its market demand and price are also higher.

BRRI dhan56 is a drought tolerant high yielding (5.0 t/ha) short duration (110 days) variety which could survive under rainless condition up to 14-21 days at the reproductive stage without sacrificing significant yield losses. Under normal climatic condition its straw yield is also good. Its grain size is long bold and taste of cooked rice is well, so it has a good market demand. It is some extent insect-pest and stem borer resistant. It requires less fertilizer and irrigation cost leading to cost of production; thus, the growers could harvest more benefits.

BRRI dhan71 is a drought tolerant high yielding (5.5 t/ha), short duration (115 days) early maturing *Aman* variety, which could survive under 21-28 days' drought situation at the reproductive stage. Its grain size is medium slender, bold and good taste to eat BRRI dhan72 is a zinc (22.8 mg/kg) and protein (8.9%) enriched, short duration, high yielding (5.7 t/ha) *Aman* variety. After harvesting BRRI dhan72, farmers can easily cultivate wheat, mustard or pulses crops easily. Its grain size is long bold and good taste to eat, so its market price is high.

BRRI dhan72 is some extent insect-pest and stem borer resistant, requires less amount of fertilizers and irrigation cost rendering low the cost of production, eventually, generates more economic return.

BRRI dhan73 is a salt tolerant high yielding (3.5-6.0 t/ha), short duration (115-125 days) *Aman* variety which tolerates up to 12-14 dS/m salinity at seedling stage and 8 dS/m salinity level rest of the life span. There are opportunities to cultivate sun flower and saline tolerant/escaping mustard in medium high land in saline coastal belt after harvesting BRRI dhan73. Its grain size is long bold and good taste to eat, so its market demand and price are high.

BRRI dhan74 is a zinc enriched (24.2 mg/kg), blast resistant high yielding (7.1 t/ha) *Boro* variety, which white grain is medium bold and taste is good. So, its market demand and price are high. Its stem is strong and lodging resistant; so, straw yield remains high and have no shattering problems. This variety is less affected by insect and pests infestation. It requires less fertilizer also.

BRRI dhan75 is short duration (115 days), high yielding (5.5 t/ha) *Aman* variety. It is some extent insect-pest and stem borer resistant. It is suitable in low laying land for its tall plant but resistant to lodging and shattering problems. So, its grain and straw yields are better. Its grain size is medium slender and have good eating quality thus, ensures good market demand and price. Side by side, it requires less fertilizer and irrigation cost which induces low cost of production; thus, the growers can earn more benefit.

BRRI dhan76 is a high yielding (5.0 t/ha) *Aman* variety, suitable for non-saline tidal prone low laying areas. Its seedling height is tall which is apt to tidal prone low land areas. Its strong, tall stem can tolerate lodging which produce a good quality harvest of straw yield. Grain size of BRRI dhan76 is medium bold and have good eating quality which ensures good market demand and price. It requires less fertilizer and irrigation cost which makes cost of production lower.

BRRI dhan78 is a multi-stress tolerant variety which can tolerate up to 6-9 dS/m salinity and submergence simultaneously. It is suitable for tidal saline prone coastal areas. Its grain size is medium slender and good tasted to eat so, it has good market demand. BRRI dhan80 is rainfed a high yielding (5.0 t/ha) early maturing *Aman* variety which stem is strong and does not tilt. Its grain size is long slender, similar to 'Jasmine' type, a popular variety of Thailand.

BRRI dhan80 is an exportable variety which cooked rice is crispy, has aroma and good eating quality, and ensures better market demand and prices. BRRI dhan81 a high yielding (6.5 t/ha) popular 'Jira' type *Boro* variety, a potential substitute of mega variety-BRRI dhan28, contains higher level (10.3%) of amylose. Its grain size is slenderer than BRRI dhan28 and scented, have

good market demand and potentiality to export. Its plant height is comparatively shorter (100 cm), so it can tolerate lodging and shattering problems and also quality of straw remains good after harvesting.

BRRI dhan82 is a short duration (102 days), high yielding (4.7 t/ha), early maturing *Aus* variety which is about 5 days earlier than popular BRRI dhan48. Its grain size is medium bold and cooked rice is crispy, contains higher level of amylose (27.0%). It has more tillering capacity and stem is strong; so can tolerate lodging hazards and produces good straw yield. BRRI dhan82 requires a smaller number of fertilizers also. BRRI dhan87 is a high yielding (6.5 t/ha) *Aman* variety, was released in 2018.

BRRI dhan87 is about 7 days earlier than BRRI dhan49 and contains 27% amylose. Its grain is white and long slender which cooked rice is good tasted to eat. For this reason, it has a good market demand. Its plant height though tall but it does not susceptible to lodging as its stem is strong. It has no shattering problem also and reap a good straw yield. BRRI dhan87 is tolerant to insect-pests and it requires lower cost of production.

BRRI dhan90 is a highly protein (10.3%) enriched, high yielding (5.0 t/ha), short duration (117 days) *Aman* variety, was released in 2019. Its grain size is short bold and slightly aromatic, good tasted to eat. It's a premium quality variety which has higher market demand and price and export potential.

Bina dhan7 is early maturing high yielding *Aman* variety. Its grain size is medium bold and good tasted to eat; so, it has better market demand. Its grain and straw yields are better and free of lodging and shattering problems. Bina dhan in some extent insect-pest and stem borer resistant, requires less amount of fertilizers and irrigation cost which renders the cost of production a bit lower; eventually, generates more economic return.

Bina dhan8 is also early maturing high yielding *Aman* variety. Its grain size is medium slender and good tasted to eat which ensures better market demand. Its grain and straw yields are better and free of lodging and shattering problems. Bina dhan8 is some extent insect-pest and stem borer resistant, requires less amount of fertilizers and irrigation cost which confirms lower production cost.

Bina dhan17 is an early maturing short duration *Aman* variety. It has higher yield potential and its grain size is fine with good taste. It is some extent insect-pest and stem borer resistant, requires less amount of fertilizers and irrigation cost which reduces the cost of production a bit lower; ultimately, generates more return.

9.8 Salient features of some hybrid rice varieties

ACI is a high yielding hybrid variety, have good eating quality; consequently, better market demand and prices. It has good straw yield potential also. It has good grain and straw yield potential with better market demand. **Aftab** is a high yielding hybrid variety, have good eating quality and market demand. **Aloron** is another high yielding hybrid variety which has better yield potential. It also produces good quality straw yield. For its good eating quality captures, the market demand largely.

Atom is a high yielding hybrid, have good eating quality and better market demand also. **AZ** is a short duration hybrid which has higher yield potential associated with fine grain size, good eating taste so have a better market demand. It has no lodging and shattering problems; so, its straw yield is also better and good quality which is good feed for the cattle. It is a low input required variety, so it is more profitable.

Dhanigold is a medium growth duration hybrid variety which has good yield potential. Its grain size is medium bold which have good eating quality, so it has a good market demand. It's also a lower input demanded variety, so its cultivation is more profitable.

Hira is a lodging tolerant shattering free, insect-pest resistant, less input required hybrid variety for *Aman* season. It's high yielding both in terms of grain and straw. Its taste of eating is good, so it has good market demand.

SL8 is a short duration hybrid which has higher yield potential associated with fine grain size, good eating taste so have a better market demand. It has no lodging and shattering problems; so, its straw yield is also better and good quality which is good feed for the cattle.

Sonar Bangla is a high yielding hybrid rice variety for *Aman* season with good grain and straw yield potential. It required less fertilizer cost. **Tej** is a high yielding hybrid rice variety for *Aman* season with bold grain size and good taste. Its market demand and price are high. It's a low input required variety, possess low cost of production.

Kanchan is a high yielding hybrid rice variety for *Aman* season with medium slender grain size and has good taste of eating so, attracts the attention of the consumers. Consequently, its market demand and price are high. It's a low input required variety, possess low cost of production. **Madhobi** is an Indian/local variety which is cultivated in border areas of Bangladesh. It's a good yielder and grain size is fine and quality of cooked rice is very good, so it has better market demand prices. Its plant is tall but don't tilt or lodges contains lower amount of unfilled grain, so grain and straw production are better. **Madhobi** is some extent insect-pest resistant, requires lower inputs, thus the cost of production is lower.

Poroshmoni is another high yielding local variety, which grain is fine and eating quality is very good, so it has better market preferences and prices.

9.9 Salient features of some Indian rice varieties

Miniket is an Indian high yielding variety. It is very popular to the border areas of Bangladesh for multi-various highly positive attributes; like, more tillering ability with short duration, less insect-pests and weed infestation, no lodging and shattering problems, etc. Its grain size is long slender and cooked rice is very good tasted, so it has good market demand. Side by side, it requires low inputs cost, which persuades lower cost of production and good economic returns.

Ranjit is an Indian high yielding variety. It is also popular to the border areas for higher yield performance and other traits like good quality straw yield. Its grain is slender type with good eating

quality. So, it is popular to the consumers; hence, also to the growers. It is low input variety, so its cost of production comparatively low and profitable.

Swarna is a highly popular Indian variety across the border areas of Bangladesh. It has more tillering capacity and can be cultivated in all types of lands (low, medium and high). It has lots of positive and influential traits which induced the producers to grow it. First, it's a high yielding drought tolerant, short duration-early maturing, fine grain slightly scented variety which quality of cooked rice is very decent. So, it has good market demand and ensures the producers to get better market prices also. Except main diet (cooked rice), it is suitable for making other diversified products like, puffed and flatten rice, etc. Generally, insect-pests (BPH, sheath rot, stem borer, etc.) infestation is comparatively lower in this variety and its plant height is short, so no lodging and shattering problems. Finally, it requires less fertilizers, low irrigation costs that reduces the cost of production and generates better economic returns.

Zira is another highly popular Indian variety across the border region of Bangladesh. It's a high yielding drought tolerant, short duration-early maturing, fine grain slightly scented variety which quality of cooked rice is very decent. So, it has good market demand and ensures the producers to get better market prices also. It also produces better quality straw yield. Generally, insect-pests (BPH, sheath rot, stem borer, etc.) infestation is comparatively lower in this variety and its plant height is short, so no lodging and shattering problems. Finally, it requires less fertilizers, low irrigation costs that reduces the cost of production and generates better economic returns for the producers.

9.10 Salient features of some local rice varieties

Nerika is an African variety which is suitable for drought prone areas, where seed was given to the farmers free of cost. Its yield is good with insect-pests and lodging tolerance. Its grain size is fine and eating quality is good, so it has a good market demand.

Pajam is a high yielding variety with fine grain size. Its cooked rice is very tasty, so have a good market demand and price also. It has no lodging problem, so produces good quality straw yield which is favorite to the cattle. It requires low fertilizer and insect-pest's costs, which induces lower cost of production; consequently, better economic return.

Kalijira is a popular niche aromatic rice variety cultivated throughout the country. Its grain size is short bold and highly scented. It has a very good taste and mainly used as a special diet item in different occasion or on festival like, weeding ceremony in rural areas and in seminar, symposium/ workshop or public meeting/hotels in urban areas. It's very costly and high valued to the general consumers. So, its market demand and price are high.

Najirshail is a short duration local variety which grain size is long slender and very good taste to eat. So, its market demand and price are high. It is good yielder in terms of rice and straw, and required lower cost of production. So, growers can earn a handsome return.

Chinigura is a popular niche aromatic rice variety cultivated throughout the country. Its grain size is short bold and highly scented. It has a very good taste and mainly used as a special diet item in

different occasion or on festival like, weeding ceremony in rural areas and in seminar, symposium/ workshop or public meeting/hotels in urban areas. It's very costly and high valued to the general consumers. So, its market demand and price are high.

Jamaibabu is an Indian high yielding variety, which is very popular to the border areas of Bangladesh for higher yield performance and other traits like good quality straw yield. Its grain is slender type with good eating quality. So, it is popular to the consumers; hence, also to the growers. It is low input variety, so its cost of production comparatively low and profitable.

Haridhan is a drought tolerant medium bold grain variety. It's a good grain and straw yielder and cooked rice is very good, so it has better market demand prices. Its plant is tall but don't tilt or lodges contains lower amount of unfilled grain, so grain and straw production are better. It's some extent insect-pest resistant, requires lower inputs like fertilizer and irrigation, thus the cost of production is lower.

9.11 Technologies practiced by the rice farmers

Rice production depends on different types of technologies. In different ecosystem, farmers' usage few technologies for rice cultivation such as: (i) power thresher machine, (ii) mixed fertilizer, (iii) *Guti* urea, (iv) integrated pest management (IPM), (v) perching, (vi) vermi-compost, (vii) crop rotation, and (viii) straw retaining on the crop field (Table 9.8). It was observed that although the average technology usage by the farmers was low in all ecosystems but the rate of using power threshing machine and perching tool was comparatively higher than that of other technology usage (Figure 9.1).

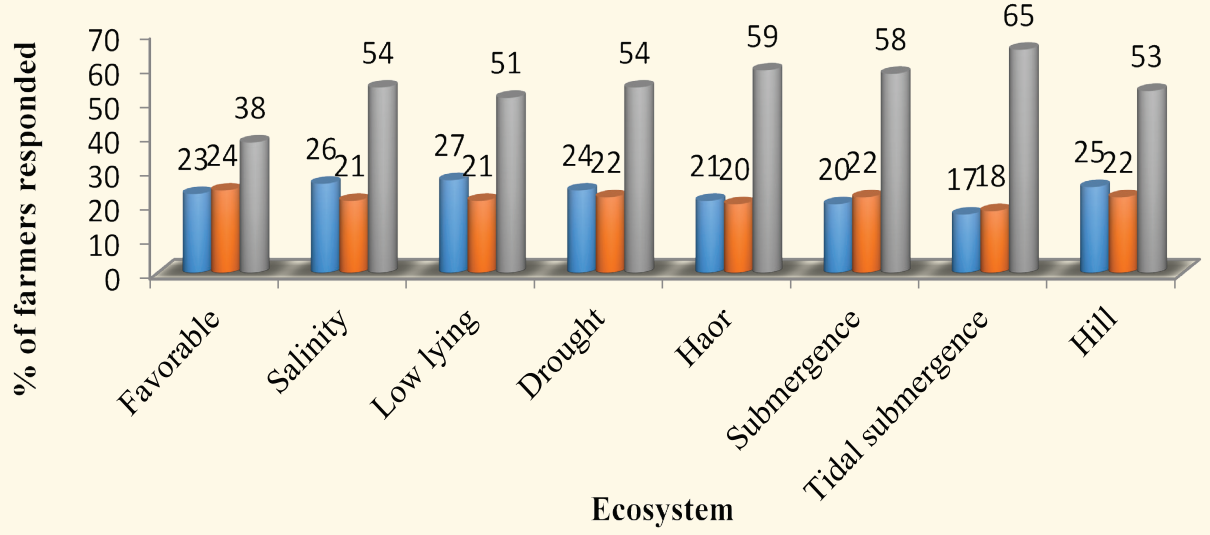


Figure 9.1: Average technology usage in different ecosystems

Table 9.8: Rice cultivation technologies at the farmers' level in different ecosystems

Particulars	Extent of technology usage (% of farmers)								
	Favorable			Salinity			Low lying		
	High	Medium	Low	High	Medium	Low	High	Medium	Low
Use of power threshing machine	48	34	18	61	24	15	56	27	17
Use of mixed fertilizer	12	25	64	9	18	73	11	16	74
Use of Guti urea	10	22	69	6	15	79	8	13	80
Integrated Pest Management (IPM)	6	15	30	18	12	70	25	23	53
Use of perching	50	34	16	51	31	19	54	31	16
Use of vermi-compost	11	16	23	13	21	65	18	16	67
Crop rotation	30	18	27	25	23	52	30	17	54
Straw retaining on the crop land	14	26	60	22	21	57	19	29	53
Average level of the users	23	24	38	26	21	54	27	21	51
Use of power threshing machine	53	26	21	57	24	19	57	32	11
Use of mixed fertilizer	6	23	71	12	22	66	3	7	90
Use of Guti urea	10	14	76	5	17	78	4	2	94
Integrated Pest Management (IPM)	15	17	68	6	12	82	-	-	-
Use of perching	54	28	18	48	27	25	21	34	45
Use of vermi-compost	10	24	66	9	12	79	-	-	-
Crop rotation	20	21	59	15	32	53	12	6	82
Straw retaining on the crop land	25	19	56	15	22	63	6	25	67
Average level of the users	24	22	54	20	22	58	17	18	65
Use of power threshing machine	64	20	16	49	32	20			
Use of mixed fertilizer	5	12	83	10	14	76			
Use of Guti urea	5	15	80	12	14	74			
Integrated Pest Management (IPM)	13	19	68	15	22	64			
Use of perching	46	28	26	51	30	17			
Use of vermi-compost	11	25	64	21	13	67			
Crop rotation	10	17	73	16	25	59			
Straw retaining on the crop land	15	24	61	30	26	44			
Average level of the users	21	20	59	25	22	53			

Source : Field survey, 2019-2021

10. Financial and risk analysis of rice production in different ecosystems

10.1 Financial and risk analysis of rice production under favorable ecosystem

Representative farm budgets for seasonal rice production were computed with the market prices in 2020 for the average/moderate/typical value of all farm categories. Based on average value from sample survey, was estimated and cross checked with focus group discussion (FGD) as well as key informant survey (KIS), Representative farm budget, variation in both yield and price under weather and market variability were finally developed.

10.1.1 Input use pattern and productivity of rice in favorable ecosystem

The pattern of inputs uses in seasonal rice cultivation by three (small, medium and large) farm types in favorable ecosystem can be viewed in table 10.1. The level of per ha inputs use in *Boro* season by small farmer was relatively higher compared to large and medium farmer in favorable ecosystem. In some cases, magnitude of inputs use seems to be same for large, medium and small farmer in *T. Aman* and *T. Aus* season. Contractual costs of large farmer were much higher compared to medium and small farmer due to dependent on hired labor in all rice growing seasons. All farmers used HYV rice seed from market and most of them did not treat the rice seed to control diseases before sowing. Seed rate was not quite higher than recommended rate among different farmers' categories. Large farmer used seed rate of 42 kg/ha in *T. Aman* and 33 in *T. Aus* and 30 kg/ha in *Boro* season, whereas small farmer used seed rate of 37 kg/ha in *T. Aman* and T. *Aus* and 39 kg/ha in *Boro*. Medium farmer used seed rate of 31 kg/ha in *T. Aus* and 28 kg/ha in *Boro* but they used higher seed rate of 39 kg/ha in *T. Aman*. This is because many farmers practiced double transplanting in *T. Aman* season in order to avoid flood and damage due to heavy rain.

Only large farmer applied about 84 kg/ha more urea in *T. Aman* season than the recommended dose (150 kg/ha), but they used 27 kg/ha less than the recommended dose (150 kg/ha) in *T. Aus* and 25 kg/ha higher more of urea in *Boro* season (Table 10.1). Medium farmer applied moderate rate of urea in *T. Aman* and *T. Aus* but used 45 kg/ha higher than recommended rate in *Boro* season. Small farmer used 63 kg/ha more urea in *Boro* season which significantly higher but in *T. Aus* and *T. Aman* season the use was moderate. In addition, large, medium and small farmer used to apply more TSP and MOP than the than recommended rate. Large farmer usually avoids to apply DAP, Gypsum, Zinc and theovit in *T. Aus* and *Boro* but they were found to apply considerable dose in *T. Aman*. Average yield of medium farmer (6.83 t/ha) in *Boro* season is considerably higher than large (6.69 t/ha) and small farmer (6.33 t/ha). In *T. Aman*, yield performance was found to be same (4.52 t/ha) for both large and medium farmer and for small farmer it was 4.71. In case of *T. Aus* season, average yield of medium farmer (4.24 t/ha) is higher compared to small (3.98t/ha) and large farmer (3.64 t/ha).

Table 10.1: Input use pattern, productivity and price of seasonal rice in favorable ecosystem

Input items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Seed (Kg/ha)	33	42	30	31	39	28	37	37	39
Land preparation	7195	7721	6656	6842	8481	7543	6505	7579	6830
Human labor (man-days/ha)									
Hired	30	35	43	42	38	48	33	35	38
Family	7	9	7	17	21	22	33	33	37
Contractual	18338	22779	28199	12635	13615	19680	7865	10106	16591
Fertilizer (Kg/ha)									
Urea	123	234	210	152	172	220	195	176	248
TSP	70	90	112	64	73	109	73	87	108
MOP	92	79	102	100	99	107	87	82	108
DAP	47	34	41	71	79	83	80	69	85
Gypsum	5	26	44	44	48	46	40	37	55
Sulpher	0	23	6	0	9	9	27	9	10
Zinc	0	9	3	4	9	9	4	7	7
Mg	0	7	0	12	7	7	10	7	7
Theovit	0	6	6	6	7	9	4	10	7
Irrigation	1607	4149	7659	2799	2309	9762	3816	3079	8140
Herbicides	225	190	343	627	862	498	1259	534	512
Insecticides	1009	1848	3401	3361	2669	2705	6039	7413	3209
Yield (ton/ha)	3.645	4.525	6.695	4.245	4.525	6.83	3.985	4.715	6.335
Straw (Tk/ha)	13241	16926	14738	17991	16235	15988	18614	14494	17485

Source: Authors' estimation based on field survey, 2019-2021.

10.1.2 Scenario of cost and return of rice production in favorable ecosystem

Data in Table 10.2 showed that per ha total cost of rice production for medium farmer was higher by Tk. 7658 and Tk. 3180 compared to large and small farmer in *Boro* growing season due to differences in the man-days of hired labor and irrigation costs. Per ha total cost of *T. Aman* season was relatively higher for small farmer than large farmer by Tk. 5105 and medium farmer by Tk.5772 because of the man days of hired labor, contractual cost and fertilizers application differences. In addition, per ha total cost of *T. Aus* season was relatively higher for medium farmer than large farmer by Tk. 15497 and for small farmer by Tk.4934 due to family labor and fertilizer application differences. It is important to mention that wages and market price of input did not vary across the season among farmer's categories.

The actual total paid out cost usually includes seed, land preparation, hired labor, fertilizers, herbicides, insecticides, and power thresher which were the major items for large, medium and small farmer, respectively standing for 80%, 71% and 67% of total cost in *T. Aman* season. On the contrary, the total imputed cost which includes land rent and family labor was 32%, 28% and 19% of total cost for small, large and medium farmer, respectively in *T. Aman* growing season. The total paid out cost of large farmer was 78% of total cost, and decreased to 67-73% of total cost for medium and small farmer in *T. Aus* season. The total imputed cost of small farmer in *T. Aus* season was 35% of total cost and declined to 26% of total cost for large farmer and 21% for medium farmer. Similarly, the total paid out cost in *Boro* season showed 82% of total cost for large farmer and it was 76% for medium farmer and 66% for small farmer, respectively. In *Boro* season, the imputed cost was 33%, 23% and 17% of total cost for small, large and medium farmer, respectively. The BCR found more than one on cash cost and full cost basis in all rice season and the positive net return denoting that return outyielded total investment in rice production (Table 10.2).

Table 10.2: Production cost and return in rice production in different seasons in favorable ecosystem

Cost and income (Tk/ha)	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Paid out cost (A)	58858	69821	85119	66812	61271	85205	55538	61379	71575
Seed	1630	2118	1462	1545	2172	1438	1911	1841	2073
Land preparation	7195	7721	6656	6842	8481	7543	6505	7579	6830
Hired labour	13731	16332	25148	28233	16588	27710	13832	16906	18251
Contractual	20168	20168	22999	10135	13615	19680	7865	10106	16591
Power thresher	6360	4307	7360	3623	3771	3397	3517	3771	2827
Fertilizer	6933	12988	10091	9647	10804	12472	10794	10150	13142
Irrigation	1607	4149	7659	2799	2309	9762	3816	3079	8140
Herbicides	225	190	343	627	862	498	1259	534	512
Insecticides	1009	1848	3401	3361	2669	2705	6039	7413	3209
Imputed cost (B)	16582	16682	18272	24125	24565	25844	30465	30229	36294
Seedbed	1796	1916	1602	2041	1980	1872	1955	2109	1769
Family labour	4020	2601	3311	11366	10913	10432	17421	15983	20534
Land rent	10276	11583	12650	10161	11161	12830	10626	11626	13395
IOC at 4% for 5 months	490	582	709	557	511	710	463	511	596
Total cost (A+B)	75440	86503	103391	90937	85836	111049	86003	91608	107869
Gross return (Tk/ha)	89793	107960	117227	94325	92619	123799	89612	94510	123198
Net return (Tk/ha)	14353	21457	13836	3388	6783	12750	3609	2902	15329
BCR (Cash cost)	1.53	1.55	1.38	1.41	1.51	1.45	1.61	1.54	1.72
BCR (Full cost)	1.19	1.25	1.13	1.04	1.08	1.11	1.04	1.03	1.14

Source: Authors' estimation based on field survey, 2019-2021.

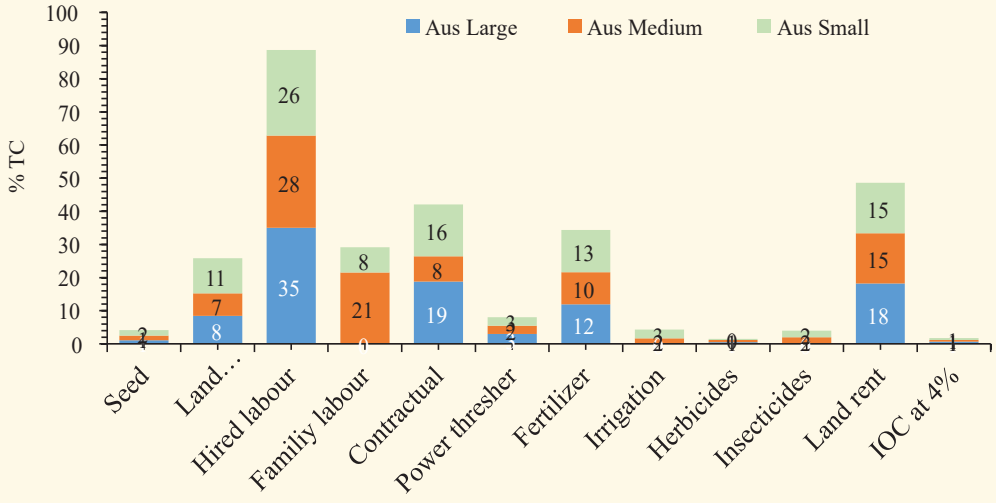


Figure 10.1: Share of per hectare inputs cost to total cost of *T. Aus* cultivation in favorable ecosystem

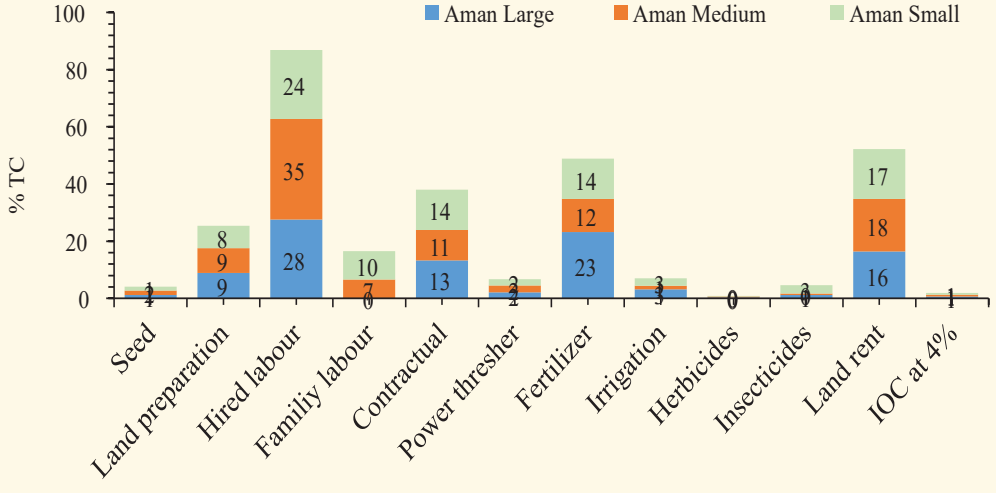


Figure 10.2: Share of per hectare inputs cost to total cost of *T. Aman* cultivation in favorable ecosystem

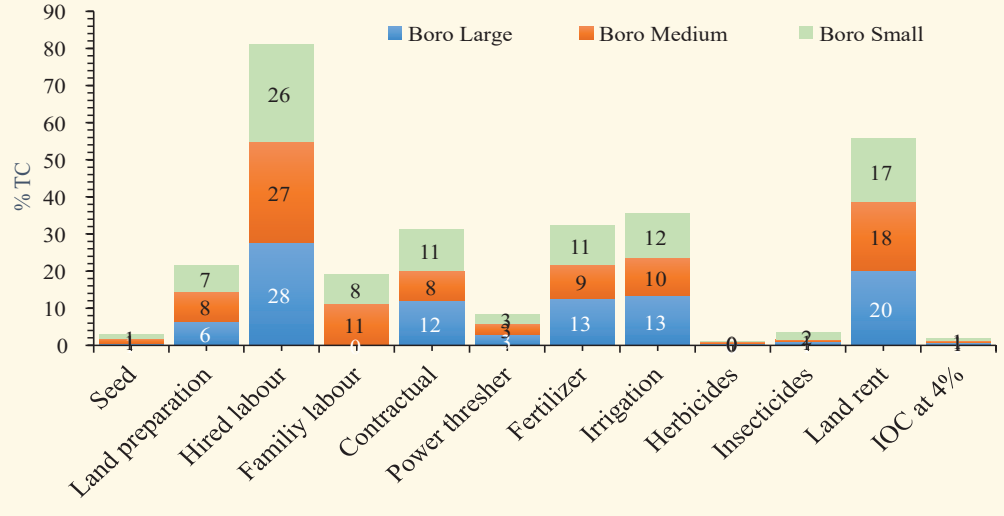


Figure 10.3: Share of per hectare inputs cost to total cost of *Boro* cultivation in favorable ecosystem

10.1.3 Risk analysis of rice production in favorable ecosystem

In assessing economic viability of rice cultivation at the reported market price, the result revealed that variability of yield of rice and straw value in the favorable ecosystem on farm profit was synthesized based on the households' survey and key informants survey.

The average/moderate/typical value of rice yield, straw value, inputs use and market price of rice from household survey were crosschecked with the key informant survey so as to get more realistic data. The gross return (GR) of rice was computed by multiplying rice yields by the reported price (Table 10.3). Farmers have well-being to sell their produces at a higher price than in the worst case. In constructing the stochastic budgeting of seasonal rice production in favorable ecosystem, production cost and profitability of favorable ecosystem was taken into risk analysis (table 10.3). Stochastic budgets were constructed for seasonal rice cultivation considering farmers' perceived variation in yield and market price by different farm types. The stochastic budget analysis displayed that seasonal rice cultivation was economically viable at the reported average/typical price and yields. In this analysis, triangular distribution was constructed by different levels of worst, typical/average, and best yields, straw value and price for different farm types. In addition, the distribution of the collected data based on farmers' observations fully support the triangle algorithm of risk prediction. Figure 10.4-10.6 showed that rice production in all seasons for large, medium and small farmers was found to be more profitable in the farmers' perceived typical and best case than average and worse case. However, farmers always suffer from negative net-income in the worst case caused by weather stress (unpredictive climatic factor such as erratic temperature and rainfall).

Table 10.3: Stochastic budgeting of rice production by farm types in favorable ecosystem

Items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
					Yield (ton per ha)				
Worst case	2.255	2.965	4.37	2.675	3.015	3.595	2.73	3.015	3.995
Typical case	3.645	4.525	6.695	4.245	4.525	6.83	3.985	4.715	6.335
Best case	5.085	5.75	9.495	5.32	7.005	9.44	5.25	6.13	9.93
					Straw (Tk per ha)				
Worst case	8496	8121	7186	11371	8870	8496	11243	7747	8121
Typical case	13241	16926	14738	17991	16235	15988	18614	14494	17485
Best case	20614	20988	26228	21235	28720	21860	24356	18743	23728
					Price (Tk per ton)				
Worst case	9622	10871	9871	12496	8371	8997	9123	9622	12369
Typical case	24635	23859	17510	22220	20468	18126	22487	20045	19447
Best case	25734	29962	24228	24000	24228	19000	23489	23103	21000
Paid out cost (Tk/ ha) (A)	58858	69821	85119	66812	61271	85205	55538	61379	71575

Items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Imputed cost (Tk/ ha) (B)	16582	16682	18272	24125	24565	25844	30465	30229	36294
Total cost (Tk/ha) (A+B)	75440	86503	103391	90937	85836	111049	86003	91608	107869
Net-income (Tk per ha)									
Worse case	-45247	-46149	-53069	-46139	-51727	-70209	-49854	-54851	-50334
Typical case	27594	38383	28574	21379	23018	28738	22223	17396	32814
Best case	76031	106767	152882	57978	112602	90171	61670	68756	124389

Source: Authors' estimation based on field survey, 2019-2021.

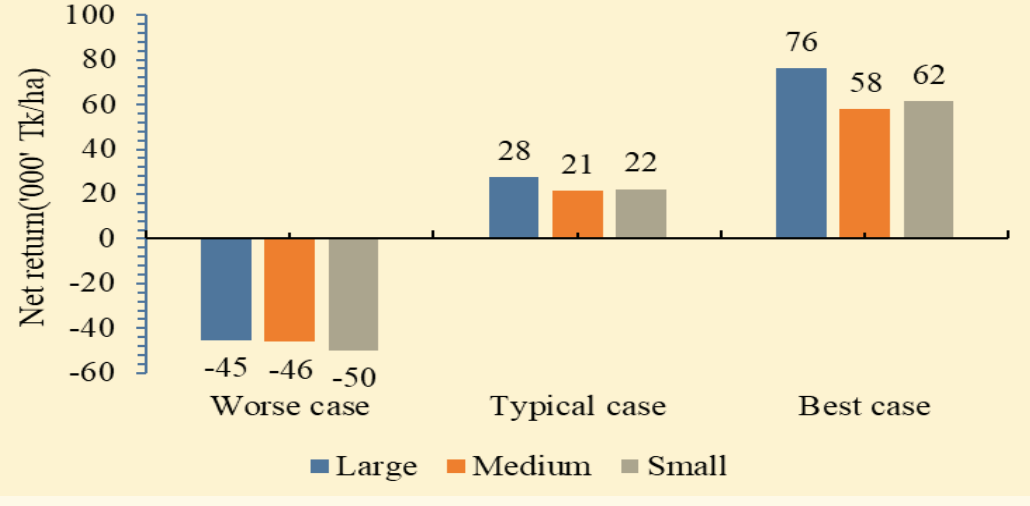


Figure 10.4: Farm types and case wise comparison in net-income (Tk per ha) for *T. Aus* in favorable ecosystem

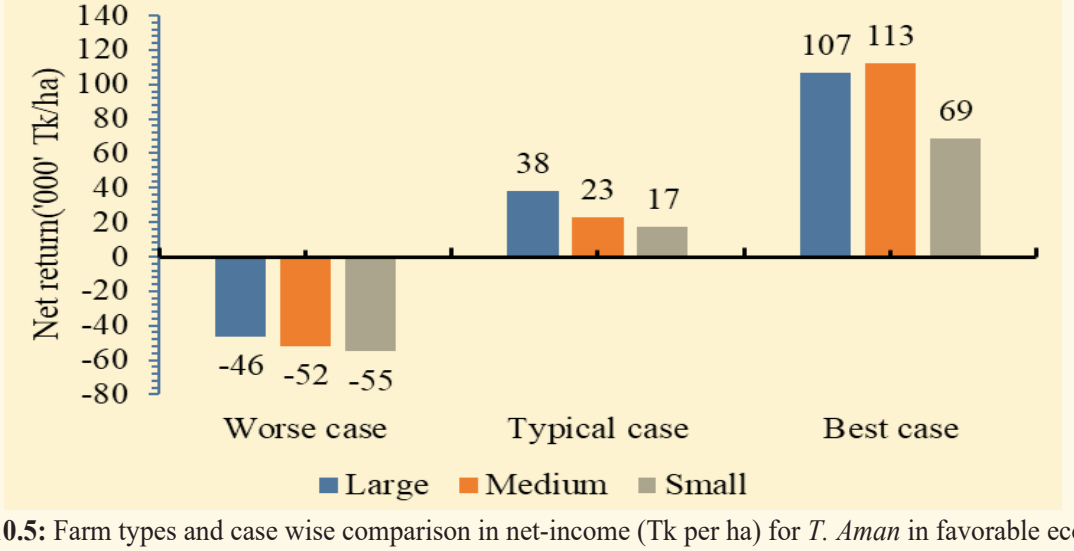


Figure 10.5: Farm types and case wise comparison in net-income (Tk per ha) for *T. Aman* in favorable ecosystem

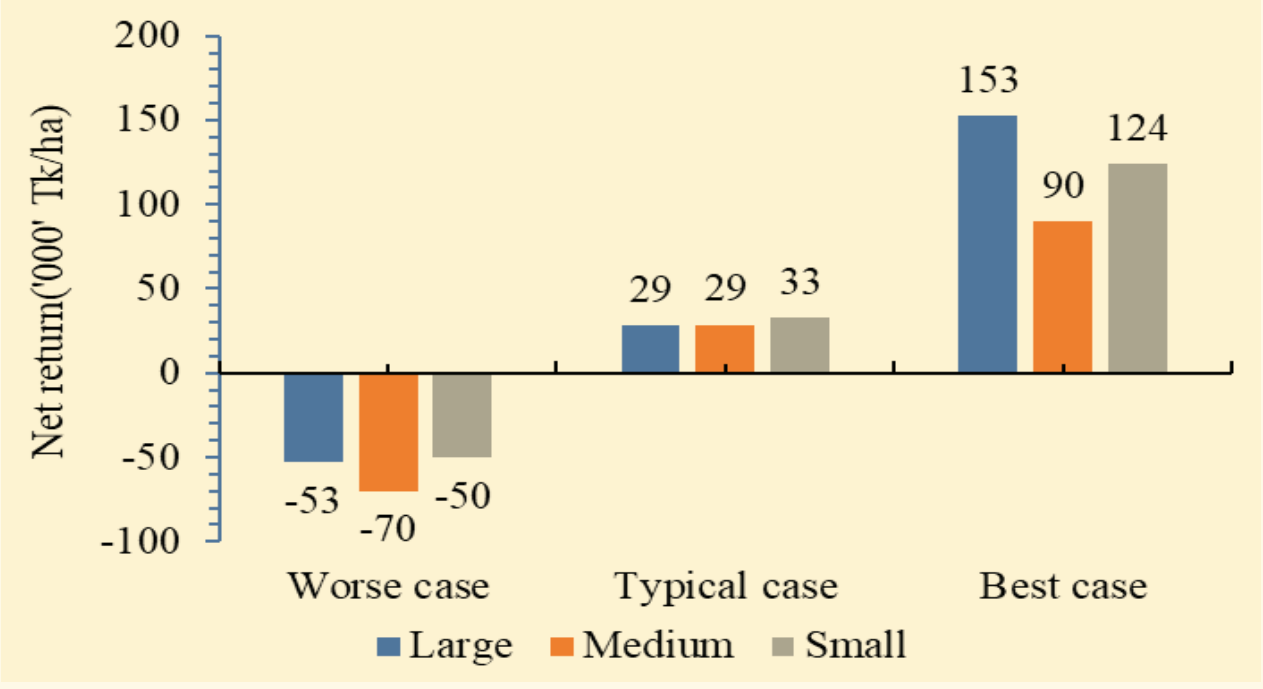


Figure 10.6: Farm types and case wise comparison in net-income (Tk per ha) for *Boro* in favorable ecosystem

The lower benchmark (Tk. 16000) was selected based on total imputed cost per ha, while the upper benchmark (Tk. 53000) was chosen randomly. The CDF of NI per ha from *T. Aus* showed that large farmer had about 39% chance of receiving NI per ha above the lower benchmark, implying that it could cover the cost of owned resources including family labour. The chance of receiving NI per ha above this threshold decreased to 26% for both medium farmer and small farmer (Figure 10.7(a)). The lower benchmark (Tk. 56000) was selected based on total paid out cost for small farmer, while the upper benchmark (Tk. 121000) was chosen randomly. The chance of getting GR per ha from *T. Aus* showed that medium farmer and small farmer had 95% and 94% respectively, respectively above the lower benchmark, respectively meaning it could cover the cost of all cash costs while the chance of getting GR above this threshold slightly decreased to 93% for large farmer.

The lower benchmark (Tk. 16000) was selected based on the total imputed cost (total imputed cost) per ha for large farmers while the upper benchmark (Tk. 64000) was chosen randomly. The Cumulative density function (CDF) of net-income (NI) per ha from *T. Aman* showed that large farmers had about 60% chance of getting NI per ha above the lower benchmark, denoting that the higher probability of recovering the benchmark cost of large farmers including family labour. The probability of receiving NI per ha above this threshold decreased to nearly 49% for medium farmers and 25% for small farmers (Figure 10.8(a)). The lower benchmark (Tk. 61000) was selected based on the total paid-out costs (total paid out cost per ha) for medium farmer, while the upper benchmark (Tk. 121000) was chosen randomly. The CDF of gross return per ha from *T. Aman* showed that small farmers (small farmer) had about 91% chance of getting gross return (GR) per ha above the lower benchmark, respectively meaning it could cover the cost of all cash costs of rice production. The chance of receiving GR per ha above this threshold decreased to 63% for medium farmer (Figure 10.7(b)). However, the chance of probability of getting NI for small farmers become negative in *T. Aman* in favorable ecosystem.

The lower benchmark (Tk.18000) was selected based on total imputed cost per ha for large farmer, while the upper benchmark (Tk. 84000) was chosen randomly. The probability of getting NI per ha from *Boro* showed that both large farmer and small farmer had 60% chance of getting NI per ha above the lower benchmark, meaning it could cover the cost of home supply resources including family labour. The chance of receiving NI per ha above this threshold decreased to 32% for medium farmer (Figure 10.9(a)). The lower benchmark (Tk. 71000) was selected based on the total paid out cost per ha for small farmer, while the upper benchmark (Tk. 150000) was chosen randomly. The probability of obtaining GR per ha from *Boro* showed that medium farmer had about 89% chance of GR per ha above the lower benchmark, respectively meaning it could cover the cost of all cash costs. The chance of receiving GR per ha above this threshold tremendously decreased to 71% for both large farmer and small farmer (Figure 10.9(b)).

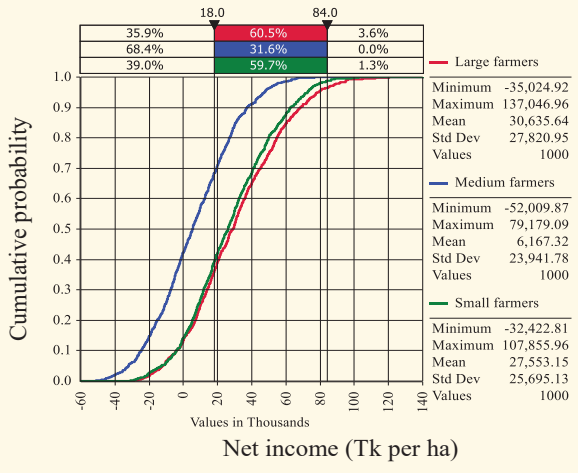


Figure 10.7(a): Cumulative probability of net-income (Tk per ha) of *T. Aus* rice cultivation in favorable ecosystem

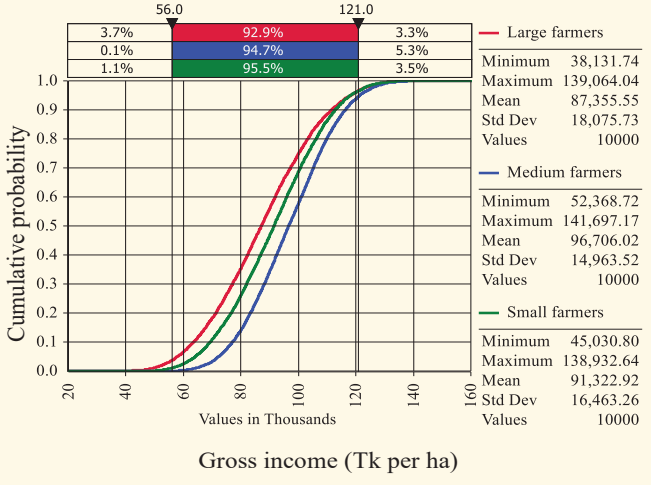


Figure 10.7(b): Cumulative probability of gross income (Tk per ha) of *T. Aus* rice cultivation in favorable ecosystem

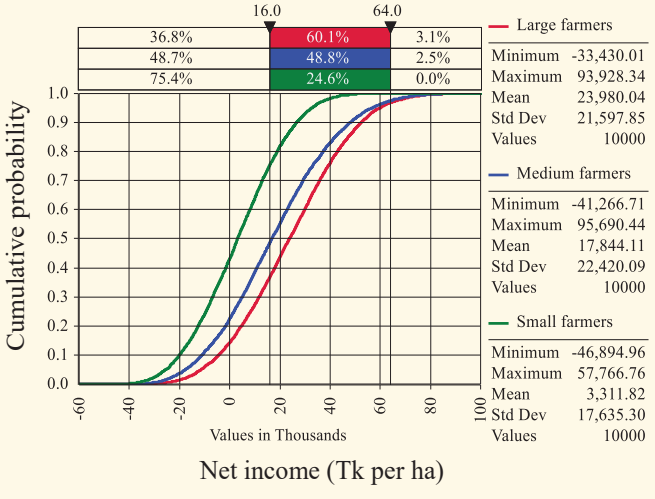


Figure 10.8(a): Cumulative probability of net-income (Tk per ha) of *T. Aman* rice cultivation in favorable ecosystem

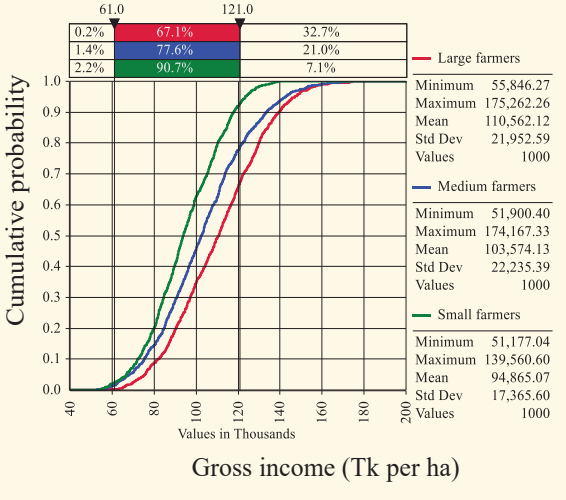


Figure 10.8(b): Cumulative probability of gross income (Tk per ha) of *T. Aman* rice cultivation in favorable ecosystem

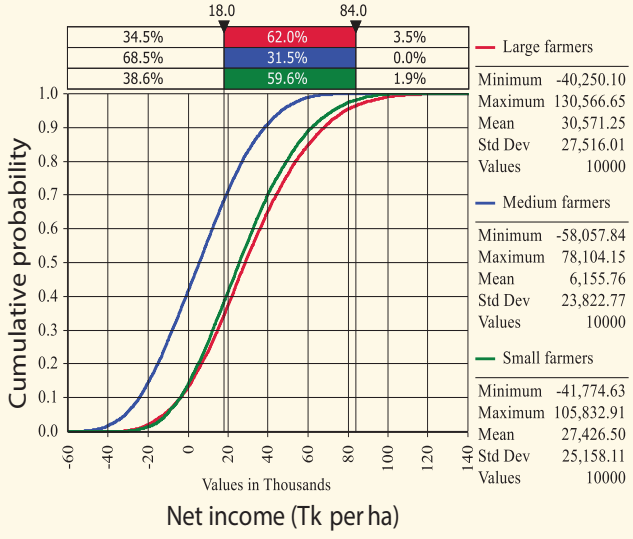


Figure 10.9(a): Cumulative probability of net-income (Tk per ha) of *Boro* rice cultivation in favorable ecosystem

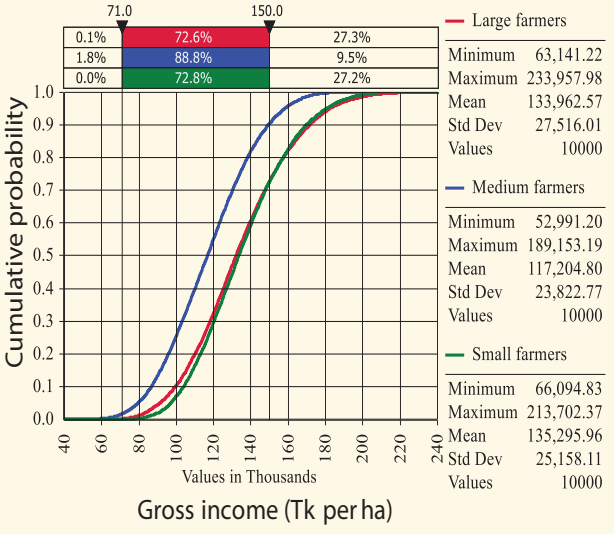


Figure 10.9(b): Cumulative probability of gross income (Tk per ha) of *Boro* rice cultivation in favorable ecosystem

The outcome of ecosystem wise environment and market risky is major effect on the gross return (GR) and net-income (NI) of seasonal rice cultivation. This risk was taken into consideration in order to assess the economic viability based on farmers' perceived variation in yield and market price (lower/worse, moderate/average/typical and best case). Assessing seasonal variation on economic viability of rice cultivation at current price, the result revealed that variability in the yield of rice in the favorable ecosystem had influence on profitability of rice production with current market price. Figure 10.10 showed that, with all variables being constant other than yield, straw value and price, rice yield and straw value contributed together by about 60% to the risk occurrence in getting NI per ha above benchmark cost in *T. Aman* followed by *T. Aus*. The contribution of yield and straw value of *Boro* to risk occurrence in getting NI per ha below benchmark markedly reduced to 50% for small farmer. Risk in *T. Aus* (nearly 46-60%) appeared due to both yield and straw value, higher than that in *Boro* for all farm types. medium farmer experienced extreme effect of price variation (45-50%) on NI in both *T. Aus* and *Boro* followed by *T. Aman*. However, the fluctuation in the price of rice was found relatively lower than the combined effect of yield and straw value. The risk occurred in getting the NI per ha above benchmark cost of owned resources from yield and straw value was higher for large farmer and medium farmer than that for small farmer. Similar pattern of risk (a bit more than 60% arose from yield and straw value) was observed in getting GR above benchmark cash cost for all farm types across the seasons. The analysis revealed that the rice production was economically viable at current price and average seasonal yields, but yield and price have outmost effect on the profitability of the rice cultivation seriously which was aroused from adverse weather and market distortion (Figure 10.11).

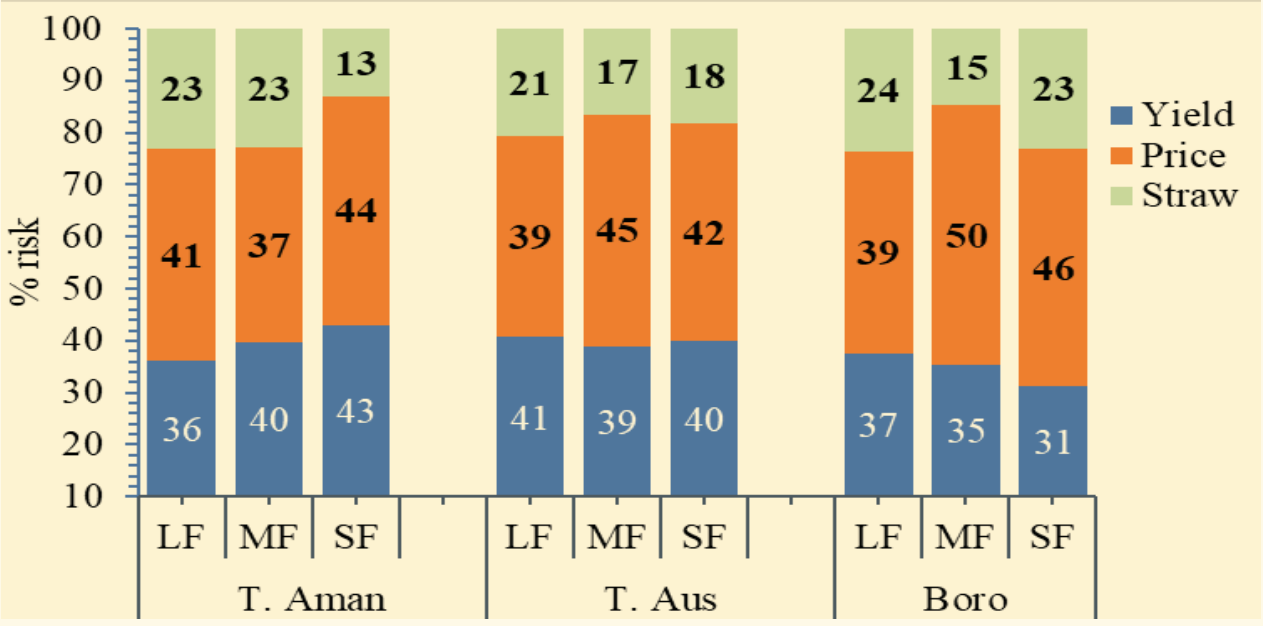


Figure 10.10: Inputs' effect ranked on NI for *T. Aman*, *T. Aus* and *Boro* rice in favorable ecosystem

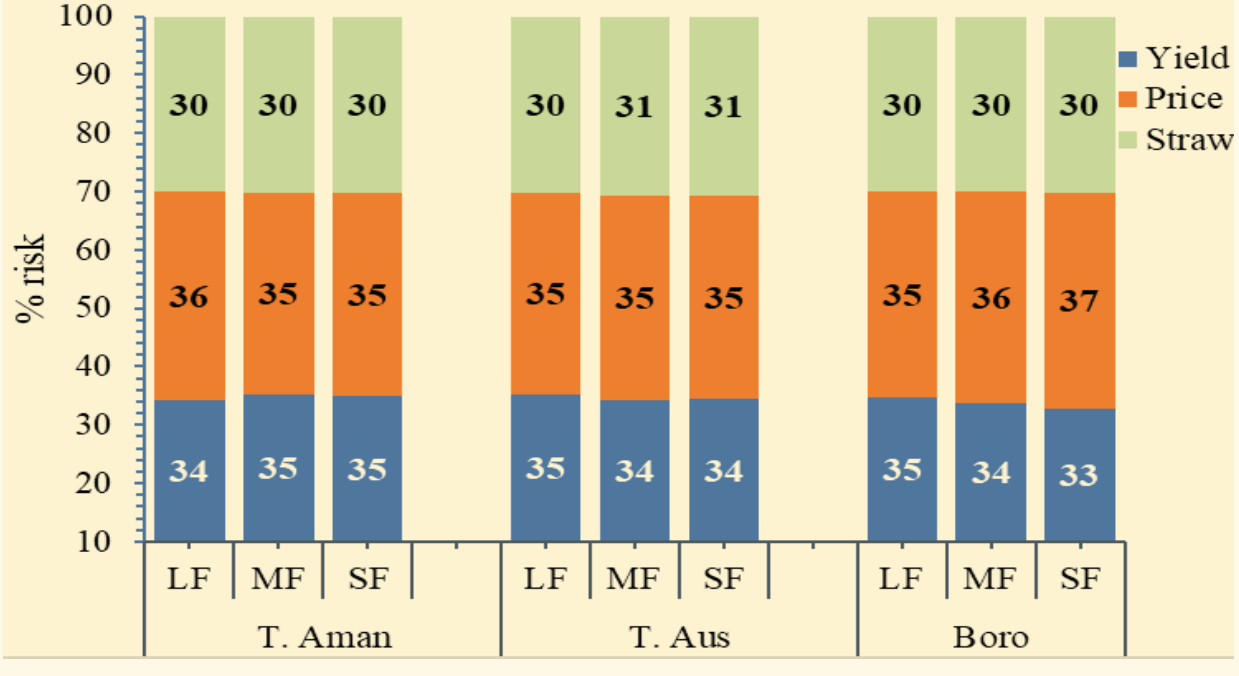


Figure 10.11: Inputs' effect ranked on GR for *T. Aman*, *T. Aus* and *Boro* rice in favorable ecosystem

10.2 Financial and risk analysis of rice production in *haor* ecosystem

Representative farm budgets for seasonal rice production were computed with the market prices in 2020 for the average/moderate/typical value of all farm categories. Based on average value from sample survey, was estimated and cross checked with focus group discussion (FGD) as well as key informant survey (KIS). Representative farm budget, variation in both yield and price under weather and market variability were finally developed.

10.2.1 Input use pattern and productivity of rice in *haor* ecosystem

The pattern of inputs use in seasonal rice cultivation by three farm types in *haor* ecosystem can be viewed in table 10.4. Large farmer of *T. Aman*, *T. Aus* and *Boro* rice used more than 80% hired labor, for all kind of production activities. On the contrary, Small farmer used nearly 43%, 50% and 39% of family labor in *T. Aman*, *T. Aus* and *Boro* in rice cultivation, respectively. Medium farmer used 75%, 45% and 57% of hired labor in the respective season to accomplish intercultural and postharvest activities. Contractual costs of rice production in all growing seasons was higher for large farmer compared to medium and small farmer in *haor* ecosystem. Most of the farmers purchased HYV rice seed from market. All farm types used seed rate of 41 kg/ha and 35 kg/ha in *T. Aman* and *Boro* season respectively, whereas large and medium farmer used about 22 kg/ha and 33 kg/ha in *T. Aus* season. In practice, 28-35 days old seedlings were used when transplanting *T. Aman* up to second week of August, 27-35 days old seedling in *T. Aus* up to late May, 25-35 days old seedlings in *Boro* seedlings up to late December. It implied that per hectare inputs use in *Boro* season by large and medium farmer was relatively higher than that by small farmer.

Only large farmer applied about 11% and 19% lower amount of urea than the recommended dose (185kg/ha) in case of *T. Aman* and *T. Aus* season. On the other hand, they also used 45% higher dose of urea in *Boro* season (BRRI Adhunik Dhaner Chas 2020). Medium and small farmer applied much lower dose of urea in all rice growing seasons. In addition, small and medium farmer applied more TSP as well as MOP than large farmer even more than recommended rate. Farmers of all categories applied lower rate of DAP, Gypsum, Zinc and theovit in rice cultivation than recommended rate. Small farmer obtained higher yield (7.59 t/ha) from *Boro* rice compared to large (6.93 t/ha) and medium farmer (6.59 t/ha). In case of *T. Aman* season, yield of both Small and medium farmer (4.49 t/ha) was lower than large farmer (5.47 t/ha). Yield of Medium farmer (3.94 t/ha) was higher in *T. Aus* season compared to large (3.90t/ha) and medium farmer (3.89t/ha).

Table 10.4: Input use pattern, productivity and price of seasonal rice in *haor* ecosystem

Input items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	***T. Aman***	***Boro***	***T. Aman***	***T. Aus***	***Boro***	***T. Aus***	***T. Aman***	***Boro***
Seed (Kg/ha)	22	41	35	41	33	34	41	41	35
Land preparation	7485	8233	8233	8233	8233	8233	5233	8233	8233
Human labour (man-days/ha)									
Hired	67	72	56	33	22	38	33	33	38
Family	10	9	11	11	27	28	33	25	25
Contractual	15905	16230	18407	16075	13000	18112	8233	9880	16347
Fertilizer (Kg/ha)									
Urea	150	165	270	190	130	257	131	165	238
TSP	75	82	77	82	82	92	82	82	91
MOP	75	82	75	82	82	94	82	82	97
DAP	0	82	59	82	82	55	82	82	37
Gypsum	0	82	49	82	41	41	41	82	82

Input items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aman*	*T. Aus*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Sulpher	7	8	8	8	8	8	8	8	8
Zinc	7	8	8	8	8	8	8	8	8
Mg	0	16	16	16	16	16	16	16	16
Theovit	2	8	8	8	8	8	8	8	8
Irrigation	1235	3900	16467	1293	1976	16467	1647	4117	16467
Herbicides	600	499	873	823	329	823	1198	329	329
Insecticides	1411	988	2994	1153	329	823	1482	1482	1482
Yield (ton/ha)	3.9	5.47	6.93	4.95	3.94	6.59	3.89	4.94	7.59
Straw (Tk/ha)	12982	18712	9730	14970	7485	14970	10982	18712	8982

Source: Authors' estimation based on field survey, 2019-2021.

10.2.2 Scenario of cost and return of rice production in *haor* ecosystem

Data in table 10.5 show that per ha total cost of large farmer was higher by Tk. 807 and Tk. 6499 compared to medium and small farmer in *Boro* growing season due to differences in the man-days of hired labor, fertilizer costs and irrigation. Per ha total cost of *T. Aman* rice was relatively higher for large farmer than that for medium farmer by Tk. 20310 and for small farmer by Tk. 12200, due to differences in hired labor, contractual cost and fertilizer application. In addition, per ha total cost *T. Aus* rice was also higher for large farmer than that for medium farmer by Tk. 7384 and for small farmer by nearly Tk. 1766 (Table 10.5).

The actual paid-out costs includes seed, land preparation, hired labor, fertilizers, herbicides, insecticides, and power thresher which were the major items of rice cultivation and standing more than 70% of total cost for large farmer and 60% of total cost for medium as well as small farmer in all rice growing seasons. On the contrary, the imputed cost of land rent and family labor stood almost 22-28% of total cost for large farmer and more than 30% for medium and small farmer in all seasons (Figure 10.12-10.14). The BCR found more than one on cash cost and full cost basis in all rice seasons and the positive net return denoting that return outyielded total investment in rice production in *haor* ecosystem. (Table 10.5).

Table 10.5: Production cost and return in rice production in different seasons in *haor* ecosystem

Cost and income (Tk/ha)	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Paid out cost (A)	66731	80455	90840	51054	61773	76966	56228	61845	75644
Seed	946	1763	1925	1419	1763	2421	1763	1763	2227
Land preparation	7485	8233	8233	8233	8233	8233	5233	8233	8233
Hired labour	26800	28800	25200	8800	13200	13200	13200	13200	16400
Contractual	15905	16230	18407	13000	16075	18112	14653	14653	14653

Cost and income (Tk/ha)	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Power thresher	3485	4775	4199	2799	4117	4199	3499	2799	3499
Fertilizer	8864	15267	12542	13534	15751	12688	13553	15269	12354
Irrigation	1235	3900	16467	1293	1976	16467	1647	4117	16467
Herbicides	600	499	873	823	329	823	1198	329	329
Insecticides	1411	988	2994	1153	329	823	1482	1482	1482
Imputed cost (B)	26854	28027	30143	35147	26400	43210	35591	34437	38840
Seedbed	1846	2305	2054	2470	2470	1837	2470	2470	2278
Family labour	4000	3600	4400	10800	4400	14800	13200	10000	10000
Land rent	20452	21452	22932	21452	19015	25932	19452	21452	25932
IOC at 4% for 5 months	556	670	757	425	515	641	469	515	630
Total cost (A+B)	93585	108482	120983	86201	88173	120176	91819	96282	114484
Gross return (Tk/ha)	98782	137670	155218	93228	121438	138470	100528	117512	156922
Net return (Tk/ha)	5198	29187	34235	7026	33265	18294	8710	21230	42437
BCR (Cash cost)	1.48	1.71	1.71	1.83	1.97	1.80	1.79	1.90	2.07
BCR (Full cost)	1.06	1.27	1.28	1.08	1.38	1.15	1.09	1.22	1.37

Source: Authors' estimation based on field survey, 2019-2021.

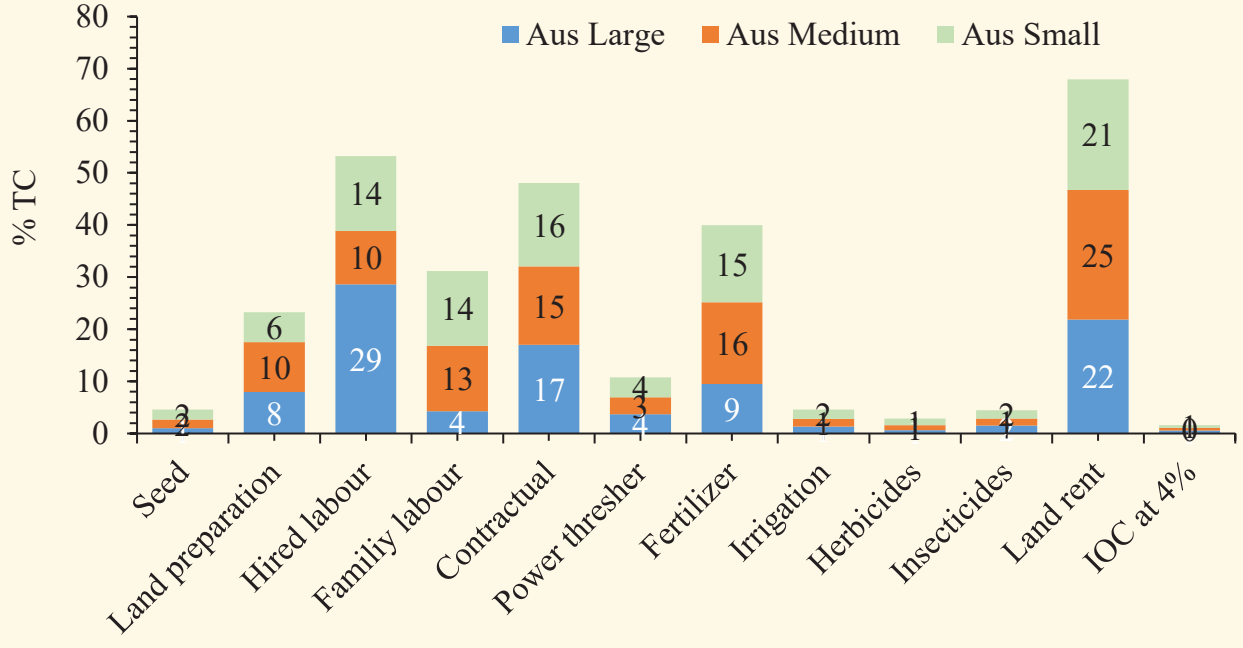


Figure 10.12: Share of per hectare inputs cost to total cost of *T. Aus* cultivation in *haor* ecosystem

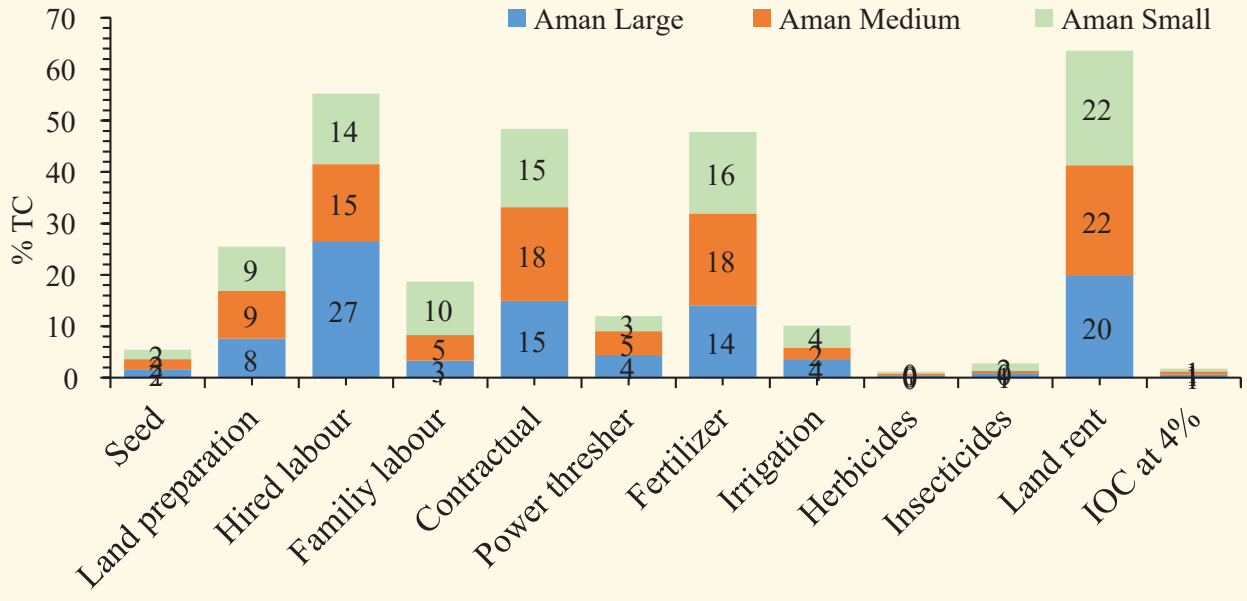


Figure 10.13: Share of per hectare inputs cost to total cost of *T. Aman* cultivation in *haor* ecosystem

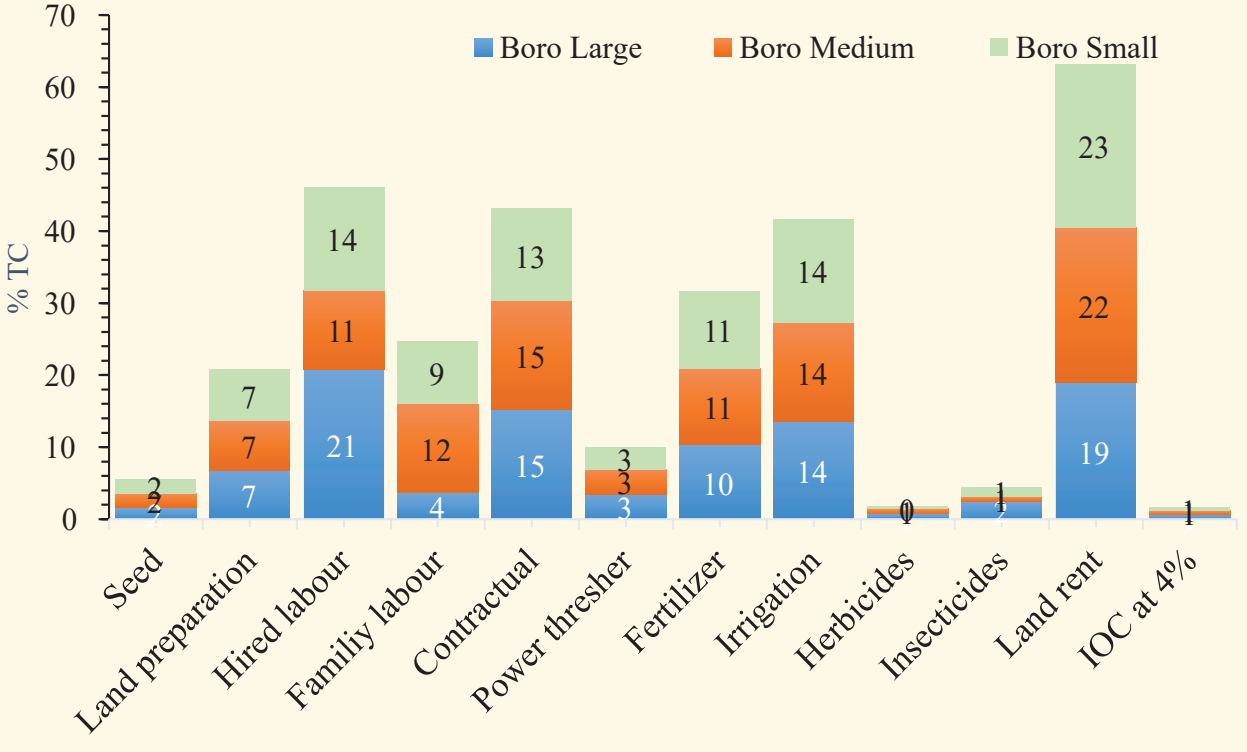


Figure 10.14: Share of per hectare inputs cost to total cost of Boro cultivation in *haor* ecosystem

10.2.3 Risk analysis of rice production in *Haor* ecosystem

In assessing the seasonal variation on economic viability of rice cultivation at current price, the result revealed that variability in the yield of rice in the *Haor* ecosystem had influence on farm profit with the reported market price. The average/moderate/typical value of rice yield, straw value, inputs use and market price of rice estimated from household survey of *Haor* ecosystem were

crosschecked with the key informant survey so as to get more Representative data. Moreover, farmers sold their produces at a higher price than that in the worst case. The gross return (GR) of rice was computed by multiplying rice yields by the reported price (Table 10.6). In constructing the stochastic budgeting of rice production in *Haor* ecosystems, production cost and profitability of *Haor* ecosystem was taken into risk analysis (table 10.6). Stochastic budgets were eventually constructed for seasonal rice cultivation considering farmers' perceived variation in yield and market price by different farm types. The stochastic budget analysis displayed that seasonal rice cultivation was economically viable at the reported average/typical price and yields. In this analysis, triangular distribution was constructed by different levels of worst, typical/average, and best yields, straw value and price for different farm types across the seasons. Figure 10.15-10.17 showed that rice production in all seasons for large, medium and small farmers was found to be more profitable in the farmers' perceived typical and best case than that in the worst case. However, farmers always suffer from negative net-income in the worst case caused by weather stress (unpredictive climatic factor such as erratic temperature and rainfall, heat wave and casual flood).

Table 10.6: Stochastic budgeting of rice production by farm types in *haor* ecosystem

Items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Yield (ton per ha)									
Worse case	2.25	3.29	4.91	2.65	3.29	4.29	2.47	3.29	4.12
Typical case	3.9	5.47	6.93	3.94	4.95	6.59	3.89	4.94	7.59
Best case	4.94	5.94	9.26	4.94	6.04	9.88	4.94	6.59	9.48
Straw (Tk per ha)									
Worse case	6736	7485	3742	5988	7485	3742	4491	7485	3742
Typical case	12982	18712	9730	7485	14970	14970	10982	18712	8982
Best case	14479	22455	11227	11227	18712	18712	11227	22455	11227
Price (Tk per ton)									
Worse case	15000	15000	12500	18000	13750	15000	20000	12500	10000
Typical case	22000	21750	21000	21750	21500	18750	23000	20000	19500
Best case	30000	30000	25000	25000	25000	25000	25000	25000	25000
Paid out cost (Tk per ha) (A)	66731	80455	90840	51054	61773	76966	56228	61845	75644
Imputed cost (Tk per ha) (B)	26854	28027	30143	35147	26400	43210	35591	34437	38840
Total cost (Tk per ha) (A+B)	93585	108482	120983	86201	88173	120176	91819	96282	114484
Net return (Tk per ha)									
Worse case	-53099	-51647	-55866	-32513	-35450	-52084	-37928	-47672	-69542
Typical case	5197	29202	34277	6979	33222	18356	8633	21230	42503
Best case	69094	92173	121744	48526	81539	145536	42908	90923	133743

Source: Authors' estimation based on field survey, 2019-2021.

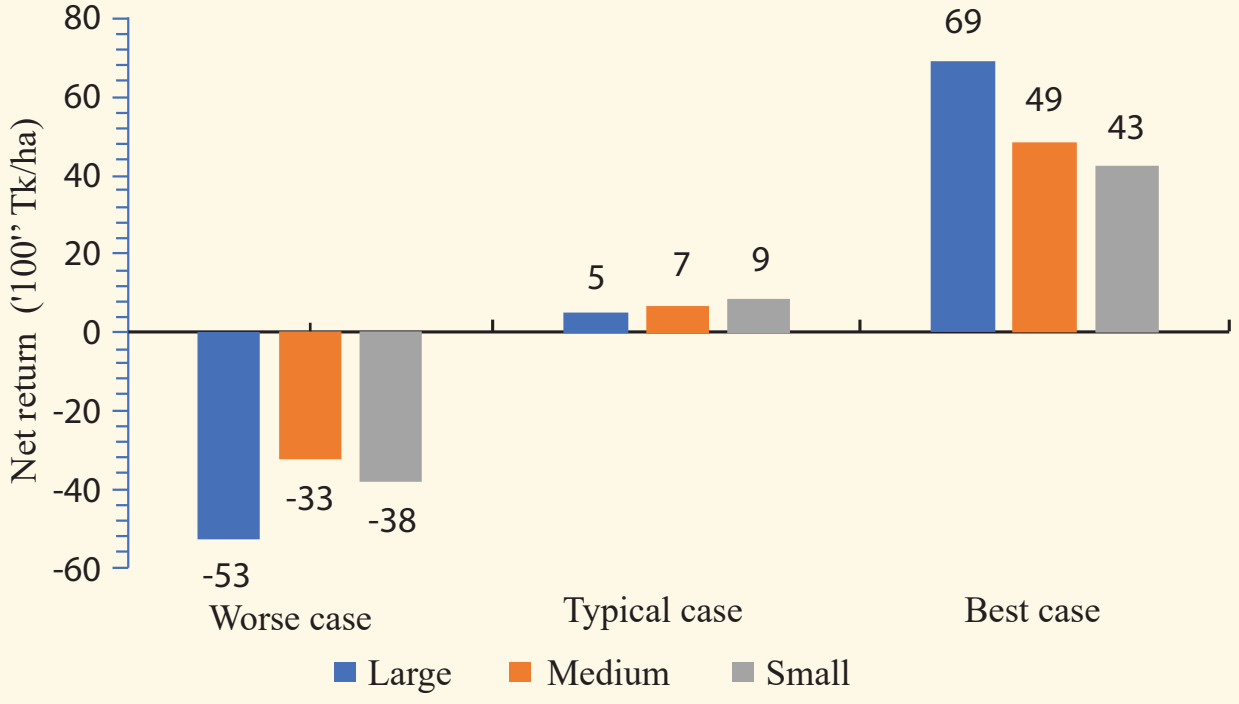


Figure 10.15: Farm types and case wise comparison in net-income (Tk per ha) for for *T. Aus* in *haor* ecosystem

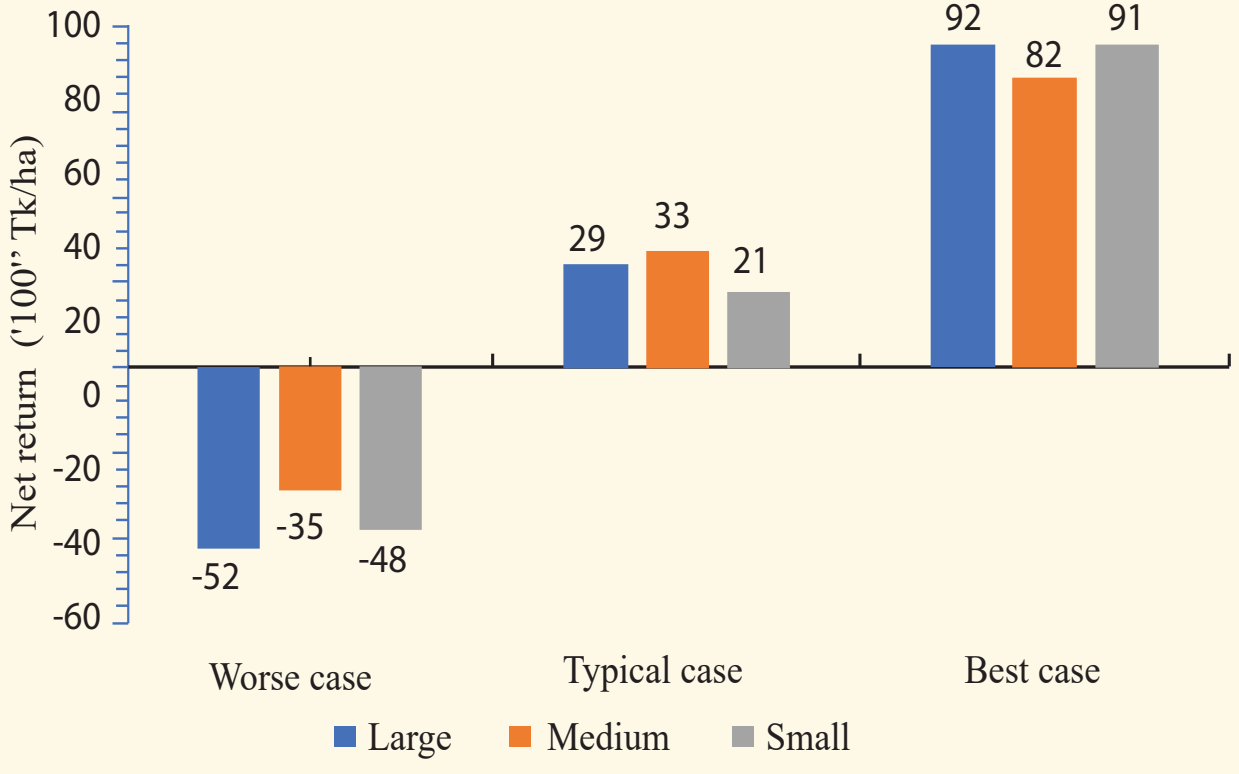


Figure 10.16: Farm types and case wise comparison in net-income (Tk per ha) for for *T. Aman* in *haor* ecosystem

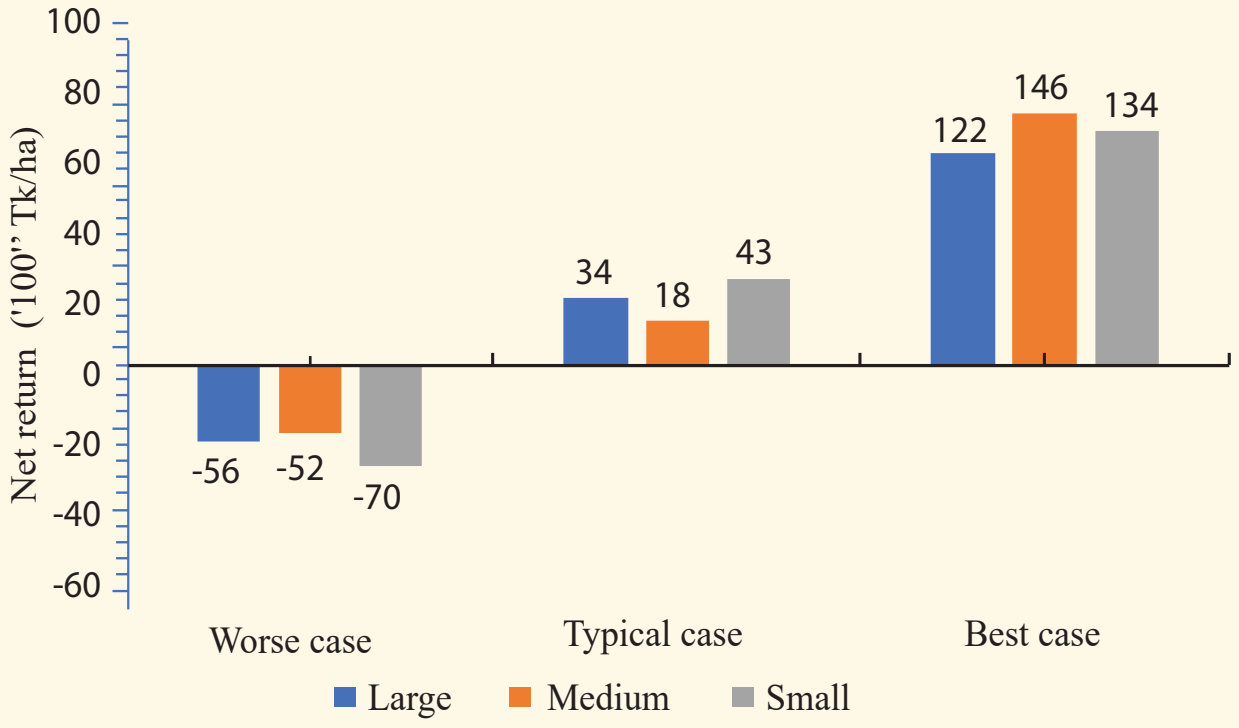


Figure10.17: Farm types and case wise comparison in net-income (Tk per ha) for for *Boro* in *haor* ecosystem

The lower benchmark (Tk. 25000) was selected based on total imputed cost per ha, while the upper benchmark (Tk. 47500) was chosen randomly. The probability of achieving NI per ha from *T. Aus* showed that large farmer had about 8% chance of getting NI per ha above the lower benchmark total imputed cost in *T. Aus*, meaning it could cover the cost of owned resources including use of family labour in *T. Aus* rice production. The chance of receiving NI per ha above this threshold decreased to 4% for medium farmer and 3% for small farmer (Figure 10.18(a)). The likelihood of achieving NI per ha above the benchmark appeared to be highly negative for all farm types in *T. Aus* season. The lower benchmark (Tk. 52000) was selected based on total paid out cost per ha in *T. Aus* for medium farmer, while the upper benchmark (Tk. 124000) was chosen randomly. The CDF of GR per ha from *T. Aus* showed that medium farmer and small farmer had 100% chance of achieving GR per ha above the benchmark total paid out cost per ha in *T. Aus*, respectively above the lower benchmark, respectively meaning it could cover the cost of all cash costs of *T. Aus* production. The chance of receiving GR per ha above this threshold slightly decreased to 96% for large farmer (Figure10.18(b)). It appeared that the best chances of getting paid back of GR per ha in *T. Aus* rice production above the benchmark total paid out cost per ha.

The lower benchmark (Tk. 26000) was selected based on total imputed cost per ha in *T. Aman* for medium farmers, while the upper benchmark (Tk. 64000) was chosen randomly. The probability of achieving net-income (NI) per ha from *T. Aman* showed that medium farmer had about 40% chance of getting NI per ha above the lower benchmark total imputed cost per ha, denoting that the probability of getting paid back the cost of owned resources including family labour in *T. Aman* rice production of *Haor* ecosystem. The chance of receiving NI per ha above this

threshold decreased to 31% for large farmer and 27% for small farmer (Figure 10.19(a)). The lower benchmark (Tk. 61000) was selected based on the paid-out costs (total paid out cost per ha) of *T. Aman* rice production for medium farmer, while the upper benchmark (Tk. 140000) was chosen randomly. The probability of getting GR per ha showed that medium farmer and small farmer had about 98% and 94% chance of GR per ha above the lower benchmark total paid out cost per ha in *T. Aman*, respectively meaning it could cover the cost of all cash costs of *T. Aman* rice production. The chance of receiving GR per ha above this threshold decreased to 76% for large farmer (Figure 10.19(b)). However, the chance of achieving NI per ha above the benchmark total imputed cost per ha become negative in *T. Aman*.

The lower benchmark (Tk. 30000) was selected based on total imputed cost per ha for large farmer, while the upper benchmark (Tk. 91000) was chosen randomly. The probability of achieving NI per ha of *Boro* rice production showed that medium farmer had about 43% chance of getting NI per ha above the lower benchmark, meaning that it could cover the cost of owned resources including use of family labour in *Boro* rice production. The chance of receiving NI per ha above this threshold decreased to 41% for large farmer and 38% for small farmer (Figure 10.20(a)). The lower benchmark (Tk. 75000) was selected based on the total paid out cost per ha for medium farmer, while the upper benchmark (Tk. 161000) was chosen randomly. The probability of achieving GR per ha of *Boro* showed that large farmer had about 78% chance of achieving the GR per ha, respectively above the lower benchmark, respectively implying that it could cover the cost of all cash costs of *Boro* rice production in *Haor* ecosystem. The chance of receiving GR per ha above this threshold slightly decreased to 67% for medium farmer and 50% for small farmer (Figure 10.20(b)).

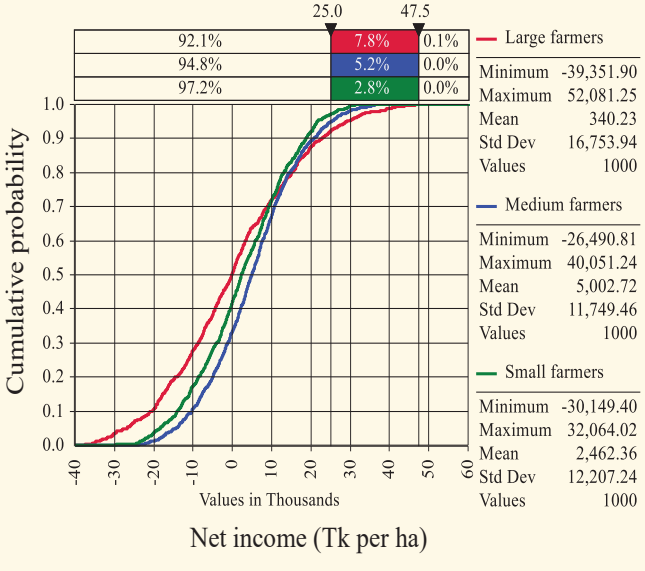


Figure 10.18(a): Cumulative probability of net-income (Tk per ha) of *T. Aus* rice cultivation in *Haor* ecosystem

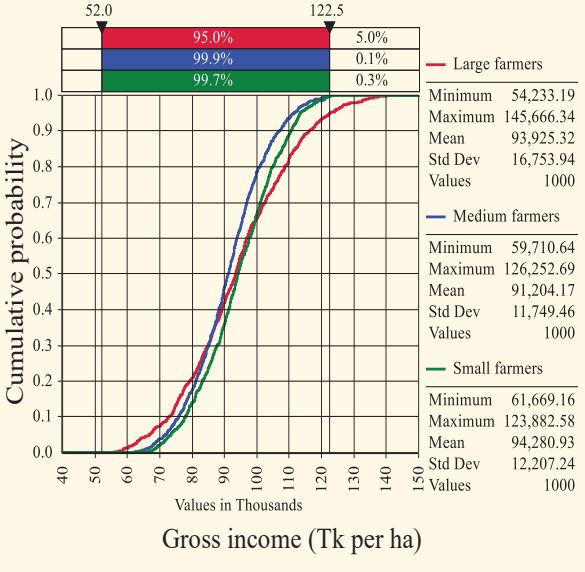


Figure 10.18(b): Cumulative probability of gross income (Tk per ha) of *T. Aus* rice cultivation in *Haor* ecosystem

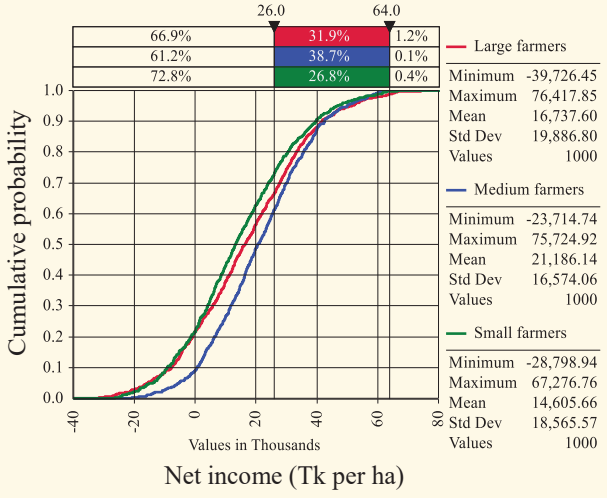


Figure 10.19(a): Cumulative probability of net-income (Tk per ha) of *T. Aman* rice cultivation in *Haor* ecosystem

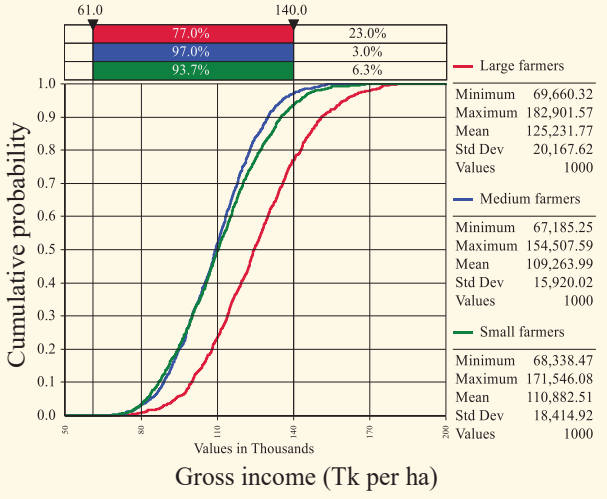


Figure 10.19(b): Cumulative probability of gross income (Tk per ha) of *T. Aman* rice cultivation in *Haor* ecosystem

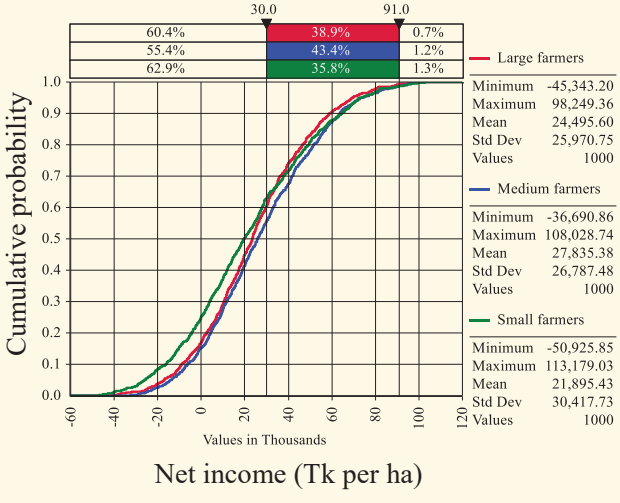


Figure 10.20(a): Cumulative probability of net-income (Tk per ha) of *Boro* rice cultivation in *Haor* ecosystem

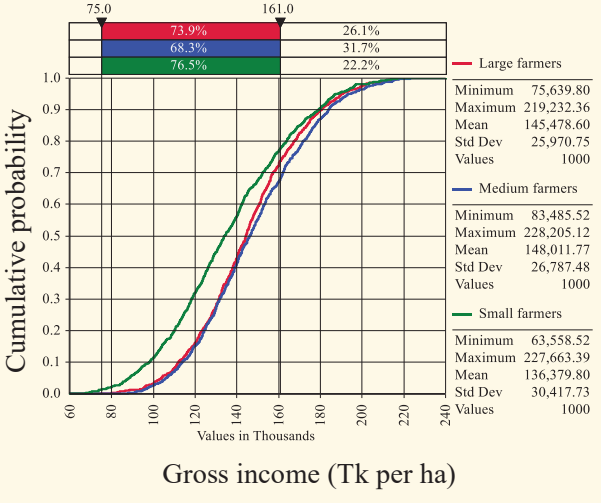


Figure 10.20(b): Cumulative probability of gross income (Tk per ha) of *Boro* rice cultivation in *Haor* ecosystem

In assessing seasonal variation on economic viability of rice cultivation at current price, the result revealed that variability in the yield of seasonal rice and straw value in the *Haor* ecosystem had influence on farm profit with the reported market price. Figure 10.21 showed that, with all variables being constant other than yield, straw value and price, rice yield and straw value contributed together to the risk occurrence ranging from 55 to 67% in getting NI per ha above benchmark total imputed cost cost in all season. large farmer experienced higher risk of price variation on achievement of NI per above the lower benchmark total imputed cost per ha in both *T. Aman and T. Aus* (43%) while small farmer experienced higher risk of price variation (42%) in *Boro* followed by and medium farmer (35%) in *T. Aman* rice production. However, the risk of marker price volatility of rice was found relatively lower than the combined effect of yield and straw value in the rice production in

all seasons. The risk occurred in getting the NI per ha above benchmark cost of owned resources from yield and straw value was higher for large farmer than that for both medium farmer and small farmer in drought ecosystem. Similar pattern of risk (65% arose from yield and straw value) was observed in getting GR per ha above benchmark cash cost for all farm types across the seasons. The analysis revealed that the rice production was economically viable at current price and average seasonal yields, but yield and price have outmost effect on the profitability of the rice cultivation which was aroused by erratic climate (temperature, heat wave and rainfall), occurrence of casual flood and market distortion in *Haor* ecosystem (Figure 10.22).

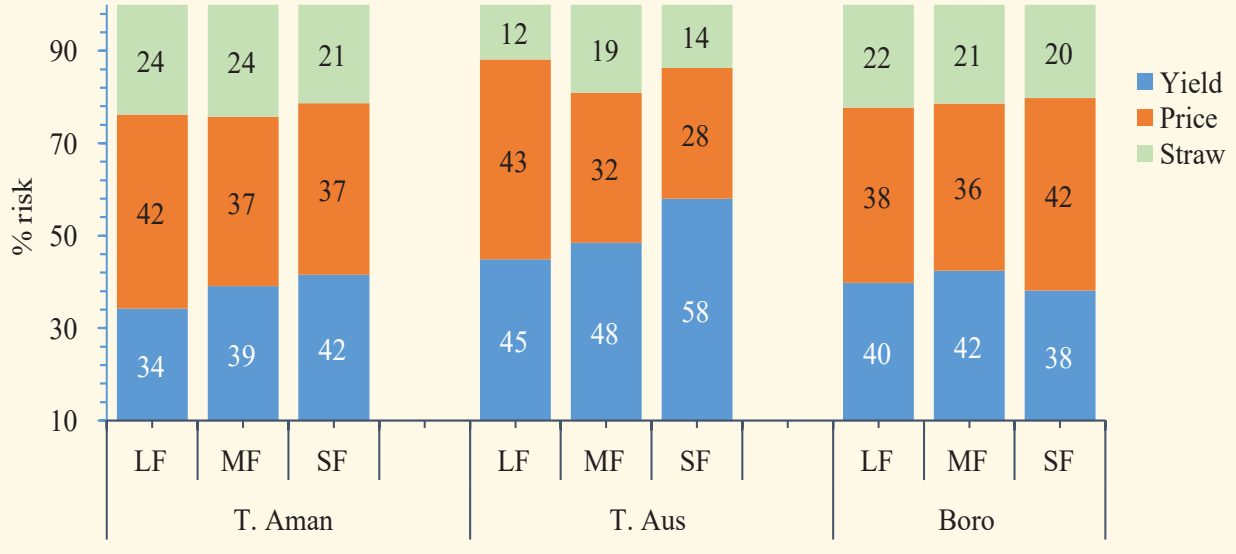


Figure 10.21: Inputs' effect ranked on NI for *T. Aman*, *T. Aus* and *Boro* rice in *haor* ecosystem

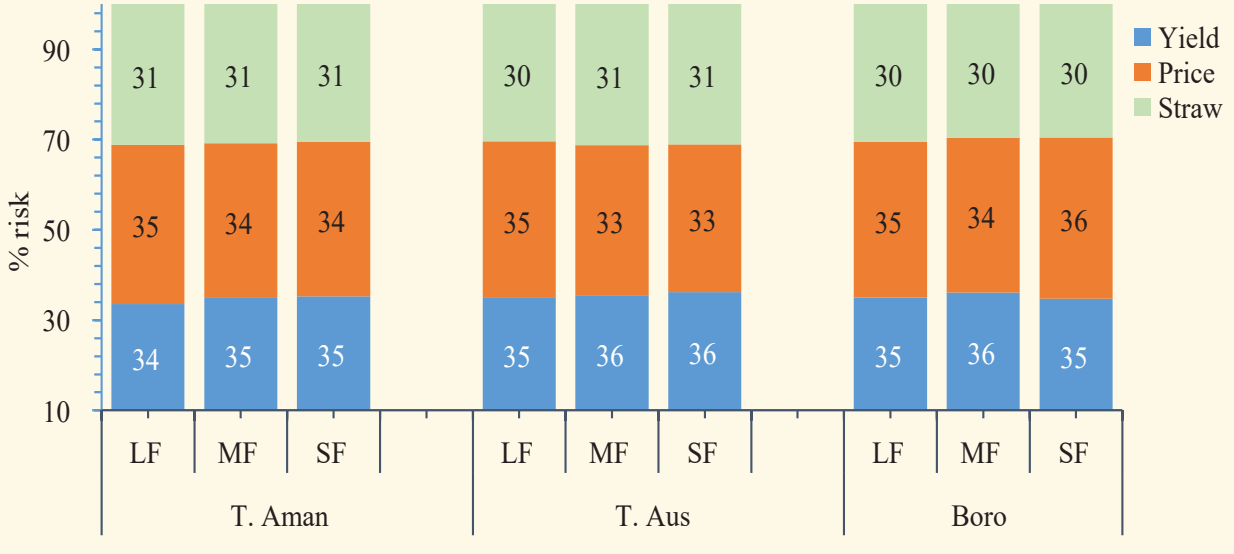


Figure 10.22: Inputs' effect ranked on GR for *T. Aman*, *T. Aus* and *Boro* rice in *haor* ecosystem

10.3 Financial and risk analysis of rice production under salinity ecosystem

Representative farm budgets for seasonal rice production were computed with the market prices in 2020 for the average/moderate/typical value of all farm categories. Based on average value from sample survey, was estimated and cross checked with focus group discussion (FGD) as well as key informant survey (KIS). Representative farm budget, variation in both yield and price under weather and market variability were finally developed.

10.3.1 Input use pattern and productivity of rice in salinity ecosystem

The pattern of inputs use in seasonal rice cultivation by three farm types in saline ecosystem can be viewed in table 10.7. The level of per ha inputs use in *Boro* season by small farmer was relatively higher compared to large and medium farmer in salinity ecosystem. In some case, magnitude of inputs use seems to be same for large, medium and small farmer in *T. Aman* and *T. Aus* season. Contractual costs of large farmer were comparatively higher compared to medium and small farmer due to dependency on hired labor in all rice growing seasons. All farmers used HYV rice seed from market and most of them did not treat the rice seed to control diseases before sowing. Seed rate was not quite higher than recommended rate among different farmers' categories. Only significant change was noticed in the case of large farmer, where large farmer used 16.5 kg/ha less seed than the medium and small farmer in *Boro* season. This is because many farmers practiced double transplanting in *T. Aman* and *T. Aus* seasons in order to avoid flood and damage due to heavy rain.

Only large farmer applied about 63 kg/ha more amount of urea in *Boro* season, whereas in case of *T. Aman* season medium farmer applied 68 kg/ha more amount of urea than the recommended dose (185 kg/ha). In addition, large, medium and small farmer applied more TSP and MOP for producing rice than the recommended rate. Large farmer usually avoids to apply DAP, Gypsum, Zinc and theovit in producing *T. Aus* and *Boro* rice, but this application is slightly different in case of in *T. Aman* production. Average yield of medium farmer (7.05 t/ha) in producing *Boro* rice was considerably higher than large (6.95 t/ha) and small farmer (6.46 t/ha), In *T. Aman*, yield performance of small farmer (5.46 t/ha) was higher compared to medium (5.16 t/ha) and large farmer (4.51 t/ha). In case of *T. Aus* season, average yield of large farmer (4.51 t/ha) was higher compared to medium (4.14 t/ha) and small farmer (4.22 t/ha) in salinity ecosystem (Table 10.7).

Table 10.7: Input use pattern, productivity and price of seasonal rice in salinity ecosystem

Input items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	T. *Aman*	Boro	*T. Aus*	T. *Aman*	Boro	*T. Aus*	T. *Aman*	Boro
Seed (kg/ha)	26	36	22.5	30	39	39	35	37	39
Land preparation	6587	9880	7136	6469	8645	9880	9880	8233	9115
Human labour (man-days/ha)									
Hired	31.5	61.5	60	46	50.5	60.5	37	49	57
Family	11	17	15	13.5	23	23.5	29	28	20.5
Contractual	14348	12848	17489.5	16462.5	10845	16083.5	18068	14083.5	15583.5

Input items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	T. *Aman*	Boro	*T. Aus*	T. *Aman*	Boro	*T. Aus*	T. *Aman*	Boro
					Fertilizer (kg/ha)				
Urea	130	190	248.5	99.5	218.5	174.5	105	190	249
TSP	80.5	107	88	119	80.5	116	68.5	137	121.5
MOP	60.5	87	104.5	96	90.5	97	102.5	68.5	106
DAP	19.5	99.5	41.5	21	68.5	61.5	129.5	99.5	118
Gypsum	39.5	50.5	54	59.5	45	53	58	68.5	53
Sulpher	0	31	4	0	25.5	4	13	7.5	28
Zinc	4	57	4	4	9	7.5	11.5	11.5	10.5
Theovit	6.5	7	9.5	6	7.5	9.5	6.5	9.5	9.5
Irrigation	0	3529	14820	1544	1235	12350	2470	2744	15438
Herbicides	425	375	510	618	278	494	278	278	278
Insecticides	0	1323	1112	1853	494	741	1853	3088	2470
Yield (t/ha)	4.145	4.51	6.95	4.14	5.165	7.05	4.22	5.465	6.465
Straw (Tk/ha)	16841	22454	16841	20583	22529	14970	11227	20583	16841

Source: Authors' estimation based on field survey, 2019-2021.

10.3.2. Scenario of cost and return of rice production in salinity ecosystem

Data in table 10.8 show that per ha total cost of small farmer was higher by Tk. 19380 and Tk. 8637 compared to large and medium farmer in producing *Boro* rice due to differences in the man-days of hired labor and irrigation costs. Per ha total cost was relatively higher for large farmer than that for medium farmer by Tk. 11369 and small farmer by Tk.6757, because of differences in the man days of hired labor, contractual cost and fertilizers application in *T. Aman* season. In addition, per ha total cost of *T. Aus* season was relatively higher for medium farmer compared to large farmer by Tk. 16007 and small farmer by Tk.799, because of differences in family labor and fertilizer application. It is important to mention that wages and market price of input did not vary across the season among farmer's categories.

The actual total paid out cost usually includes seed, land preparation, hired labor, fertilizers, herbicides, insecticides, and power thresher which were the major items for large, medium and small farmer, respectively standing for 80%, 72% and 69% of total cost in *T. Aman* season. On the contrary, the total imputed cost which includes land rent and family labor was 30%, 27% and 19% of total cost for small, large and medium farmer, respectively in *T. Aman* growing season. The total paid out cost of large farmer in *T. Aus* was 78% of total cost and 60-73% of total cost for medium as well as small farmer. The total imputed cost of small farmer and medium farmer was 25-40% of total cost and 21% of total cost for large farmer. Similarly, the total paid out cost in *Boro* season was 77%, 72% and 67% of total cost for large farmer, small farmer and medium farmer, respectively. Similarly, imputed cost was 32% of total cost for medium farmer and 27% of total cost for large farmer as well as small farmer in salinity ecosystem. The BCR found more than one on cash cost and full cost basis in all rice season and the positive net return denoting that return outyielded total investment in rice production (Table 10.8).

Table 10.8: Production cost and return in rice production in different seasons in salinity ecosystem

Cost and income (Tk/ha)	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Paid out cost (A)	61620	89939	85376	56779	71883	82064	69022	72655	94500
Seed	836	1340	570	1330	1557	1557	1557	1406	1557
Land preparation	6587	9880	7136	6469	8645	9880	9880	8233	9115
Hired labor	27384	30670	30670	26289	35052	32861	24098	25193	33956
Contractual	14718	14718	13221	7151	10712	9712	14653	14653	14653
Power thresher	2350	2350	3350	2350	2350	3350	2350	2350	3350
Fertilizer	9320	25754	13987	9175	11560	11119	11883	14710	13683
Irrigation	0	3529	14820	1544	1235	12350	2470	2744	15438
Herbicides	425	375	510	618	278	494	278	278	278
Insecticides	0	1323	1112	1853	494	741	1853	3088	2470
Imputed cost (B)	16628	21223	25060	37476	27910	39115	24434	31750	35316
Seedbed	1846	2205	2080	2470	2470	2470	2470	2470	1853
Family labor	0	0	0	20264	6572	13692	7120	10406	10406
Land rent	14269	18269	22269	14269	18269	22269	14269	18269	22269
IOC at 4% for 5 months	513	749	711	473	599	684	575	605	788
Total cost (A+B)	78248	111162	110436	94255	99793	121179	93456	104405	129816
Gross return (Tk/ha)	89793	107960	117227	94325	92619	123799	89612	94510	123198
Net return (Tk/ha)	14353	21457	13836	3388	6783	12750	3609	2902	15329
BCR (Cash cost)	1.53	1.55	1.38	1.41	1.51	1.45	1.61	1.54	1.72
BCR (Full cost)	1.19	1.25	1.13	1.04	1.08	1.11	1.04	1.03	1.14

Source: Authors' estimation based on field survey, 2019-2021.

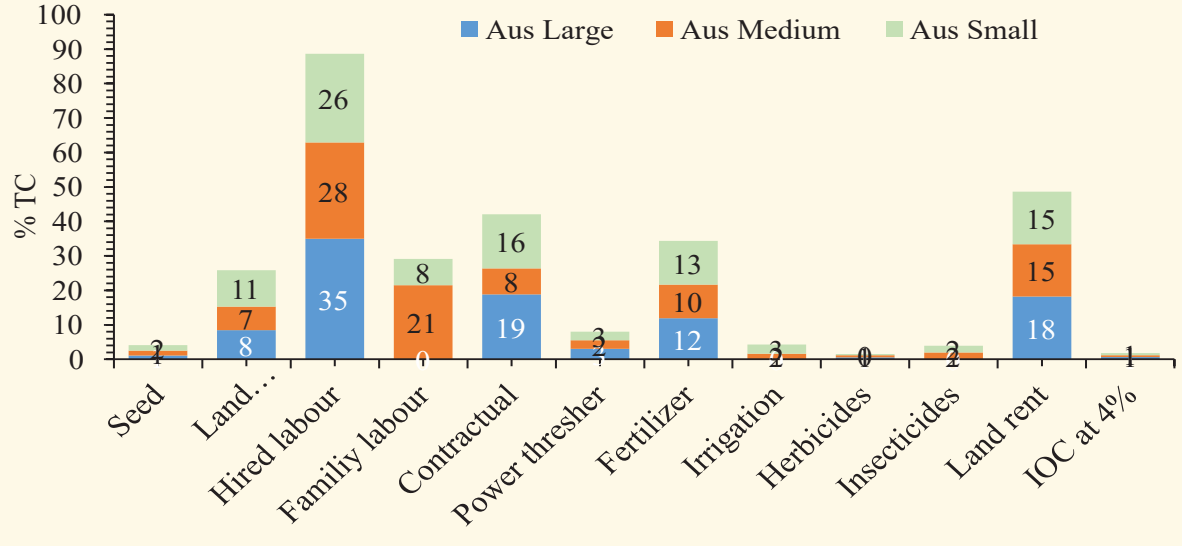


Figure 10.23: Share of per hectare inputs cost to total cost of *T. Aus* cultivation in salinity ecosystem

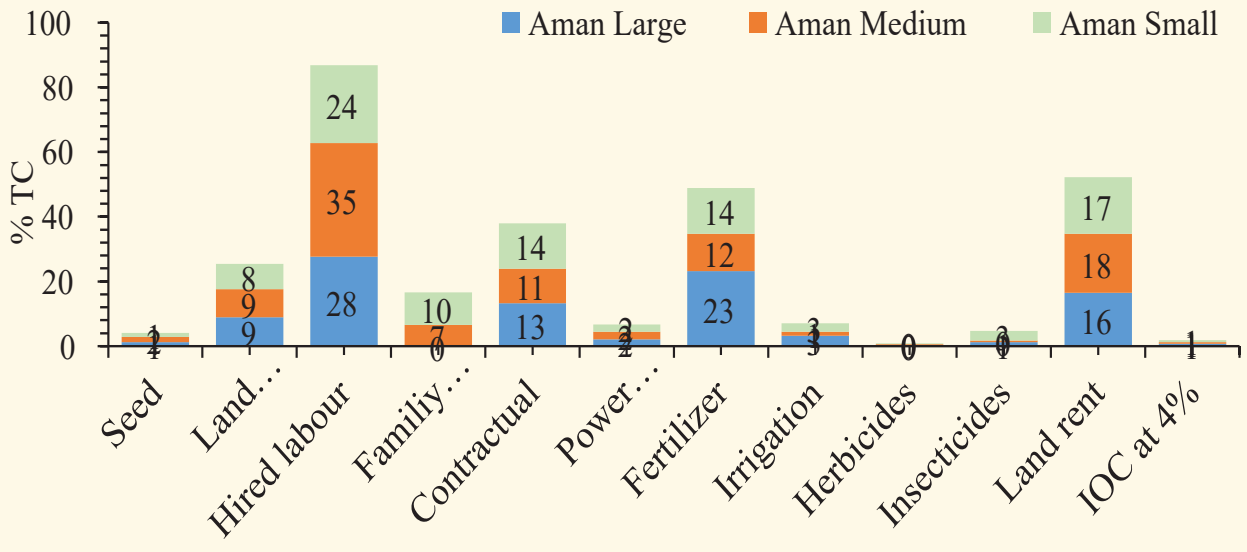


Figure 10.24: Share of per hectare inputs cost to total cost of *T. Aman* cultivation in salinity ecosystem

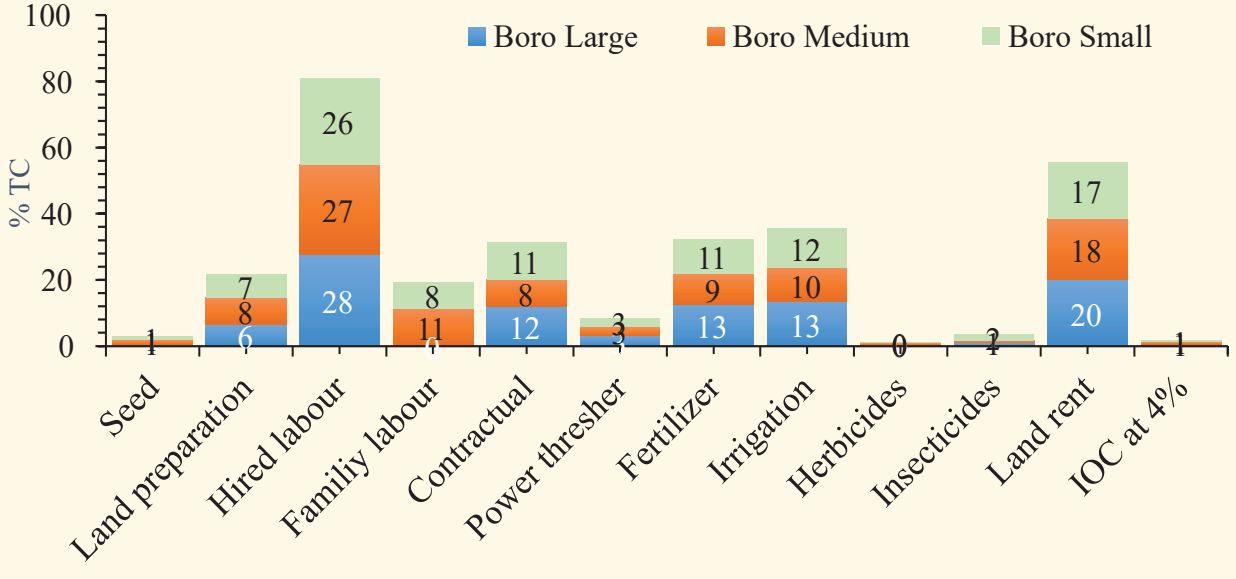


Figure 10.25: Share of per hectare inputs cost to total cost of *Boro* cultivation in salinity ecosystem

10.3.3 Risk analysis of rice production in salinity ecosystem

Following the similar procedure mentioned in favorable ecosystems, stochastic budgets were constructed for seasonal rice cultivation considering farmers' perceived variation in yield and market price for large, medium and small farmers. In constructing the stochastic, production cost and profitability of salinity ecosystem was taken into risk analysis (table 10.9). Stochastic budgets were constructed for seasonal rice cultivation considering farmers' perceived variation in yield and market price by different farm types. In this analysis, triangular distribution was constructed by different levels of worst, typical/average, and best yields and price for large farmer, medium farmer and small farmer. The stochastic budget analysis for salinity ecosystem can be viewed in table 10.9 displaying that seasonal rice cultivation was economically viable at the reported price and average

yields. It was found that farmers constantly suffer from negative net-income in the worst case caused by abiotic stress (unpredictive climatic factor such as erratic temperature, rainfall, salinity and water logging) (Figure 10.26-10.28). It is encouraged that rice production in all seasons for large, medium and small farmers was found profitable in the farmers' perceived typical and best case than that in worse case (Table 10.9).

Table 10.9 Stochastic budgeting of rice production by farm types in salinity ecosystem

Items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Yield (ton per ha)									
Worse case	2.54	3.085	3.805	2.61	3.27	4.885	2.505	2.73	4.1
Typical case	4.145	4.51	6.95	4.14	5.165	7.05	4.22	5.465	6.465
Best case	5.585	6.62	8.39	6.475	6.025	9.265	5.365	7.185	8.695
Straw (Tk per ha)									
Worse case	6736	6362	11227	13473	9731	4491	8233	6362	7111
Typical case	16841	22455	16841	20584	22530	14970	11228	20583	16841
Best case	28068	41167	24326	26946	31811	16841	20584	29940	20584
Price (Tk per ton)									
Worse case	11250	16000	15000	12250	13750	13750	15625	13750	15625
Typical case	24482	29252	22868	24364	23223	20809	24015	21263	23748
Best case	28500	30000	27250	25625	27500	25714.5	27500	25000	27500
Paid out cost (Tk per ha) (A)	61620	89939	85376	56779	71883	82064	69022	72655	94500
Imputed cost (Tk per ha) (B)	16628	21223	25060	37476	27910	39115	24434	31750	35316
Total cost (Tk per ha) (A+B)	78248	111162	110436	94255	99793	121179	93456	104405	129816
Net return (Tk per ha)									
Worse case	-42937	-55440	-42134	-48810	-45100	-49520	-46082	-60506	-58643
Typical case	40070	43219	65338	27194	42682	40494	19117	32380	40555
Best case	108993	128605	142518	98612	97705	133907	74665	105160	129880

Source: Authors' estimation based on field survey, 2019-2021.

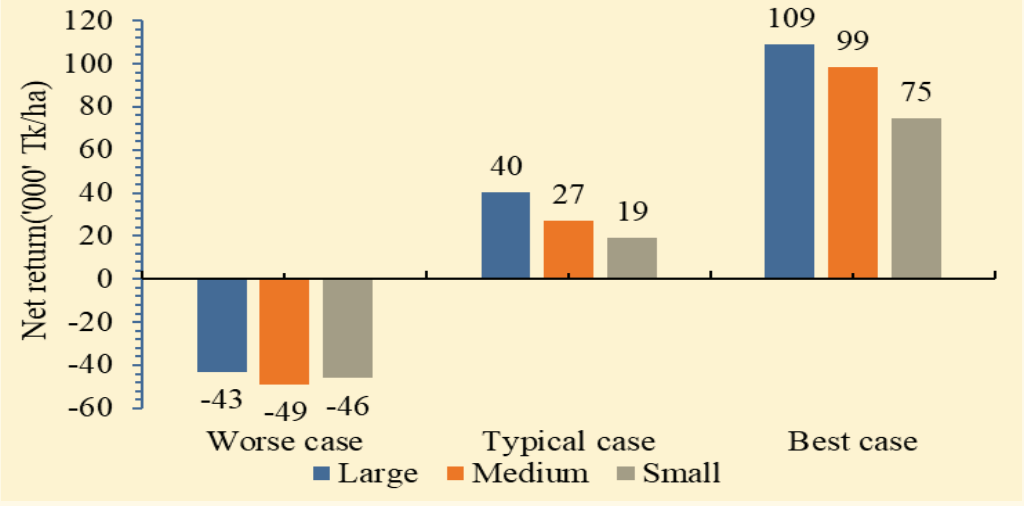


Figure 10.26: Farm types and case wise comparison in net-income (Tk per ha) for *T. Aus* in salinity ecosystem

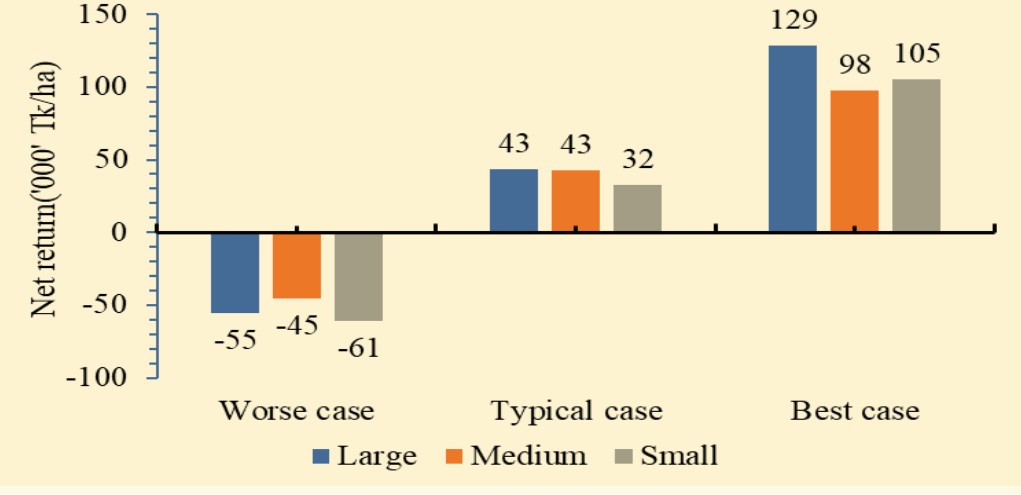


Figure 10.27: Farm types and case wise comparison in net-income (Tk per ha) for *T. Aman* in salinity ecosystem

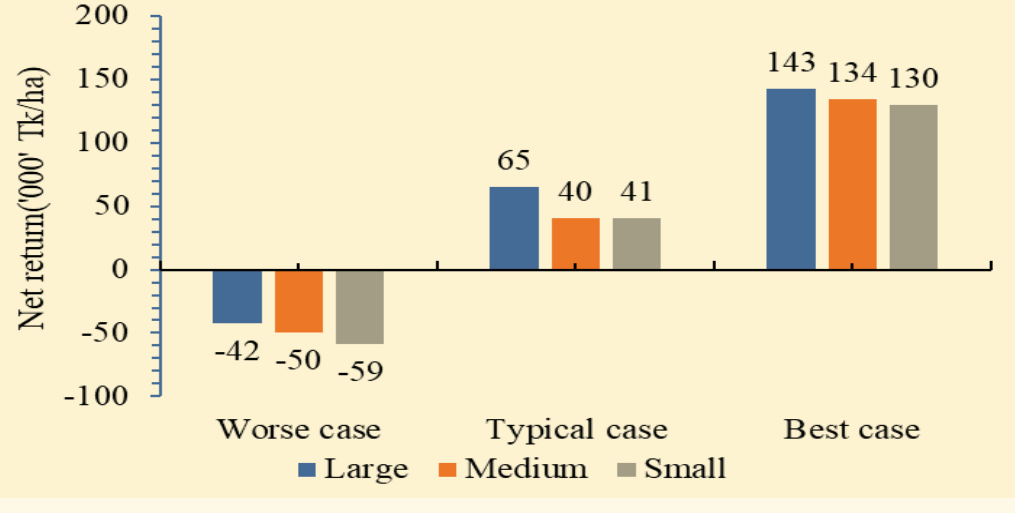


Figure 10.28: Farm types and case wise comparison in net-income (Tk per ha) for *Boro* in salinity ecosystem

The lower benchmark (Tk. 16000) was selected based on total imputed cost per ha in *T. Aus* rice production of large farmer, while the upper benchmark (Tk. 72000) was chosen randomly. The propensity of getting NI per ha from *T. Aus* showed that large farmer had about 66% chance of getting NI per ha above the lower benchmark total imputed cost per ha in *T. Aus* rice production, meaning it could cover the cost of owned resources including family labour in *T. Aus*. The chance of receiving NI per ha above this threshold decreased to 51% for medium farmer and 38% for small farmer (Figure 10.29(a)). The lower benchmark (Tk. 61000) was selected based on total paid out cost for medium farmer, while the upper benchmark (Tk. 140000) was chosen randomly. The probability of getting GR per ha from *T. Aus* showed that small farmer had about 99% chance of getting GR per ha above the lower benchmark paid out cost in *T. Aus* rice production meaning it could cover the cost of all cash costs. The chance of receiving GR per ha above this threshold slightly decreased to 93% for large farmers followed by medium farmers (90%) (Figure10.29(b)).

The lower benchmark (Tk. 21000) was selected based on total imputed cost per ha of *T. Aman* cultivation for large farmers (large farmer), while the upper benchmark (Tk. 70000) was chosen randomly. The probability of getting net-income (NI) per ha from *T. Aman* showed that both large and medium farmers had almost same chances (58%) of getting NI per ha above the lower benchmark of total imputed cost per ha in *T. Aman*, denoting that the probability to recover the cost of home supply resources including family labour. The likelihood of receiving NI per ha from *T. Aman* above this threshold decreased to 43% for small farmers (Figure 10.30(a)). The lower benchmark (Tk. 89000) was selected based on the paid-out costs (total paid out cost per ha) in *T. Aman* cultivation by medium farmer, while the upper benchmark (Tk. 160000) was chosen randomly. The probability of getting gross income (GR) per ha from *T. Aman* showed that medium farmer had about 95% chance of GR per ha above the lower benchmark meaning it could cover the cost of all cash costs of *T. Aman* rice production. The chance of receiving GR per ha from *T. Aman* above this threshold decreased to 75% for large farmer and 88% for small farmer (Figure 10.30(b)). However, chance of probability of getting NI above lower benchmark total imputed cost in *T. Aman* rice cultivation become highly negative for medium and small farmers in *T. Aman* compared to that for large farmer (43%).

The lower benchmark (Tk. 25000) was selected based on total imputed cost per ha in *Boro* rice production of large farmer, while the upper benchmark (Tk. 140000) was chosen randomly. The probability of getting NI per ha from *Boro* showed that large farmer had about 73% chance of getting NI per ha above the lower benchmark TIP per ha in *Boro* rice production, meaning it could cover the cost of owned resources including family labour. The chance of receiving NI per ha above this threshold decreased to 61% for medium farmer followed by that for small farmer (58%) (Figure 10.31(a)). The lower benchmark (Tk. 82000) was selected based on the total paid out cost per ha for medium farmer, while the upper benchmark (Tk. 200000) was chosen randomly. The probability of getting GR per ha from *Boro* showed that all farms had same changes of getting GR per ha (95%) above the lower benchmark total paid out cost per ha in *Boro* rice production, respectively, meaning that it could cover the cost of all cash costs in *Boro* rice production (Figure 10.31(b)). The risk of getting NI per ha in all rice growing appeared to be higher compared to that of getting gross income.

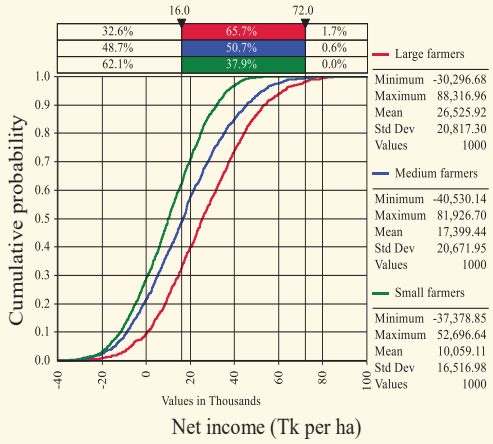


Figure 10.29(a): Cumulative probability of net-income (Tk per ha) of *T. Aus* rice cultivation in salinity ecosystem

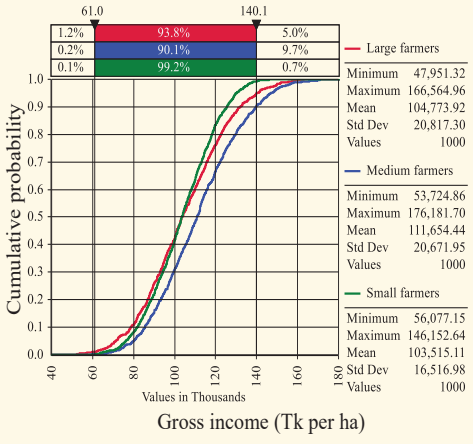


Figure 10.29(b): Cumulative probability of gross income (Tk per ha) of *T. Aus* rice cultivation in salinity ecosystem

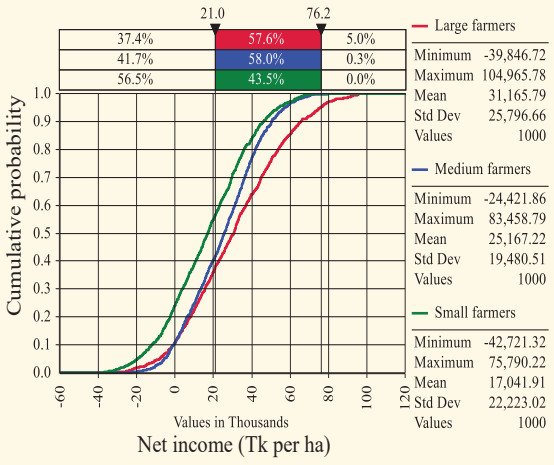


Figure 10.30(a): Cumulative probability of net-income (Tk per ha) of *T. Aman* rice cultivation in salinity ecosystem

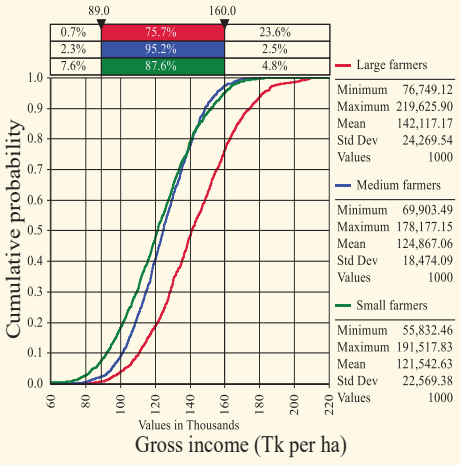


Figure 10.30(b): Cumulative probability of gross income (Tk per ha) of *T. Aman* rice cultivation in salinity ecosystem

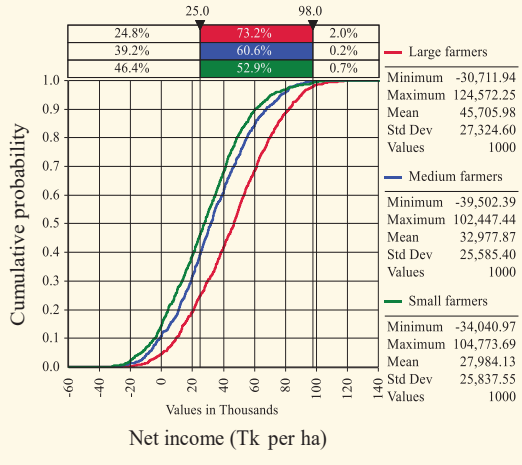


Figure 10.31(a): Cumulative probability of net-income (Tk per ha) of *Boro* rice cultivation in salinity ecosystem

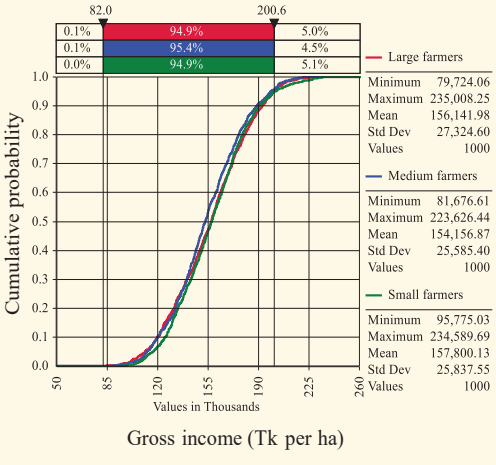


Figure 10.31(b): Cumulative probability of gross income (Tk per ha) of *Boro* rice cultivation in salinity ecosystem

The outcome of ecosystem wise environment and market risk is major risk on the gross return (GR) and net-income (NI) of seasonal rice cultivation. Taking this risk into consideration, the assessment of the economic viability was made based on farmers' perceived variation in yield and market price (lower/worse, moderate/average/typical and best case). The result revealed that variability in the yield of rice and straw value in the salinity ecosystem had influence on profitability of rice production with current market price. Figure 10.32 showed that, with all variables being constant other than yield, straw value and price, rice yield and straw value contributed together by more than 60% to the risk occurrence in getting NI per ha above benchmark total imputed cost cost in all season. large farmer experienced higher risk of price variation (40%) on NI in both by *T. Aman* followed by medium farmer in *Boro* rice production. However, the risk of marker price volatility of rice was found relatively lower than the combined effect of yield and straw value. The risk occurred in getting the NI per ha above benchmark cost of owned resources from yield and straw value was higher for small farmer than that for both large farmer and medium farmer. Similar pattern of risk (65% arose from yield and straw value) was observed in getting GR per ha above benchmark cash cost for all farm types across the seasons. The analysis revealed that the rice production was economically viable at current price and average seasonal yields, but yield and price have outmost effect on the profitability of the rice cultivation seriously which was aroused from adverse weather and market distortion in salinity ecosystem (Figure 10.33).

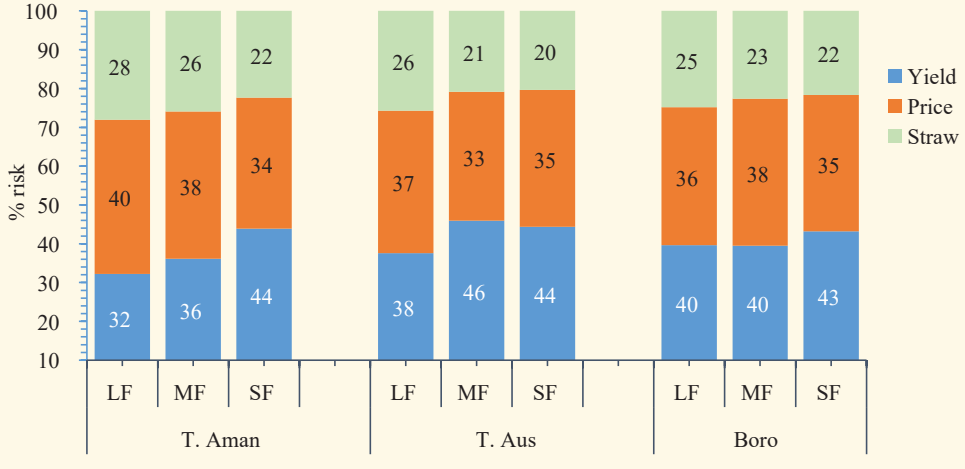


Figure 10.32: Inputs' effect ranked on NI for *T. Aman*, *T. Aus* and *Boro* rice in salinity ecosystem

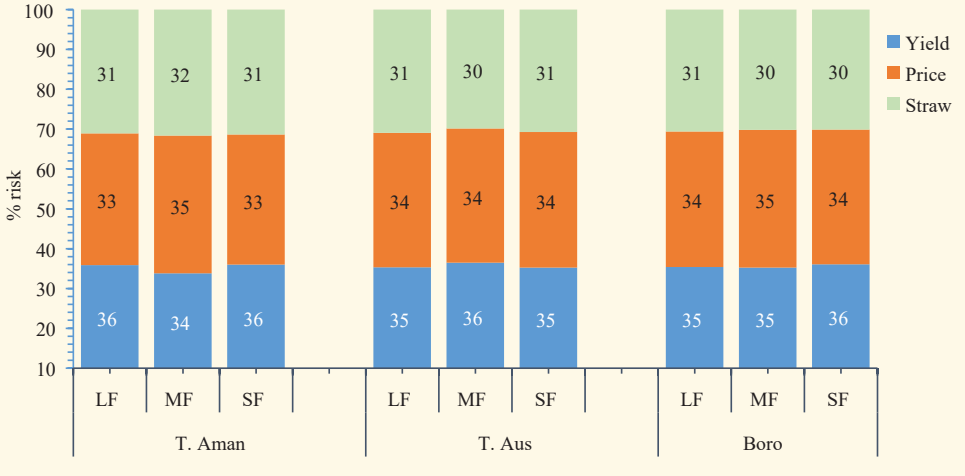


Figure 10.33: Inputs' effect ranked on GR for *T. Aman*, *T. Aus* and *Boro* rice in salinity ecosystem

10.4 Financial and risk analysis of rice production in drought ecosystem

Representative farm budgets for seasonal rice production were computed with the market prices in 2020 for the average/moderate/typical value of all farm categories. Based on average value from sample survey, was estimated and cross checked with focus group discussion (FGD) as well as key informant survey (KIS). Representative farm budget, variation in both yield and price under weather and market variability were finally developed.

10.4.1 Input use pattern and productivity of rice in drought ecosystem

The pattern of inputs use in seasonal rice cultivation by three farm types in drought ecosystem can be viewed in table 10.10. In some cases, magnitude of inputs use seems to be same for large farmer, medium farmer and small farmer in *T. Aman* and *T. Aus* and *Boro* season. Contractual costs of small farmer were lower than that of medium farmer and large farmer in all rice growing season. Seed rate was not quite higher than recommended rate among the different farmers' categories.

Large, medium and small farmer used same amount of urea (175 kg/ha) in *T. Aman* rice growing season which was quite same as recommended dose. In case of *Boro* season, large farmer applied about 77 kg/ha more urea, while medium farmer and small farmer applied 63 kg/ha and 40 kg/ha urea, respectively than the moderate recommended dose (185 kg/ha). In addition, large, medium and small farmer applied more TSP and MOP than the recommended rate. Large farmer usually avoids to apply DAP, Gypsum, Zinc and theovit in *T. Aus* and *Boro* but they were found to apply considerable dose in *T. Aman*. Average yield of large farmer (7.38 t/ha) in *Boro* season is considerably higher than medium farmer (6.78 t/ha) and small farmer (5.99 t/ha). In *T. Aman*, yield performance of small farmer was (5.69 t/ha) higher compared to medium (5.39 t/ha) and small (4.94 t/ha). Average yield of small farmer (4.84 t/ha) was higher than medium farmer (4.07t/ha) and large farmer (4.34 t/ha) in *T. Aus* rice growing season in drought ecosystem.

Table 10.10: Input use pattern, productivity and price of seasonal rice in drought ecosystem

Input items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Seed (kg/ha)	39	31.5	31	37	37	33	37	37	37
Land preparation	6830	7485	7523	6737	7485	6362	6362	6362	6362
Human labor (man-days/ha)									
Hired	63.5	73	59.5	71	70	86.5	41	47.5	41
Family	17	14	13.5	18.5	18.5	26	34.5	26	33.5
Contractual	16271.5	16446.5	18338	16811	14891.5	13206	11822.5	9726.5	13982
Fertilizer (kg/ha)									
Urea	131.5	175	262	125	175	248.5	122	175	225
TSP	73.5	97.5	130.5	75	112.5	150	112.5	112.5	112.5
MOP	84.5	98.5	111.5	112	93.5	93.5	93.5	112.5	75
DAP	17	131	24.5	93.5	75	93.5	93.5	75	112.5

Input items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Gypsum	0	75	75	56	56	75	37	75	75
Sulpher	0	11	36	26	40.5	7	22	7	41
Zinc	1	11	7	7	7	7	7	7	7
Mg	1	0	3	3.5	3.5	8.5	8.5	11	8
Theovit	1	5.5	3	7	7	8.5	8.5	7	7
Irrigation	1497	3009	12451	5884	2620	14970	2245	2985	14970
Herbicides	2	456	741	681	356	373	397	1048	373
Insecticides	1530	2233	2111	936	1123	1127	1310	2433	1310
Yield (ton/ha)	4.34	4.94	7.38	4.075	5.39	6.78	4.84	5.69	5.99
Straw (Tk/ha)	4342.5	9485	5616	10356	10606	4492.5	7736.5	12727.5	6863.5

Source: Authors' estimation based on field survey, 2019-2021.

10.4.2 Scenario of cost and profit of rice production in drought ecosystem

Data in table 10.11 show that per ha total cost of medium farmer was higher by Tk. 10937 and Tk. 14835 compared to large and small farmer, respectively in *Boro* season due to differences in the man-days of hired labor and irrigation costs. Per ha total cost of *T. Aman* season was relatively higher for medium farmer than that for large farmer by Tk. 1473 and for small farmer by Tk.9184, because of differences in the man days of hired labor, contractual cost and fertilizers application. In addition, per ha total cost of *T. Aus* season was relatively higher for medium farmer than that for large farmer by Tk. 18131 and for small farmer by Tk.12743 due to differences in family labor and fertilizer application. It is important to mention that wages and market price of input did not vary across the season among farmer's categories.

The actual total paid out cost usually includes seed, land preparation, hired labor, fertilizers, herbicides, insecticides, and power thresher which were the major items for large, medium and small farmer, respectively standing for 72%, 71% and 65% of total cost in *T. Aman* season. On the contrary, the total imputed cost which includes land rent and family labor was 34%, 27% and 28% of total cost for small, large and medium farmer, respectively in *T. Aman* growing season. The total paid out cost of medium farmer in *T. Aus* was 73% of total cost and 63-70% of total cost for medium and small farmer. The total imputed cost of medium and large farmer was 25-30% of total cost and 36% of total cost for small farmer. Similarly, the total paid out cost in *Boro* season showed 73% of total cost for large farmer and decreased to 71% for medium farmer and 65% for small farmer, respectively. In *Boro* season, the imputed cost was 34%, 26% and 28% of total cost for small, large and medium farmer, respectively. The BCR found more than one on cash cost and full cost basis in all rice season and the positive net return denoting that return outyielded total investment in rice production (Table 10.11).

Table 10.11: Production cost and return in rice production in different seasons in drought ecosystem

Cost and income	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
(Tk/ha)	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Paid out cost (A)	60979	77547	87060	77679	76881	92539	58334	65076	74591
Seed	1681	1350	1322	1601	1601	1415	1601	1601	1601
Land preparation	6830	7485	7523	6737	7485	6362	6362	6362	6362
Hired labour	25646	30577	23453	29021	28965	34685	15827	18097	15827
Contractual	16272	14272	18338	16811	14892	13206	14653	14653	14653
Power thresher	1500	4907	7674	4304	6550	4865	3368	4114	4117
Fertilizer	6023	13260	13448	11705	13291	15537	12571	13785	15379
Irrigation	1497	3009	12451	5884	2620	14970	2245	2985	14970
Herbicides	2	456	741	681	356	373	397	1048	373
Insecticides	1530	2233	2111	936	1123	1127	1310	2433	1310
Imputed cost (B)	26027	28787	30785	27459	30926	36243	34061	33546	39356
Seedbed	1846	2257	2264	2245	2245	2358	2245	2245	2245
Family labour	7126	5863	5420	8019	8019	10738	14782	10738	14113
Land rent	16548	20021	22376	16548	20021	22376	16548	20021	22376
IOC at 4% for 5 month	508	646	725	647	641	771	486	542	622
Total cost (A+B)	87006	106333	117844	105137	107806	128781	92394	98622	113946
Gross return (Tk/ha)	103778.5	117641	168885.5	109415	130513.5	173964.5	114193.5	126497	141591
Net return (Tk/ ha)	16771	9131	51040.5	4277.5	22707	45183	21742.5	27405.5	27601
BCR (Cash cost)	1.7	1.515	1.945	1.405	1.69	1.88	1.755	1.93	1.77
BCR (Full cost)	1.19	1.08	1.435	1.04	1.205	1.345	1.235	1.295	1.24

Source: Authors' estimation based on field survey, 2019-2021.

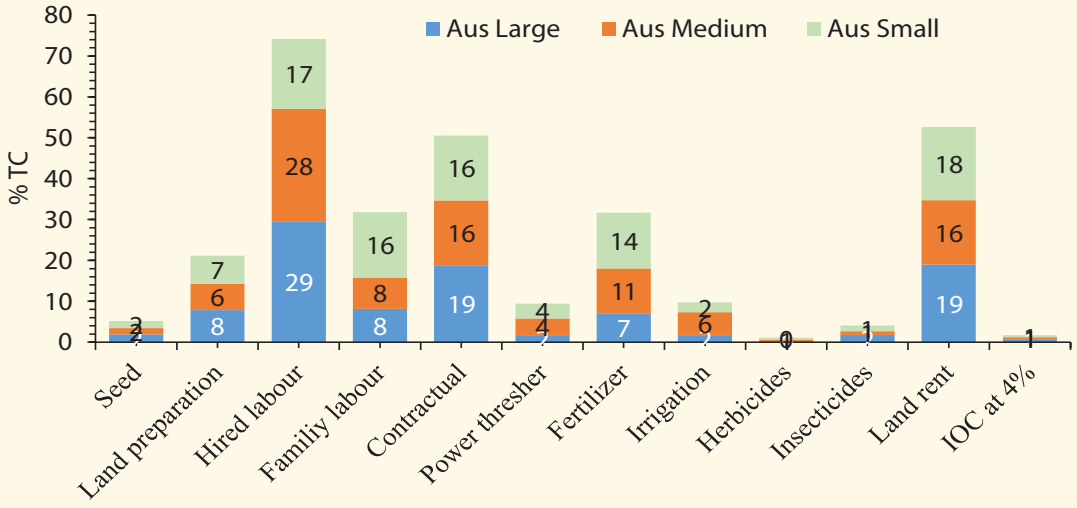


Figure 10.34: Share of per hectare inputs cost to total cost of *T. Aus* cultivation in drought ecosystem

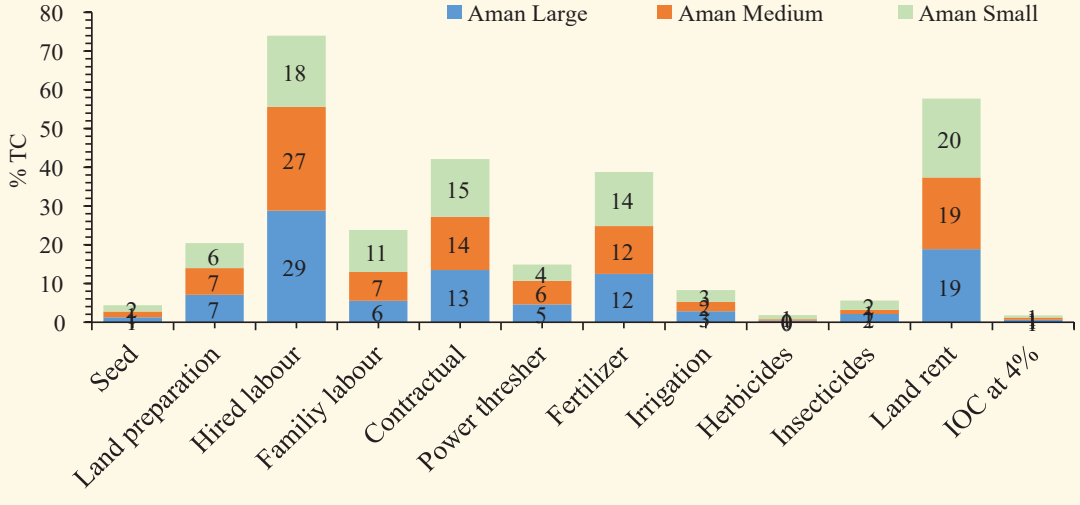


Figure 10.35: Share of per hectare inputs cost to total cost of *T. Aman* cultivation in drought ecosystem

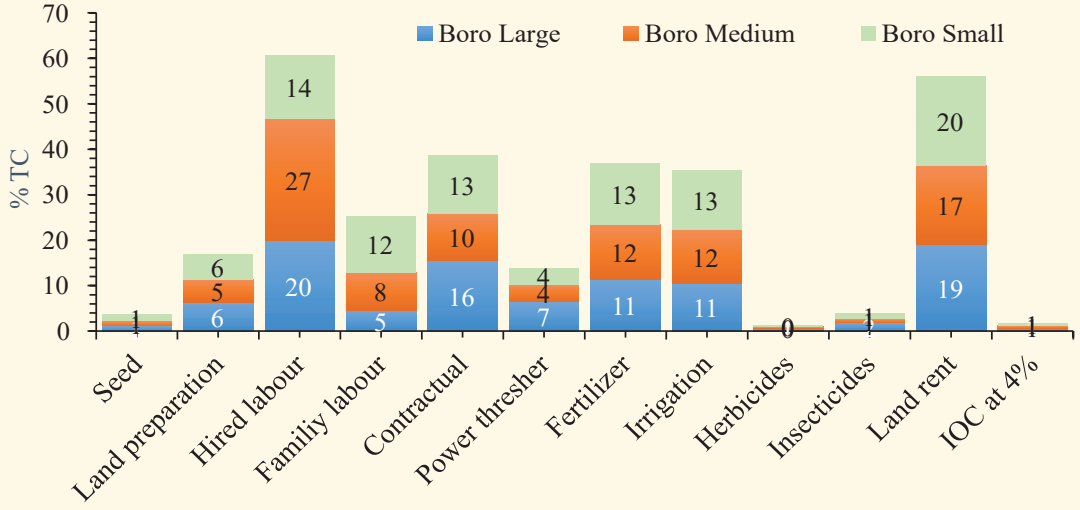


Figure 10.36: Share of per hectare inputs cost to total cost of *Boro* cultivation in drought ecosystem

10.4.3 Risk analysis of rice production under drought ecosystem

In assessing economic viability of rice cultivation at the reported market price, the result revealed that variability of yield of rice and straw value in the drought on farm profit was synthesized based on the households' survey and key informants survey.

The average/moderate/typical value of rice yield, straw value, inputs use and market price of rice from household survey were crosschecked with the key informant survey so as to get more realistic data. The gross return (GR) of rice was computed by multiplying rice yields by the reported price (Table 10.12). Farmers sold their produces at a higher price than in the worst case. In constructing the stochastic, production cost and profitability of drought ecosystem was taken into risk analysis (table 10.12). Stochastic budgets were constructed for seasonal rice cultivation considering farmers' perceived variation in yield and market price by different farm types. The stochastic budget analysis displayed that seasonal rice cultivation was economically viable at the reported average/typical price and yields. In this analysis, triangular distribution was constructed by different levels of worst, typical/average, and best yields straw value and price for different farm types. Figure 10.37-10.39 showed that rice production in all seasons for large, medium and small farmers was found to be more profitable in the farmers' perceived typical and best case than average and worse case. However, farmers always suffer from negative net-income in the worst case caused by weather stress (unpredictive climatic factor such as erratic temperature, rainfall and drought).

Table 10.12: Stochastic budgeting of rice production by farm types in drought ecosystem

Items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Yield (ton per ha)									
Worse case	2.99	3.43	4.03	2.55	2.98	4.77	2.99	3.74	4.21
Typical case	4.34	4.94	7.38	4.08	5.39	6.78	4.84	5.69	5.99
Best case	5.54	6.67	10.16	5.99	7.33	9.92	5.69	6.74	9.98
Straw (Tk per ha)									
Worse case	1897	6614	3120	4243	6114	2171	4243	4242.5	3494
Typical case	4342.5	9485	5616	10356	10606	4493	7737	12728	6864
Best case	5241	16599	7488	12478	12728	10356	8985	16969.5	12728
Price (Tk per ton)									
Worse case	13125	18125	18500	15625	15000	15000	16250	13750	15000
Typical case	22875	21875	22125	24375	22250	25000	22000	20000	22500
Best case	26875	28125	26250	26250	26250	28750	25500	25000	27500
Paid out cost (Tk per ha) (A)	60979	77547	87060	77679	76881	92539	58334	65076	74591
Imputed cost (Tk per ha) (B)	26027	28787	30785	27459	30926	36243	34061	33546	39356
Total cost (Tk per ha) (A+B)	87006	106333	117844	105137	107806	128781	92394	98622	113946
Net return (Tk per ha)									
Worse case	-45865	-37551	-40170	-61129	-57068	-55135	-39564	-42954	-47302
Typical case	16614	11214	51054	4547	22727	45211	21822	27906	27692
Best case	67122	97718	156344	64578	97334	166631	61686	86723	173231

Source: Authors' estimation based on field survey, 2019-2021.

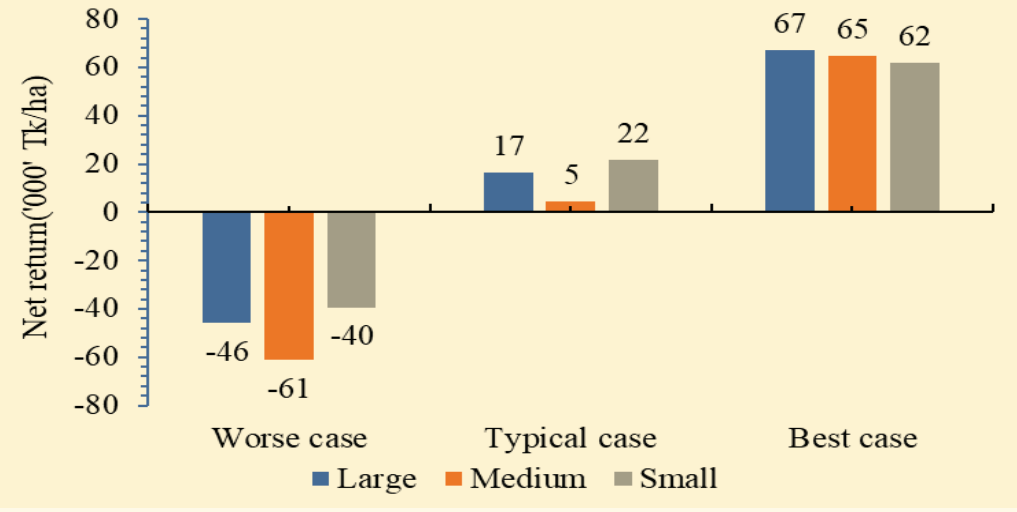


Figure 10.37: Farm types and case wise comparison in net-income (Tk per ha) for for *T. Aus* in drought ecosystem

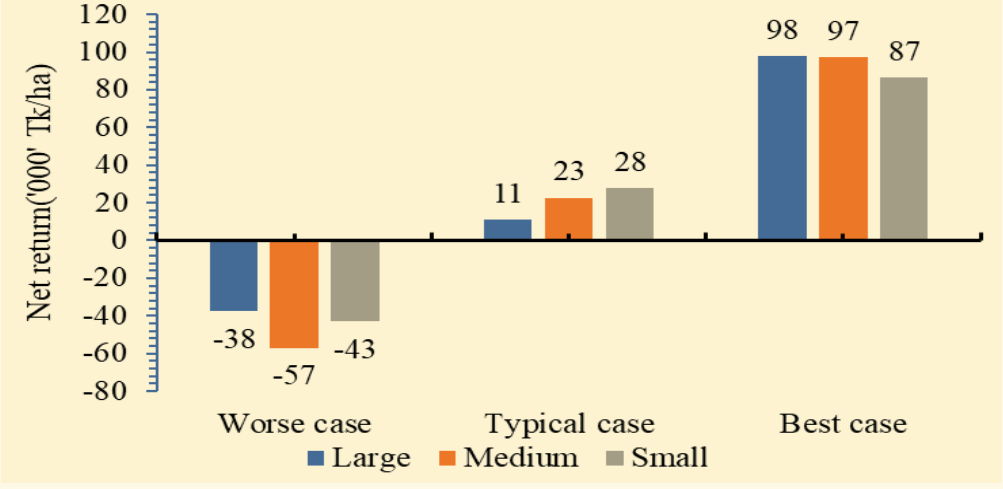


Figure 10.38: Farm types and case wise comparison in net-income (Tk per ha) for for *T. Aman* in drought ecosystem

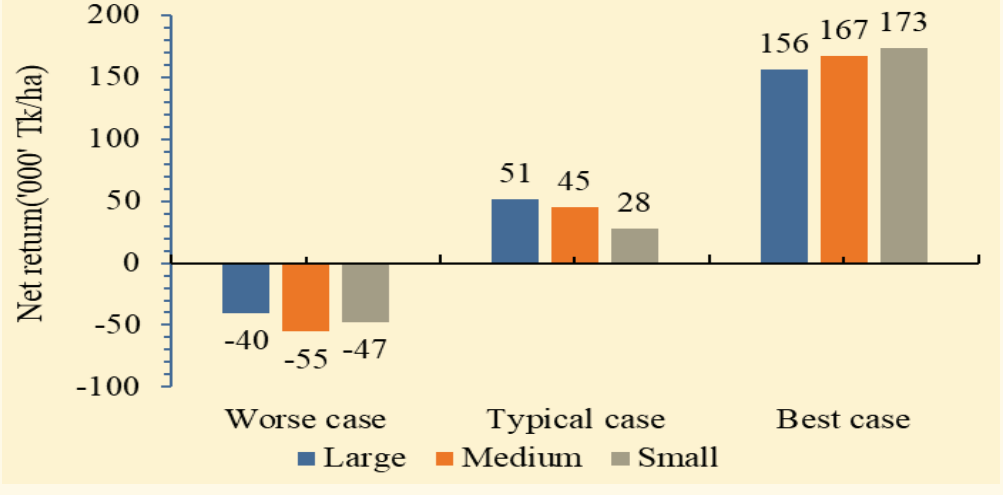


Figure 10.39: Farm types and case wise comparison in net-income (Tk per ha) for *Boro* in drought ecosystem

The lower benchmark (Tk. 26000) was selected based on total imputed cost per ha of *T. Aus* for large farmer, while the upper benchmark (Tk. 52000) was chosen randomly. The probability of getting NI per ha from *T. Aus* showed that small farmer had about 17% chance of getting NI per ha above the lower benchmark cost in *T. Aus*, denoting that the probability to recover the cost of owned resources including use of family labour in *T. Aman*. The chance of receiving NI per ha above this threshold decreased to 13% for large farmer and 7% for medium farmer (Figure 10.40(a)). The risk of obtaining net-income (NI) per ha in *T. Aus* above the lower benchmark total imputed cost per ha in *T. Aus* appeared to be higher for all categories of farmers.

The lower benchmark (Tk. 58000) was selected based on the paid-out costs (total paid out cost per ha) for medium farmer, while the upper benchmark (Tk. 120000) was chosen randomly. The CDF of GR per ha from *T. Aus* showed that large farmer and small farmer had about 100 and 92% chance of GR per ha above the lower benchmark, respectively meaning it could cover the cost of all cash costs. The chance of receiving GR per ha above this threshold decreased to 63% for medium farmer (Figure 10.40(b)). However, chance of probability of NI indicated the higher probability to become negative in *T. Aus*.

The lower benchmark (Tk. 28000) was selected based on total imputed cost per ha in *T. Aman* production for large farmers (large farmer), while the upper benchmark (Tk. 79000) was chosen randomly. The probability of getting NI per ha showed that small farmers (small farmer) had about 31% chance of getting NI per ha above the lower benchmark cost of total imputed cost in *T. Aman*, meaning it could cover the cost of owned resources including use of family labour in *T. Aman* rice production. The chance of receiving NI per ha above this threshold decreased to 29% for medium farmer and 25% for small farmer (Figure 10.41(a)). The lower benchmark (Tk. 65000) was selected based on the total paid out cost per ha in *T. Aman* for small farmer, while the upper benchmark of total paid out cost per ha (Tk. 15600) was chosen randomly. The likelihood of getting gross income showed that small farmer had about 99% chance of getting GR per ha in *T. Aman* production above the lower benchmark of total paid out cost per ha of *T. Aman,* meaning it could cover the cost of all cash costs of *T. Aman*. The chance of receiving GR per ha above this threshold slightly decreased to 95% for large farmer and 94% for medium farmer (Figure 10.41(b)).

The lower benchmark (Tk. 30000) was selected based on total imputed cost per ha in *Boro* rice production, while the upper benchmark total imputed cost per ha (Tk. 121000) was chosen randomly. The probability of obtaining NI per ha from *T. Aus* showed that large farmer had about 70% chance of getting NI per ha above the lower benchmark total imputed cost per ha in *Boro* rice production, meaning it could cover the cost of owned resources including use of family labour in *Boro* rice production. The chance of receiving NI per ha above this threshold decreased to 0.30% for medium farmer and 4.3% for small farmer (Figure 10.42 (a)). The lower benchmark (Tk. 74000) was selected based on total paid out cost per in *Boro* rice production for small farmer, while the upper benchmark (Tk. 203000) was chosen randomly. The probability of obtaining GR per ha from *Boro* showed that small farmer had about 93% chance of getting GR per ha above the lower benchmark total paid out cost of *Boro* rice production, meaning it could cover the cost of all cash costs of *Boro* rice production. The chance of receiving GR per ha above this threshold slightly decreased to 88% for large farmer and 83% chances for large farmer (Figure 10.42 (b)). It appeared that the likelihood of getting GR per ha above the threshold level always remained positive.

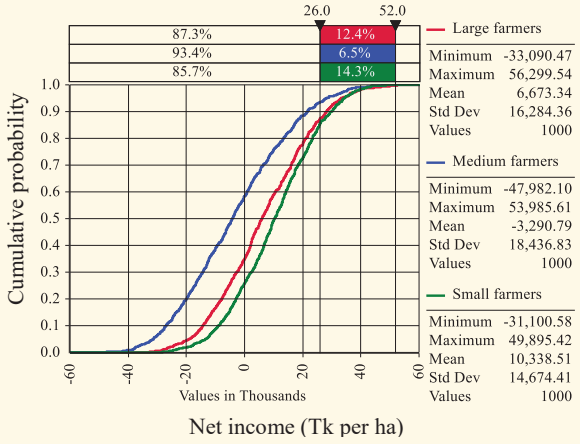


Figure 10.40(a): Cumulative probability of net-income (Tk per ha) of *T. Aus* rice cultivation in drought ecosystem

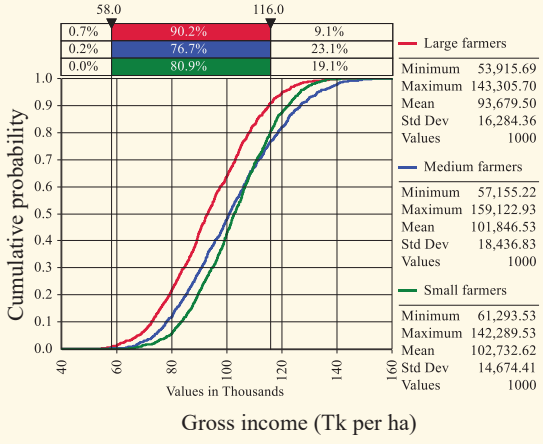


Figure 10.40(b): Cumulative probability of gross income (Tk per ha) of *T. Aus* rice cultivation in drought ecosystem

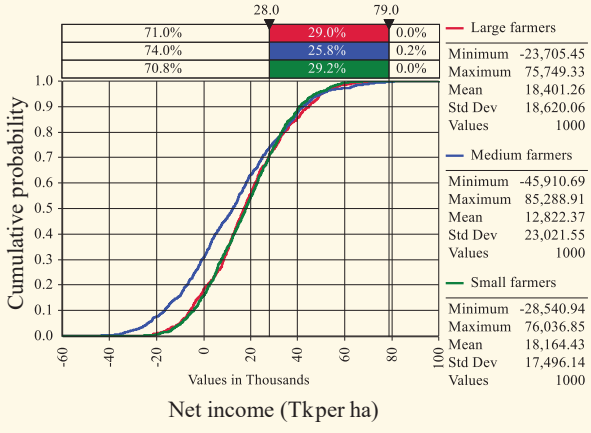


Figure 10.41(a): Cumulative probability of net-income (Tk per ha) of *T. Aman* rice cultivation in drought ecosystem

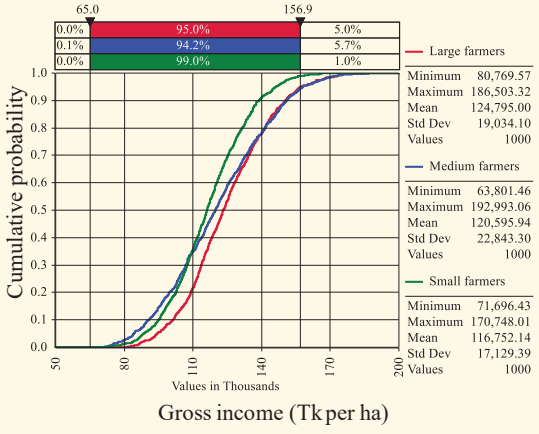


Figure 10.41 (b): Cumulative probability of gross income (Tk per ha) of *T. Aman* rice cultivation in drought ecosystem

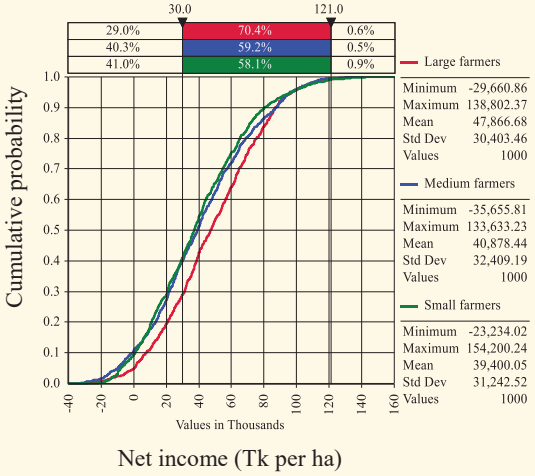


Figure 10.42(a): Cumulative probability of net-income (Tk per ha) of *Boro* rice cultivation in drought ecosystem

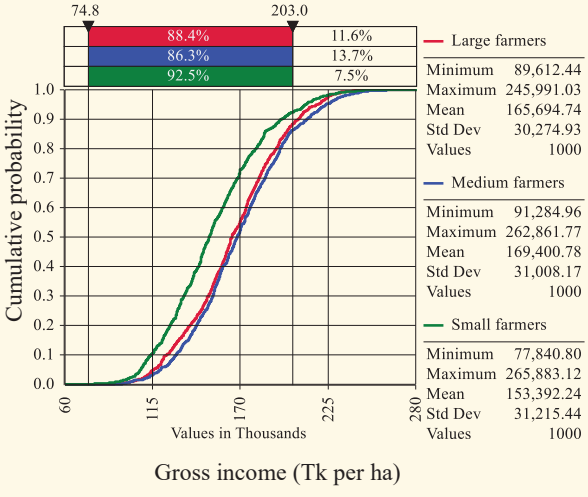


Figure 10.42(b): Cumulative probability of gross income (Tk per ha) of *Boro* rice cultivation in drought ecosystem

In assessing seasonal variation on economic viability of rice cultivation at current price, the result revealed that variability in the yield of seasonal rice and straw value in the drought ecosystem had influence on farm profit with the reported market price. Figure 10.43 showed that, with all variables being constant other than yield, straw value and price, rice yield and straw value contributed together to the risk occurrence ranging from 50 to 65% in getting NI per ha above benchmark total imputed cost cost in all season. large farmer experienced higher risk of price variation (43%) on NI in both by *T. Aman* followed by small farmer (37%) in *T. Aus* and medium farmer (35%) *in Boro* rice production. However, the risk of marker price volatility of rice was found relatively lower than the combined effect of yield and straw value in the rice production in all seasons. The risk occurred in getting the NI per ha above benchmark cost of owned resources from yield and straw value was higher for large farmer than that for both medium farmer and small farmer in drought ecosystem. Similar pattern of risk (65% arose from yield and straw value) was observed in getting GR per ha above benchmark cash cost for all farm types across the seasons. The analysis revealed that the rice production was economically viable at current price and average seasonal yields, but yield and price have outmost effect on the profitability of the rice cultivation which was aroused from drought occurrence and market distortion in drought ecosystem (Figure 10.44).

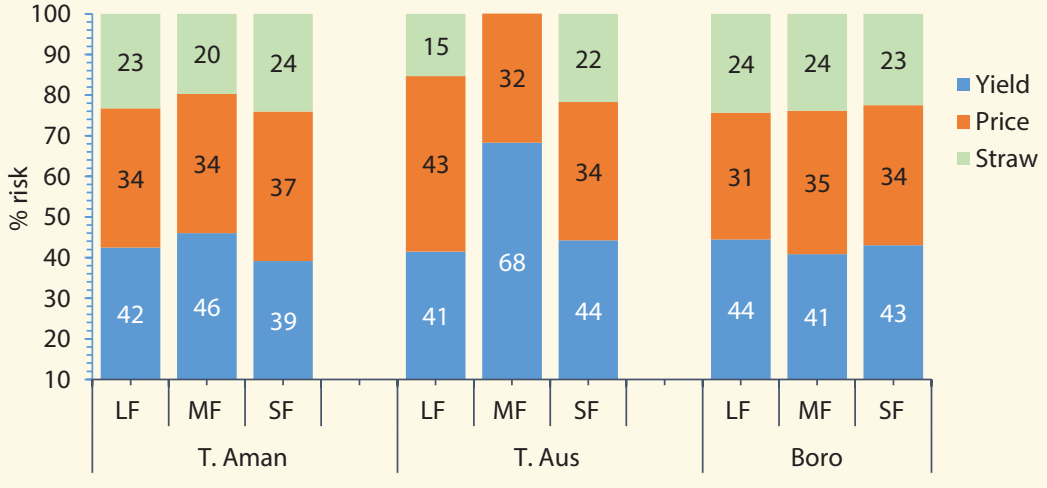


Figure 10.43: Inputs' effect ranked on NI for *T. Aman*, *T. Aus* and *Boro* rice in drought ecosystem

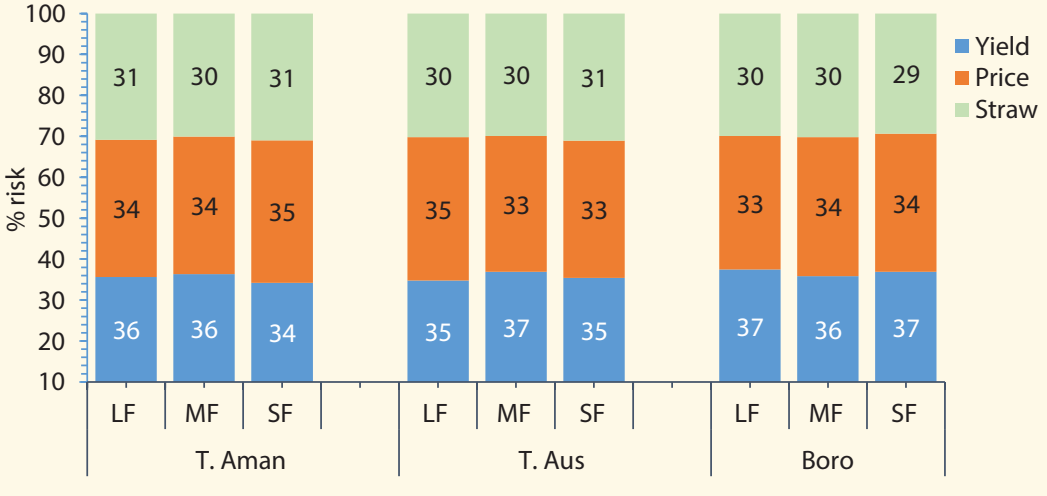


Figure 10.44: Inputs' effect ranked on GR for *T. Aman*, *T. Aus* and *Boro* rice in drought ecosystem

10.5 Financial and risk analysis of rice production in tidal submergence ecosystem

Representative farm budgets for seasonal rice production were computed with the market prices in 2020 for the average/moderate/typical value of all farm categories. Based on average value from sample survey, was estimated and cross checked with focus group discussion (FGD) as well as key informant survey (KIS). Representative farm budget, variation in both yield and price under weather and market variability were finally developed.

10.5.1 Input use pattern and productivity of rice in tidal submergence

Data in table 10.13 displayed the pattern of inputs use in seasonal rice cultivation by three farm types in tidal submergence ecosystem. Per hectare man-days used for rice cultivation varied widely among the seasons and farm types. In addition, the participation of family and hired labor among the farm types also differed in the different season. Most of the large farmer depended on hired labor such as 77% in *T. Aman* and 66% in *Boro* and 100 in *T. Aus*, respectively for intercultural and harvest operations, whereas small farmer used 35-45% family labor to carry out intercultural and post-harvest activities operation. All farm types used hired labor to carry out planting and harvesting which are usually labor-intensive operations. Contractual costs of large farmer were found higher than medium farmer and small farmer in *T. Aman* as well as *T. Aus* rice growing season. All farmers used HYV rice seed from market and most of them did not treat the rice seed to control diseases before sowing. The seeding rate used by all categories of farm was considerably higher than the recommended rate of 25-30 kg/ha (BRRI Adhunik Dhaner Chas 2020). In practice, 30-35 days old seedlings were used when transplanting *T. Aman* up to third weeks of August, *T. Aus* rice up to first week of June, *Boro* rice up to first week of January.

Large farmer and small farmer applied about 47% and 33% more dose of urea in *Boro* season than the recommended dose (185kg/ha) respectively, while medium farmer applied 33% less urea than recommendation (BRRI Adhunik Dhaner Chas 2020). Urea application for *T. Aman* and *T. Aus* season was also lower than recommended dose. In addition, all farmers applied TSP, MOP, Gypsum and other fertilizer (DAP, zinc and theovit) lower than the recommended dose in all rice growing seasons. It revealed that per hectare inputs use in *Boro* season was relatively higher among the seasons. Large farmers had given less emphasis on input use in *T. Aus* season compared to medium farmer and small farmer.

Per ha yield in three rice growing seasons and straw value for all farm types was also given in Table 10.13 under average case. The variation of yield and straw value were developed from FGD and KIS. Average value of yield (ton/ha) and straw value (Tk./ha) were calculated from sample survey as used for most likely/moderate value. Yield for small farmer (7.88t/ha) in *Boro* season is slightly higher than large farmer (7.42t/ha) and medium farmer (7.59t/ha). On the contrary, large farmer (4.99t/ha) also slightly outyielded than medium farmer and small farmer (4.94 t/ha), In *T. Aus* season, yield of medium farmer (4.74t/ha) is substantially higher than that for large farmer (3.63 t/ha) and small farmer (4.39 t/ha) (Table 10.13).

Table 10.13: Input use pattern, productivity and price of seasonal rice in tidal submergence ecosystem

Items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Seed (kg/ha)	22	30	37	40	37	37	41	37	37
Land preparation	6587	8982	7410	9880	6175	9880	8350	8645	8645
Human labour (man-days/ha)									
Hired	50	52	49	54	20	49	54	49	49
Family	0	15	25	32	37	23	29	37	37
Contractual (Tk/ha)	24700	25605	12350	13525	23712	24700	12350	12525	17964
Fertilizer use (kg/ha)									
Urea	150	160	272	120	160	124	100	160	247
TSP	50	150	86	62	99	137	165	62	124
MOP	75	112	124	99	99	99	82	99	124
DAP	0	62	49	64	25	49	62	82	62
Gypsum	0	112	25	82	88	49	82	82	49
Sulpher	0	37	0	0	0	0	0	8	1
Zinc	0	0	12	8	0	12	0	26	0
Theovit	0	7	0	0	7	1	1	8	2
Irrigation	5853	19748	13934	10454	11035	12505	11786	16683	14149
Herbicides	3705	2994	14820	2470	1235	7410	1705	6175	14820
Insecticides	0	0	741	445	882	741	412	371	222
Yield (ton/ha)	3.63	4.99	7.42	4.74	4.94	7.59	4.39	4.94	7.88
Straw (Tk/ha)	11227	18712	7485	11227	18712	7485	11227	18712	7485

Source: Authors' estimation based on field survey, 2019-2021.

10.5.2 Scenario of cost and return of rice production in tidal submergence ecosystem

Table 10.14 shows that per ha total cost of *Boro* rice was slightly higher for small farmer than that for large farmer (Tk. 9432/ha) and medium farmer (Tk. 12258/ha), respectively due mainly to differences in the man-days of family labor and fertilizers application. Per ha total cost of *T. Aman* season was relatively higher for large farmer compared to medium farmer (Tk. 19572/ha) and small farmer (Tk. 2361/ha) for the reasons of more man days of hired labour, contractual cost and fertilizers application. In addition, per ha total cost of *T. Aus* season was relatively higher for medium farmer compared to large farmer (Tk. 17015/ha) and small farmer (Tk. 3708/ha) due mainly to differences in the man days of hired labour, contractual cost and level of fertilizers application. It is important to mention that wages and market price of input did not vary across the season among farmers' categories.

Although the symmetry in total paid out cost exists in *T. Aman* among three farm types, only differences among the three farm categories had been appeared across the different input utilization costs. The actual total paid out cost includes seed, land preparation, hired labour, fertilizers, pesticides, herbicides and power thresher which were the major items for large farmer, medium farmer and small farmer, respectively standing for 63-71% of total cost in *T. Aman*. On the contrary, the imputed cost of land rent and family labor of small farmer and medium farmer showed 29% of total cost, and declined to 19% of total cost for large farmer (Figure 10.45). The total paid out cost of large farmer in *T. Aus* showed 79% of total cost, higher by 11% that that for medium farmer and small farmer (68% of total cost). Total imputed cost of land rent and family labor of small farmer and medium farmer showed 29% of total cost and declined to 17% of total cost for large farmer. Similarly, the total paid out cost of large farmer showed almost same (65-68%) of total cost for all and the total imputed cost imputed cost of land rent and family labour showed 30-32 % of total cost for large farmer, medium farmer and small farmer in *Boro* season. Benefit cost ratio (BCR) on cash and full cost basis showed more than one implying that rice production in three different seasons is economically profitable enterprises for all (Table 10.14).

Table 10.14:Production cost and return in rice production in different seasons in tidal submergence ecosystem

Cost items (Tk/ha)	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Paid out cost (A)	68454	87881	80433	69746	58029	84783	67471	74416	86978
Seed	945	1286	1590	1718	1590	1590	1761	1590	1590
Land preparation	6587	8982	7410	9880	6175	9880	8350	8645	8645
Hired labor	23576	24519	23104	25462	9430	23104	25462	23104	23104
Contractual	24700	25605	12350	13525	23712	24700	12350	12525	17964
Fertilizer	3088	4410	4631	4310	3705	4631	3175	3470	4631
Irrigation	5853	19748	13934	10454	11035	12505	11786	16683	14149
Herbicides	3705	2994	14820	2470	1235	7410	1705	6175	14820
Insecticides	0	0	741	445	882	741	412	371	222
Power thresher	0	337	1853	1482	265	222	2470	1853	1853
Imputed cost (B)	17298	24932	41274	33021	35212	39750	31588	36036	46987
Seedbed	1846	2245	3088	2470	2400	2470	2470	3088	3088
Family labor	0	7073	11788	15088	17446	10845	13674	17446	17446
Land rent	14882	14882	25728	14882	14882	25728	14882	14882	25728
IOC at 4% for 5months	570	732	670	581	484	707	562	620	725
Total cost (A+B)	85752	112813	121707	102767	93241	124533	99059	110452	133965
Gross return (Tk/ha)	98347	123502	155925	125045	122452	159218	116614	122452	165085
Net return (Tk/ha)	12595	10755	34219	22277	31587	34686	17554	12001	31121
BCR (Cash cost)	1.44	1.53	1.94	1.79	2.11	1.88	1.73	1.65	1.9
BCR (Full cost)	1.15	1.1	1.28	1.22	1.35	1.28	1.18	1.11	1.23

Source: Authors' estimation based on field survey, 2019-2021.

Even though rice production was loss concern in the several previous years due to low market price (BRRI annual report, 2018-19), market price of rice in 2020 and current situation is far more incentive for rice growers in all seasons. The BCR on cash cost basis in *Boro* season showed almost two due to high yield potential and fair market price. Moreover, the net return also showed positive meaning that net return outyield total investment in rice production.

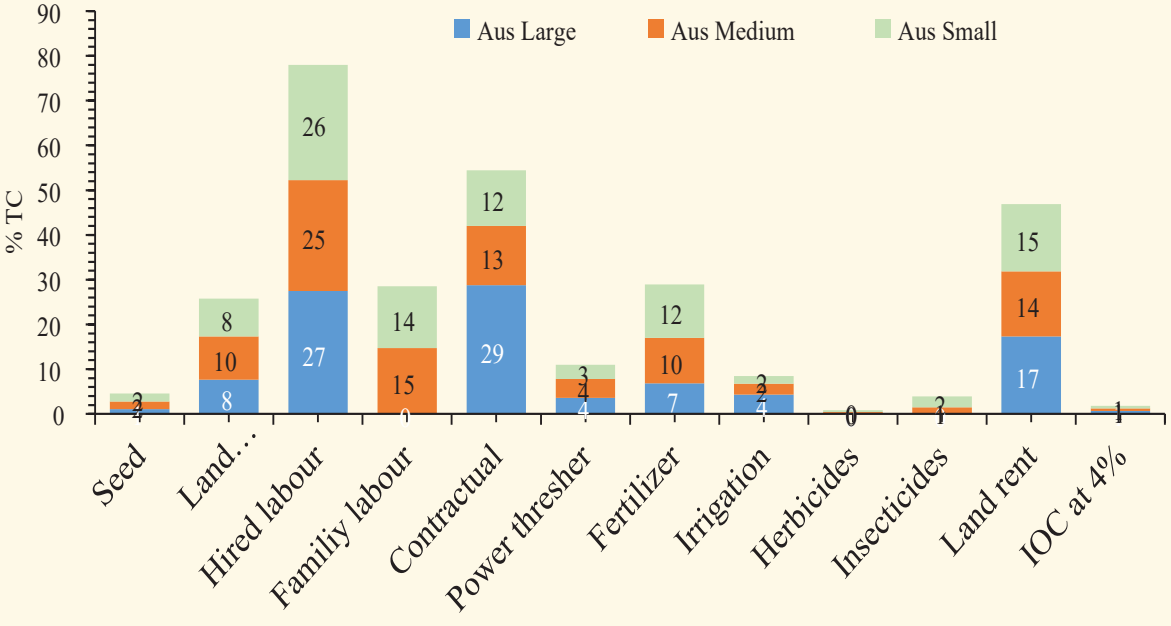


Figure 10.45: Share of per hectare inputs cost to total cost of *T. Aus* cultivation in tidal submergence ecosystem

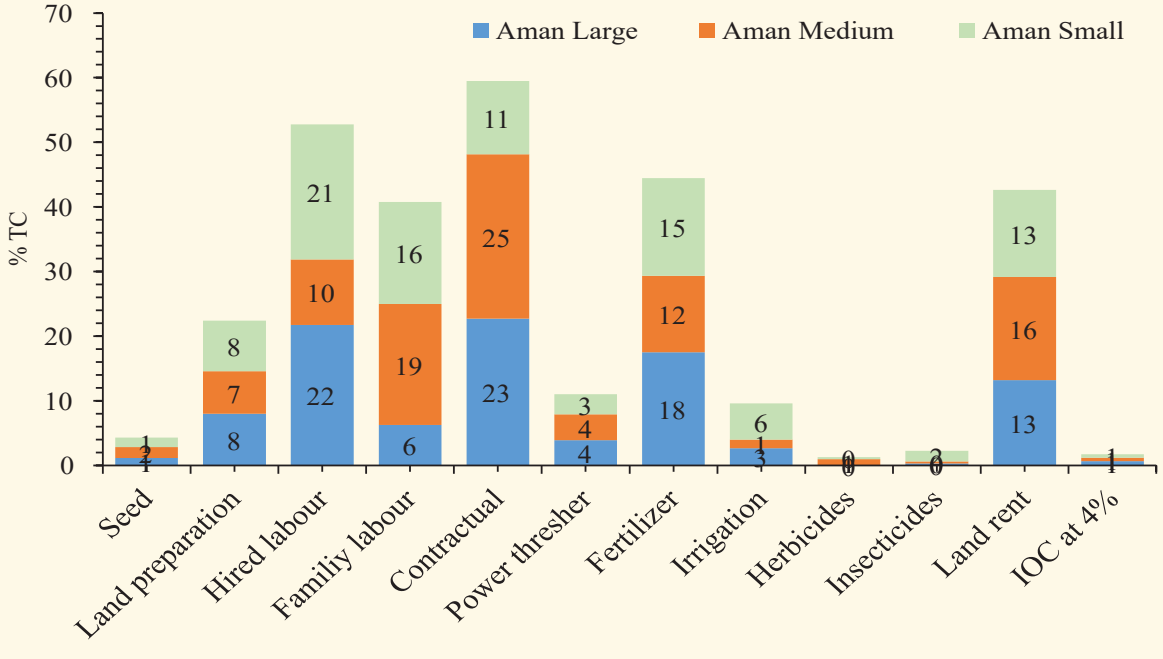


Figure 10.46: Share of per hectare inputs cost to total cost of *T. Aman* cultivation in tidal submergence ecosystem

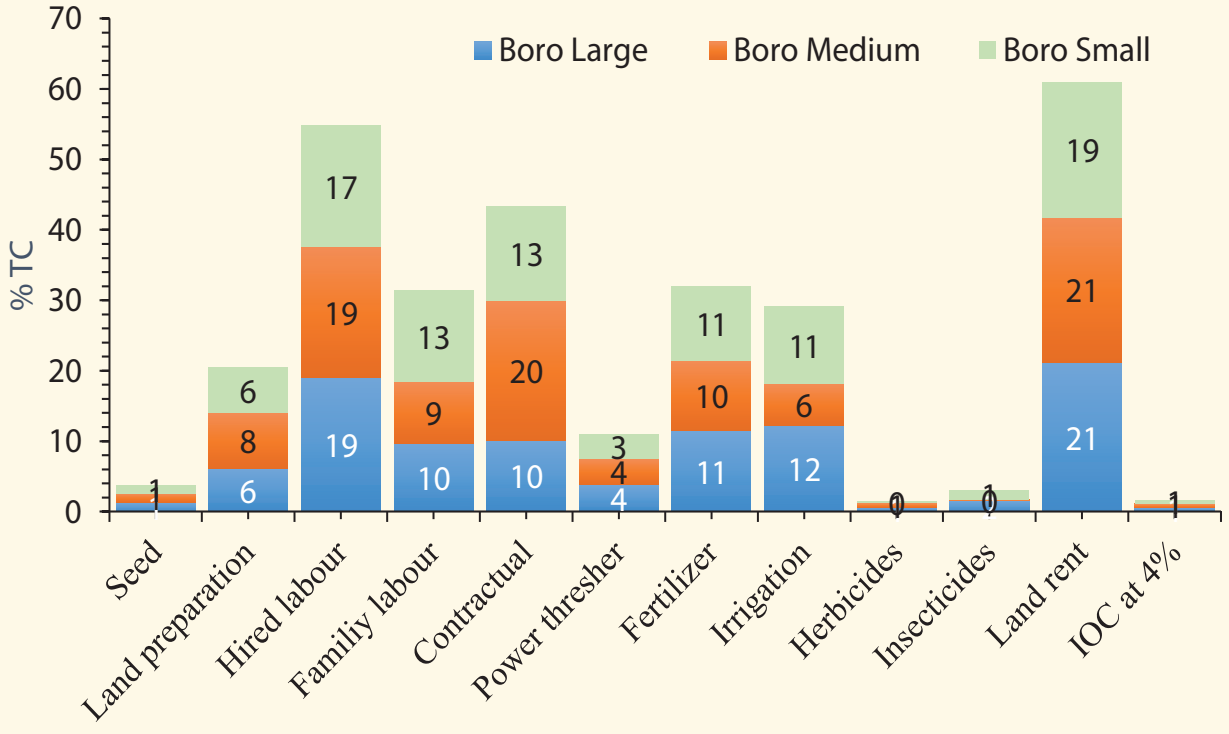


Figure 10.47: Share of per hectare inputs cost to total cost of *Boro* cultivation in tidal submergence ecosystem

10.5.3 Risk analysis of rice production in tidal submergence ecosystem

In assessing economic viability of rice cultivation at the reported market price, the result revealed that variability of yield of rice and straw value in the tidal submergence on farm profit was synthesized based on the households' survey and key informants survey.

The average/moderate/typical value of rice yield, straw value, inputs use and market price of rice estimated from household survey of the tidal submergence ecosystem were crosschecked with the key informant survey so as to get more Representative data. Moreover, farmers have well-being to sell their produces at a higher price than that in the worst case. The gross return (GR) of rice was computed by multiplying rice yields by the reported price (Table 10.15). In constructing the stochastic budgeting of rice production in the tidal submergence, production cost and profitability of the tidal submergence ecosystem was taken into risk analysis (table 10.15). Stochastic budgets were eventually constructed for seasonal rice cultivation considering farmers' perceived variation (worst, typical/average, and best case) in yield and market price by different farm types. The stochastic budget analysis displayed that seasonal rice cultivation was economically viable at the reported average/typical price and yields. In this analysis, triangular distribution was constructed by different levels of worst, typical/average, and best yields, straw value and price for different farm types across the seasons. Figure 10.48-10.50 showed that rice production in all seasons for large, medium and small farmers was found to be more profitable in the farmers' perceived typical and best case than that in the worst case. However, farmers always suffer from negative net-income in the worst case caused by weather stress (unpredictive climatic factor such as erratic temperature, rainfall and tidal flood).

Table 10.15 Stochastic budgeting of rice production by farm types in tidal submergence ecosystem

Items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Yield (ton per ha)									
Worse case	2.43	2.99	3.95	2.2	2.96	3.95	2.74	2.47	4.94
Typical case	3.63	4.99	7.42	4.74	4.94	7.59	4.39	4.94	7.88
Best case	5.85	6.48	9.4	5.49	6.06	9.56	5.92	6.25	10.87
Straw (Tk per ha)									
Worse case	7485	8982	3742	7485	8982	3742	7485	8982	3742
Typical case	11227	18712	7485	11227	18712	7485	11227	18712	7485
Best case	14970	22455	13473	14970	22455	13473	14970	22455	13473
Price (Tk per ton)									
Worse case	16000	17000	14000	16000	17000	14000	16000	17000	14000
Typical case	24000	21000	20000	24000	21000	20000	24000	21000	20000
Best case	28000	30000	27000	28000	30000	27000	28000	30000	27000
Paid out cost (Tk/ha) (A)	68454	87881	80433	69746	58029	84783	67471	74416	86978
Imputed cost (Tk/ha) (B)	17298	24932	41274	33021	35212	39750	31588	36036	46987
Total cost (Tk/ha) (A+B)	85752	112813	121707	102767	93241	124533	99059	110452	133965
Net return (Tk/ha)									
Worse case	-39387	-53001	-62665	-60082	-33939	-65491	-47734	-59480	-61063
Typical case	12595	10689	34178	22220	29211	34752	17528	12000	31120
Best case	93018	104042	145566	65923	111014	147060	81671	99503	172998

Source: Authors' estimation based on field survey, 2019-2021.

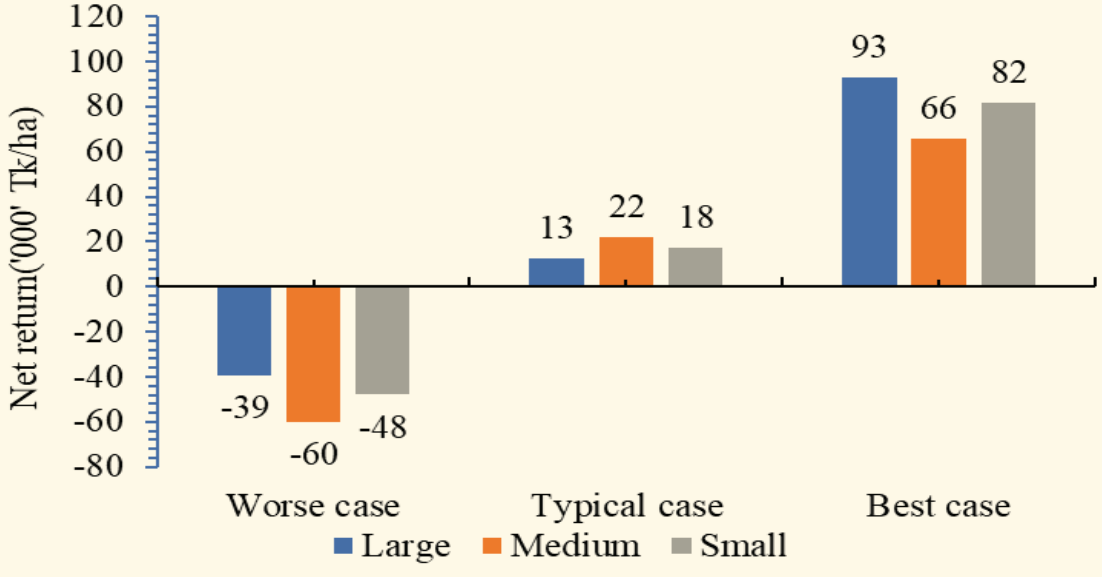


Figure 10.48: Farm types and case wise comparison in net-income (Tk per ha) for *T. Aus* in tidal submergence ecosystem

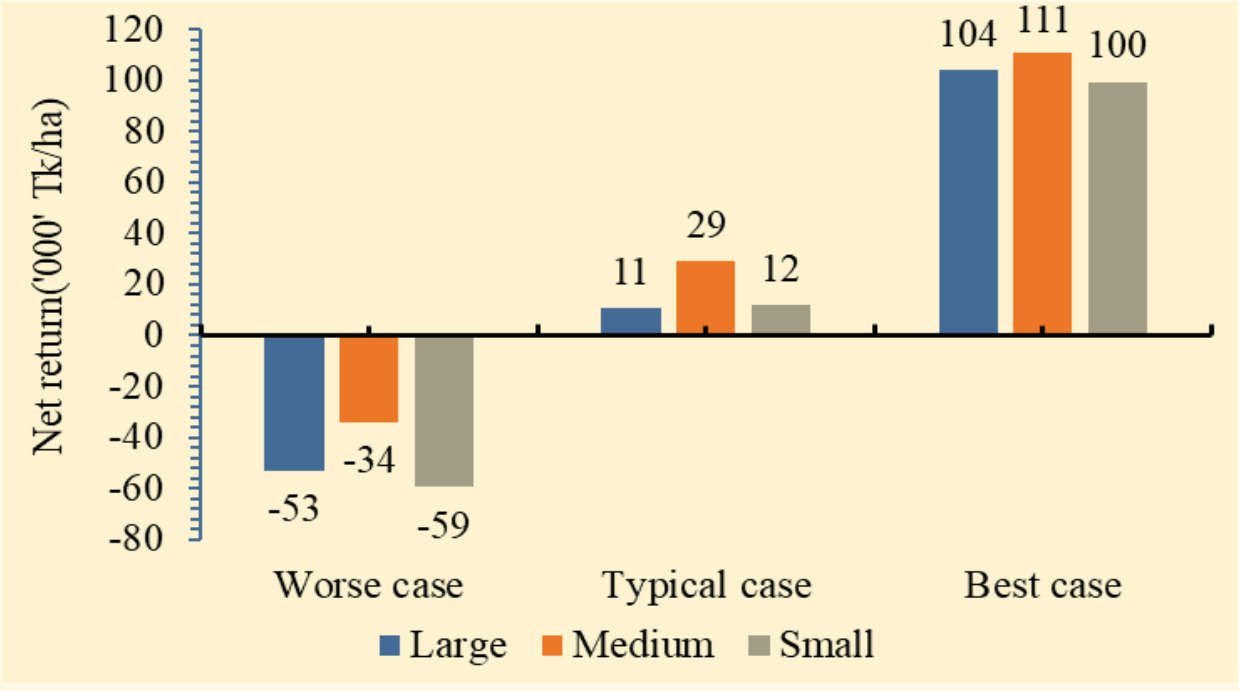


Figure 10.49: Farm types and case wise comparison in net-income (Tk per ha) for *T. Aman* in tidal submergence ecosystem

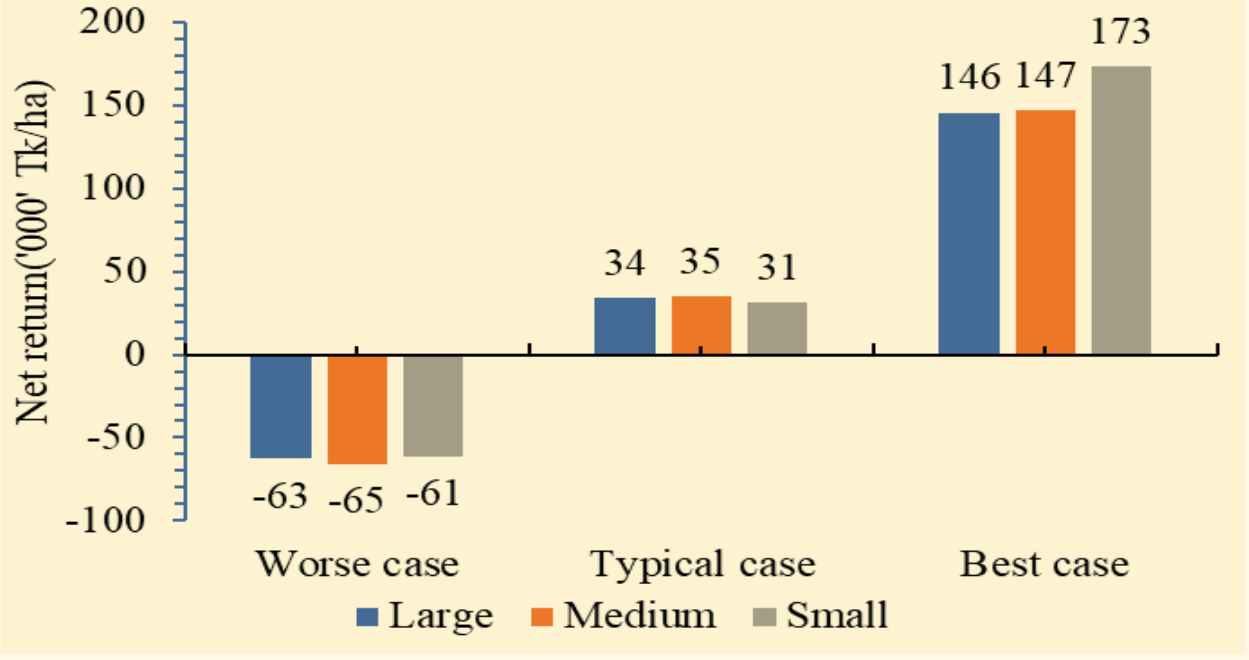


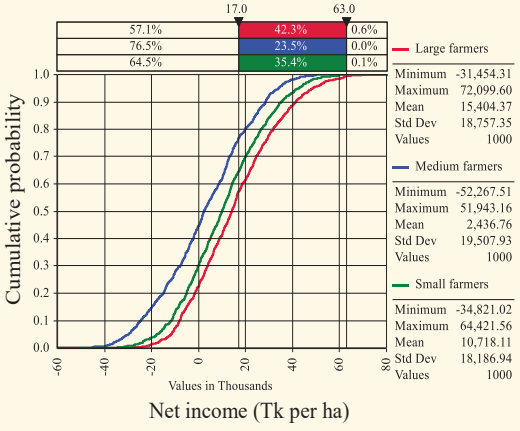
Figure 10.50: Farm types and case wise comparison in net-income (Tk per ha) for *Boro* in tidal submergence ecosystem

The lower benchmark (Tk. 17,000) was selected based on total imputed cost per ha, while the upper benchmark (Tk. 63,000) was chosen randomly. The Cumulative probability of NI per ha of *T. Aus* showed that large farmer had about 42% chance of achieving NI per ha above the lower benchmark total imputed cost of *T. Aus* rice production, meaning that it could cover the cost of

owned resources including use of family labour in *T. Aus* in the tidal submergence ecosystem. The chance of receiving NI per ha above this threshold decreased to 240% for medium farmer and 37% for small farmer (Figure 10.51(a)). The lower benchmark (Tk. 68000) was selected based on total paid out cost for medium farmer, while the upper benchmark (Tk. 135000) was chosen randomly. The cumulative probability of GR per ha of *T. Aus* showed that large farmer and medium farmer had about 92% chance of achieving GR per ha of *T. Aus*, respectively above the lower benchmark total paid out cost per ha of *T. Aus* rice production, respectively meaning that it could cover the cost of all cash costs of *T. Aus* cultivation. The chance of receiving GR per ha above this threshold slightly decreased to 90% for small farmer (Figure10.51(b)).

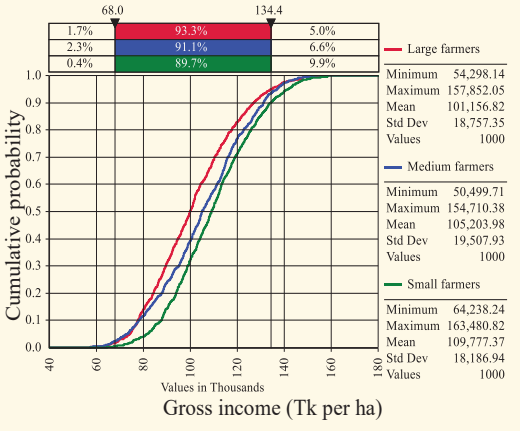
The lower benchmark (Tk. 25000) was selected based on total imputed cost per ha of *T. Aman* in tidal submergence ecosystem for large farmer, while the upper benchmark (Tk. 60000) was chosen randomly. The probability of achieving NI per ha showed that medium farmer had about 54% chance of getting NI per ha above the lower benchmark total imputed cost per ha of *T. Aman*, denoting that the probability of recovering the cost of owned resources including use of family labour in *T. Aman* production. The chance of receiving NI per ha above this threshold decreased to 27% for large farmer and 22% for small farmer (Figure 10.52(a)). The lower benchmark (Tk. 59000) was selected based on the paid-out costs (total paid out cost per ha) for medium farmer, while the upper benchmark (Tk. 161000) was chosen randomly. The probability of achieving GR per ha from *T. Aman* showed that medium farmer had about 97% chance of achieving GR per ha above the lower benchmark total paid out cost of *T. Aman* rice production, respectively meaning that it could cover the cost of all cash costs *T. Aman* rice production. The chance of receiving GR per ha above this threshold slightly decreased to 95% for large farmer and 96% for small farmer (Figure 10.52(b)). However, chance of probability of NI indicated the higher probability of becoming negative in *T. Aman* rice production in tidal submergence ecosystem.

The lower benchmark (Tk. 41000) was selected based on total imputed cost per ha of *Boro* rice production in tidal submergence ecosystem for large farmer, while the upper benchmark (Tk. 119000) was chosen randomly. The cumulative probability of NI per ha of *Boro* showed that small farmer had about 41% chance of achieving NI per ha above the lower benchmark total imputed cost of *Boro* rice production, meaning that it could cover the cost of owned resources including use of family labour. The chance of receiving NI per ha above this threshold decreased to 29% for large farmer and 58% for medium farmer (Figure 10.53(a)). The lower benchmark (Tk. 80000) was selected based on the total paid out cost per ha for medium farmer, while the upper benchmark (Tk. 202000) was chosen randomly. The cumulative probability of GR per ha of *Boro* in the same ecosystem showed that large farmer and medium farmer had about 95% and 94% chance of achieving GR per ha of *Boro* rice production above the lower benchmark total paid out cost per ha, respectively meaning that it could cover the cost of all cash costs of *Boro*. The chance of receiving GR per ha above this threshold slightly decreased to 84% for small farmer (Figure 10.53(b)).



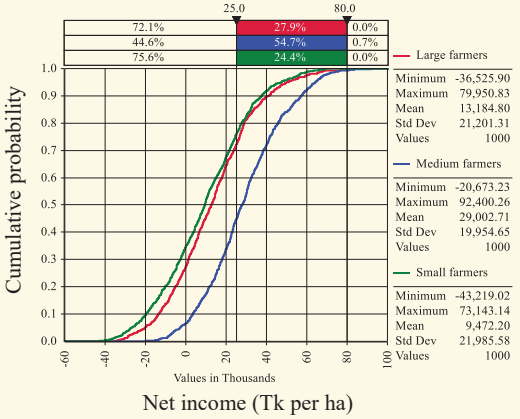
Net income (Tk per ha)

Figure 10.51(a): Cumulative probability of net-income (Tk per ha) of *T. Aus* rice cultivation in tidal submergence ecosystem



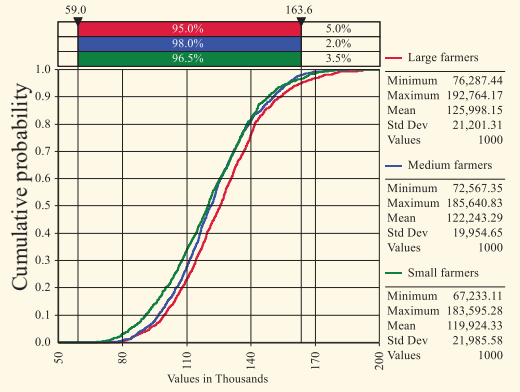
Gross income (Tk per ha)

Figure 10.51(b): Cumulative probability of gross income (Tk per ha) of *T. Aus* rice cultivation in tidal submergence ecosystem



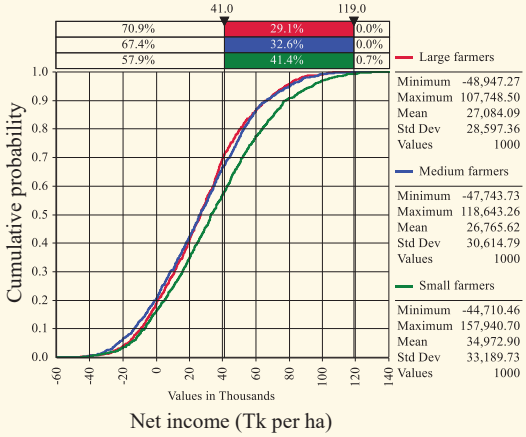
Net income (Tk per ha)

Figure 10.52(a): Cumulative probability of net-income (Tk per ha) of *T. Aman* rice cultivation in tidal submergence ecosystem



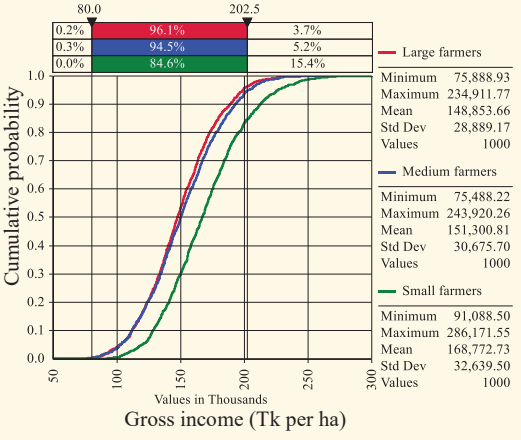
Gross income (Tk per ha)

Figure 10.52(b): Cumulative probability of gross income (Tk per ha) of *T. Aman* rice cultivation in tidal submergence ecosystem



Net income (Tk per ha)

Figure 10.53(a): Cumulative probability of net-income (Tk per ha) of *Boro* rice cultivation in tidal submergence ecosystem



Gross income (Tk per ha)

Figure 10.53(b): Cumulative probability of gross income (Tk per ha) of *Boro* rice cultivation in tidal submergence ecosystem

In assessing seasonal variation on economic viability of rice cultivation at current price, the result revealed that variability in the yield of seasonal rice and straw value in the *Haor* ecosystem had influence on farm profit with the reported market price. Figure 10.54 showed that, with all variables being constant other than yield, straw value and price, rice yield and straw value contributed together to the risk occurrence ranging from 55 to 67% in getting NI per ha above benchmark total imputed cost cost in all season. large farmer experienced higher risk of price variation on achievement of NI per above the lower benchmark total imputed cost per ha in both *T. Aman and T. Aus* (43%) while small farmer experienced higher risk of price variation (42%) in *Boro* followed by and medium farmer (35%) in *T. Aman* rice production. However, the risk of marker price volatility of rice was found relatively lower than the combined effect of yield and straw value in the rice production in all seasons. The risk occurred in getting the NI per ha above benchmark cost of owned resources from yield and straw value was higher for large farmer than that for both medium farmer and small farmer in drought ecosystem. Similar pattern of risk (65% arose from yield and straw value) was observed in getting GR per ha above benchmark cash cost for all farm types across the seasons. The analysis revealed that the rice production was economically viable at current price and average seasonal yields, but yield and price have outmost effect on the profitability of the rice cultivation which was aroused by erratic climate (temperature, heat wave and rainfall), occurrence of casual flood and market distortion in *Haor* ecosystem (Figure 10.55).

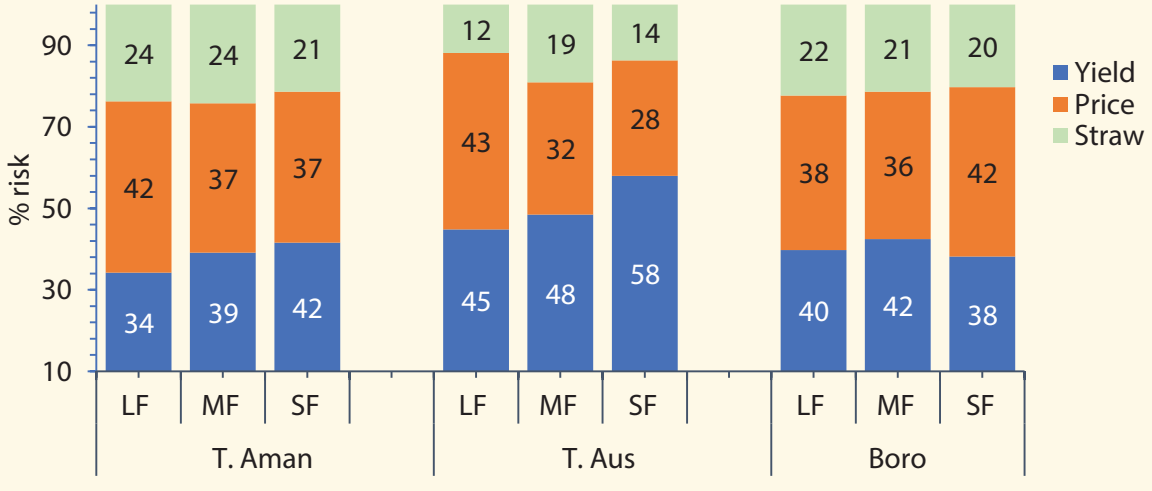


Figure 10.54: Inputs' effect ranked on NI for *T. Aman*, *T. Aus* and *Boro* rice in in tidal submergence ecosystem

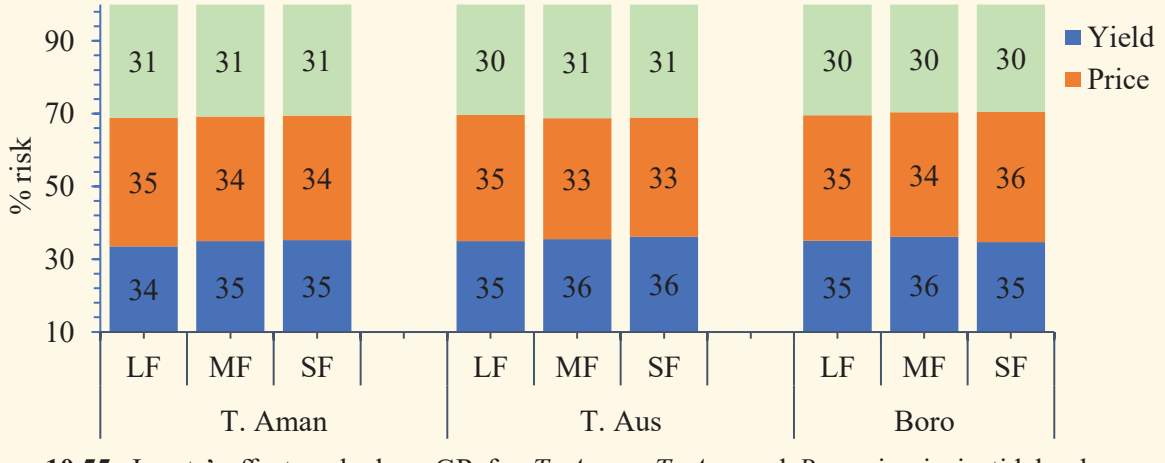


Figure 10.55: Inputs' effect ranked on GR for *T. Aman*, *T. Aus* and *Boro* rice in in tidal submergence ecosystem

10.6 Financial and risk analysis of rice production in submergence ecosystem

Representative farm budgets for seasonal rice production were computed with the market prices in 2020 for the average/moderate/typical value of all farm categories. Based on average value from sample survey, was estimated and cross checked with focus group discussion (FGD) as well as key informant survey (KIS). Representative farm budget, variation in both yield and price under weather and market variability were finally developed.

10.6.1 Input use pattern and productivity of rice in submergence ecosystem

The pattern of inputs use in seasonal rice cultivation by three farm types in submergence ecosystem are presented in table 10.16. Large farmer used almost 62%, 56% and 86% of hired labor among *T. Aman*, *T. Aus* and *Boro*, respectively for all kind of production activities. On the contrary, Small farmer used nearly 54%, 72% and 49% of family labor in *T. Aman*, *T. Aus* and *Boro*, respectively and medium farmer used 53%, 76% and 62% of hired labor in the respective three season to accomplish intercultural and postharvest activities. Contractual costs for large farmer were also higher than that for medium farmer and small farmer in all rice growing seasons. All farmers used HYV rice seed from market and most of them did not treat the rice seed to control diseases before sowing. Seed rate was not so quite higher than recommended rate among different farmers' categories. Large farmer used seed rate of 22 kg/ha in *T. Aman* and *Boro* whereas they used 33kg/ha in *T. Aus*. In practice, 28-45 days old seedlings were used when transplanting *T. Aman* up to third week of August, 25-35 days old seedling in *T. Aus* up to third week of May, 25-35 days old seedlings in *Boro* seedlings up to second week of February.

Only large farmer applied about 3% and 41% more dose of urea in *T. Aman* and *Boro* season than the recommended dose (185kg/ha), but they used 12% lower dose of urea in *T. Aus* (BRRI Adhunik Dhaner Chas 2020). Medium farmer used 26% lower dose of urea in *T. Aus*, but they used 1% and 32% more dose of urea in *T. Aus* and *Boro* season respectively. Small farmer used 14% and 16% more dose of urea in *T. Aman* and *T. Aus* rice growing season. In addition, all types of farmers applied lower rate of DAP, Gypsum, Zinc and theovit in rice cultivation than recommended rate. Average yield for large farmer (6.99 t/ha) in *Boro* season is considerably higher than medium farmer (5.99 t/ha) and small farmer (6.59 t/ha). In *T. Aman*, yield of small farmer (4.94 t/ha) was higher than large farmer (4.89 t/ha) and medium farmer (4.86 t/ha). In *T. Aus* season, yield of small farmer (3.99 t/ha) was lower than that of large farmer and medium farmer (4.49 t/ha).

Table 10.16: Input use pattern, productivity and price of seasonal rice in submergence ecosystem

Items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	Boro
Seed (kg/ha)	37	22	22	37	37	38	37	37	40
Land preparation	5239	5988	5988	5239	5988	5988	6736	5988	5988
Human labour (man-days/ha)									
Hired	20	67	83	82	38	35	25	18	41
Family	16	41	13	25	34	21	64	23	40
Contractual	21700	18700	20712	10068	18712	18098	14850	19970	14970

Items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	Boro
Fertilizer (Kg/ha)									
Urea	131	190	262	110	152	245	150	172	215
TSP	75	112	75	75	70	115	75	48	105
MOP	75	75	75	112	48	78	112	47	68
DAP	0	75	75	47	87	77	99	108	62
Gypsum	37	37	37	22	33	40	37	44	34
Sulpher	0	15	30	0	15	7	49	10	37
Zinc	0	11	7	0	7	7	15	7	7
Mg	0	0	6	0	0	0	0	1	1
Theovit	0	7	7	7	7	7	20	7	20
Irrigation	1871	3000	14970	5988	1690	9242	1871	2467	9522
Herbicides	374	374	374	374	225	187	748	337	374
Insecticides	561	1123	3742	1123	1123	1123	1123	1123	1123
Yield (ton/ha)	4.49	4.89	6.99	4.49	4.86	5.99	3.99	4.94	6.59
Straw (Tk/ha)	14970	18712	8982	13473	14970	11227	12227	22455	11227

Source: Authors' estimation based on field survey, 2019-2021.

10.6.2 Scenario of cost and return of rice production in submergence ecosystem

Table 10.17 shows that per ha total cost of *T. Aman* rice for large farmer was higher by Tk.13967 and 20899 than that for medium farmer and small farmer, respectively due to differences in the man-days of hired labor, fertilizer costs and irrigation. Per ha total cost of producing *T. Aus* rice for medium farmer was relatively higher than that for large farmer by Tk. 25400 and small farmer by Tk. 786, due mainly to differences in hired labor, contractual cost and fertilizer application. In addition, per ha total cost of *Boro* rice for large farmer was also higher than that for medium farmer and small farmer by nearly Tk. 28760 and 17097, respectively.

The actual paid-out costs includes seed, land preparation, hired labor, fertilizers, herbicides, insecticides and power thresher which were the major items for rice cultivation standing for nearly 64% of total cost in *T. Aman* for Large farmer and decreased to 59% and 56% for medium farmer and small farmer. On the contrary, the imputed cost of land rent and family labour showed almost 35% of total cost for large farmer and increased to 41% and 44%for medium farmer and small farmer, respectively (Figure 10.56). The paid-out costs in *T. Aus* showed almost 60% of total cost for all farm types whereas their imputed cost in *T. Aus* showed nearly 38% and 32% of total cost for large farmer and medium farmer, increased to 42% of total cost for small farmer (Figure 10.57). Similarly, the paid-out costs in *Boro* season showed more than 76% of total cost for large farmer and decreased to 63% and 59% for medium farmer and small farmer, respectively. In this season, the imputed cost showed 23% of total cost for large farmer and 36% for medium farmer whereas increased to 40% of total cost for small farmer (Figure 10.58). Net return of small farmer in *T. Aman* and *Boro* season showed higher than that for large farmer and medium farmer. The BCR on cash cost and full cost basis in all seasons in having much higher than one and the positive net return indicated that profit outyielded total cost of rice production.

Table 10.17: Production cost and return in rice production in different seasons in submergence ecosystem

Cost and income (Tk/ha)	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Paid out cost (A)	49107	73549	97198	70472	58261	62105	59567	51952	64894
Seed	2469	1468	1468	2469	1625	1729	2469	1746	2014
Land preparation	5239	5988	5988	5239	5988	5988	6736	5988	5988
Hired labor	7685	25743	31891	31507	17290	9606	9606	13448	13448
Contractual	21700	18700	20712	10068	18712	18098	14653	14653	14653
Power thresher	2994	3742	3742	1871	2245	3742	4940	2245	3742
Fertilizer	6214	13411	14311	11833	9363	12390	17421	9945	14030
Irrigation	1871	3000	14970	5988	1690	9242	1871	2467	9522
Herbicides	374	374	374	374	225	187	748	337	374
Insecticides	561	1123	3742	1123	1123	1123	1123	1123	1123
Imputed cost (B)	30497	40705	29154	34532	42026	35487	44651	41403	44361
Seedbed	1846	2245	2245	2245	1387	2412	2470	1586	2426
Family labor	6148	15753	4995	9606	18059	8453	24591	17290	17290
Land rent	22094	22094	21104	22094	22094	24104	17094	22094	24104
IOC at 4% for 5 months	409	613	810	587	486	518	496	433	541
Total cost (A+B)	79604	114254	126352	105004	100287	97592	104218	93355	109255
Gross return (Tk/ha)	113770	123854	131270	123500	112226	130985	111029	140955	142961
Net return (Tk/ha)	34165	9598	4917	18496	11940	33394	6811	47601	33706
BCR (Cash cost)	2.32	1.68	1.35	1.75	1.93	2.11	1.86	2.71	2.2
BCR (Full cost)	1.43	1.08	1.04	1.18	1.12	1.34	1.07	1.51	1.31

Source: Authors' estimation based on field survey, 2019-2021.

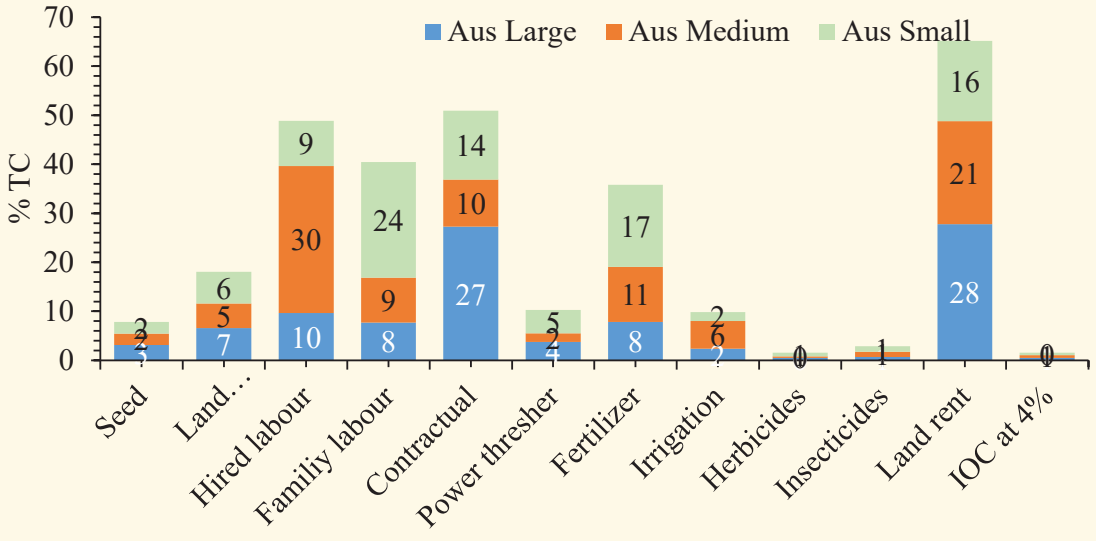


Figure 10.56: Share of per hectare inputs cost to total cost of *T. Aus* cultivation in submergence ecosystem

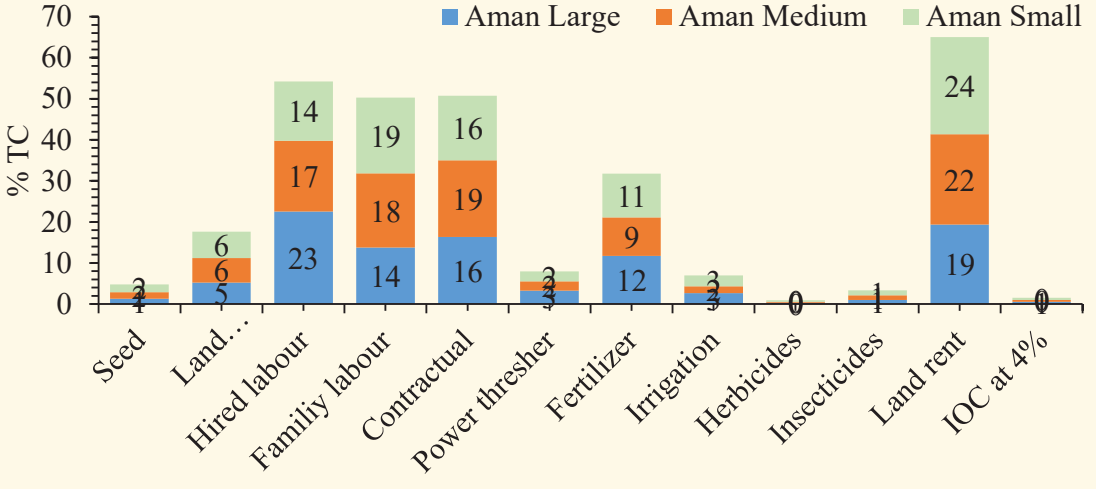


Figure 10.57: Share of per hectare inputs cost to total cost of *T. Aman* cultivation in submergence ecosystem

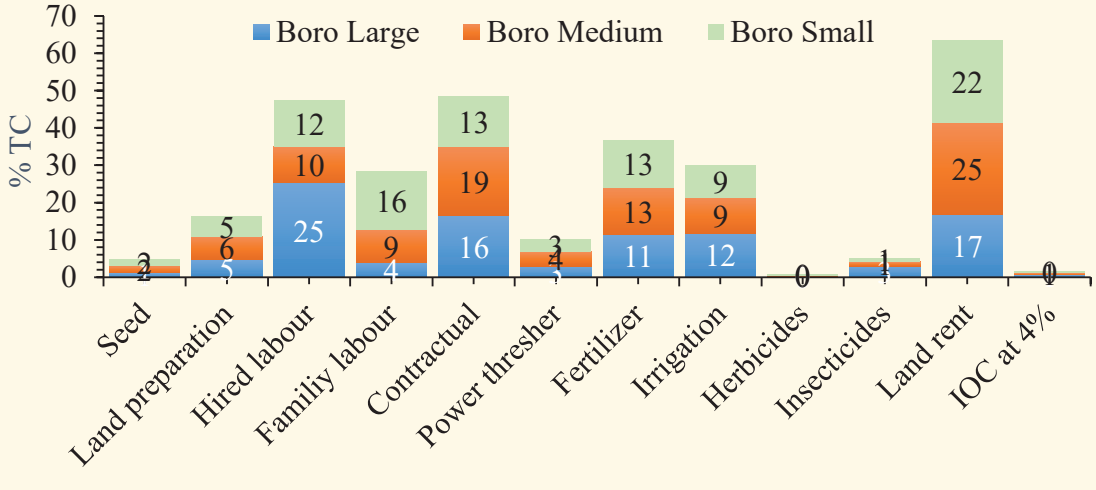


Figure 10.58: Share of per hectare inputs cost to total cost of *Boro* cultivation in submergence ecosystem

10.6.3 Risk analysis of rice production in submergence ecosystem

In assessing economic viability of rice cultivation at the reported market price, the variability of yield of rice and straw value in the submergence ecosystem on farm profit was synthesized based on the households' survey and key informants survey.

The average/moderate/typical value of rice yield, straw value, inputs use and market price of rice estimated from household survey of submergence ecosystem were crosschecked with the key informant survey so as to get more standard data. Moreover, farmers tend to supply their produces at a higher price than that in the worst case. The gross return (GR) of rice was computed by multiplying rice yields by the reported price (Table 10.18). In constructing the stochastic budgeting of rice production in submergence ecosystems, production cost and profitability of this ecosystem was taken into risk analysis (Table 10.18). Stochastic budgets were eventually constructed for seasonal rice cultivation considering farmers' perceived variation in yield and market price by different farm types. The stochastic budget analysis displayed that seasonal rice cultivation was economically viable at the reported average/typical market price and yield. In this analysis, triangular distribution was constructed by different levels of worst, typical/average, and best yields, straw value and price for different farm types across the seasons. In addition, the distribution of the collected data based on farmers' observations fully support the triangle algorithm of risk prediction. Figure 10.59-10.61 showed that rice production in all seasons for large, medium and small farmers was found to be more profitable in the farmers' perceived typical and best case than that in the worst case. However, farmers always suffer from negative net-income in the worst case caused by weather stress (unpredictive climatic factor such as erratic temperature and rainfall, and flash flood).

Table 10.18 Stochastic budgeting of rice production by farm types in submergence ecosystem

Items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Yield (ton per ha)									
Worse case	2.62	2.97	4.49	2.99	2.99	4.49	2.99	2.4	4.49
Typical case	4.49	4.89	6.99	4.49	4.86	5.99	3.99	4.94	6.59
Best case	5.99	6.92	8.98	5.37	7.48	9.14	4.94	5.99	9.88
Straw (Tk per ha)									
Worse case	6736	3742	4491	6736	11227	3742	1497	7485	3742
Typical case	14970	18712	8982	13473	14970	11227	12227	22455	11227
Best case	18712	22455	14970	18712	22455	14970	14970	29939	14970
Price (Tk per ton)									
Worse case	16250	15000	12500	16250	12500	15000	18750	15000	15000
Typical case	22000	21500	17500	24500	20000	20000	24750	25000	20000
Best case	27000	26250	28000	28000	30000	30000	30000	30000	25000
Paid out cost (Tk/ha) (A)	49107	73549	97198	70472	58261	62105	59567	51952	64894
Imputed cost (Tk/ha) (B)	30497	40705	29154	34532	42026	35487	44651	41403	44361

Items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Total cost (Tk/ha) (A+B)	79604	114254	126352	105004	100287	97592	104218	93355	109255
Net return (Tk per ha)									
Worse case	-30293	-65962	-65736	-49681	-51685	-26500	-46659	-49870	-38163
Typical case	34146	9593	4955	18474	11883	33435	6762	52600	33772
Best case	100838	89851	140058	64068	146568	191578	58952	116284	152715

Source: Authors' estimation based on field survey, 2019-2021.

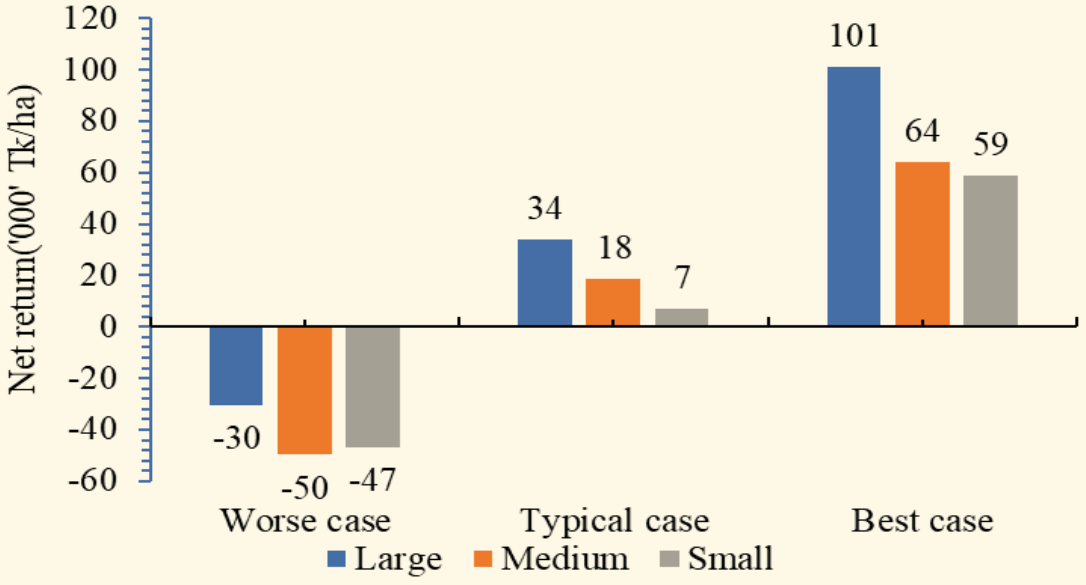


Figure 10.59: Farm types and case wise comparison in net-income (Tk per ha) for *T. Aus* in submergence ecosystem

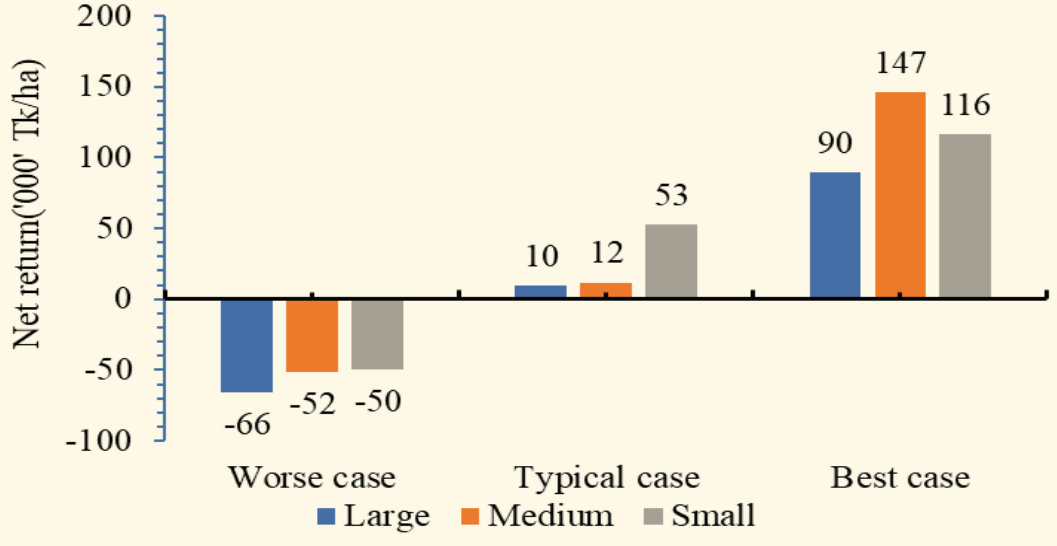


Figure 10.60: Farm types and case wise comparison in net-income (Tk per ha) for *T. Aman* in submergence ecosystem

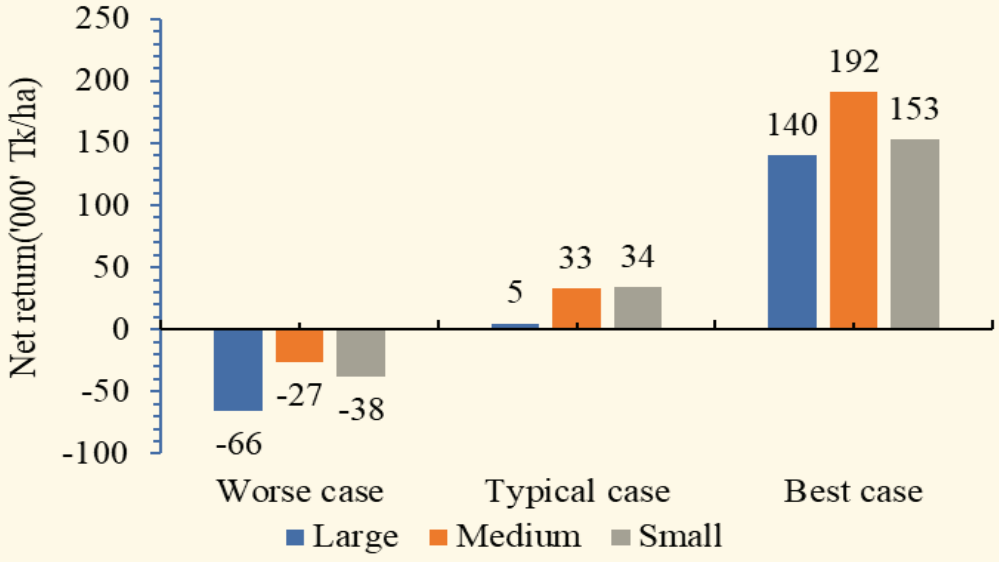


Figure 10.61: Farm types and case wise comparison in net-income (Tk per ha) for *Boro* in submergence ecosystem

The lower benchmark (Tk. 30000) was selected based on total imputed cost per ha for large farmer, while the upper benchmark (Tk. 69000) was chosen randomly. The probability of achieving NI per ha from *T. Aus* showed that large farmer had about 47% chance of gaining NI per ha above the lower benchmark, denoting that the probability to recover the cost of owned resources including family labour. The chance of receiving NI per ha above this threshold decreased to 6% for medium farmer and 13% for small farmer (Figure 10.62(a)). The lower benchmark (Tk. 49000) was selected based on the paid-out costs (total paid out cost per ha) for medium farmer, while the upper benchmark (Tk. 139000) was chosen randomly. The probability of gaining GR per ha from *T. Aus* showed that medium farmer and small farmer had about 92 and 99 % chance of gaining GR per ha above the lower benchmark, respectively meaning that it could cover the cost of all cash costs. The chance of receiving GR per ha above this threshold slightly decreased to 95% for large farmer (Figure 10.62(b)). However, The small farmers were found more riskier in *T. Aus* rice production in submergence ecosystem since higher probability of NI per ha in *T. Aus* become negative.

The lower benchmark (Tk. 40000) was selected based on total imputed cost per ha for large farmer in *T. Aman* under submergence ecosystem, while the upper benchmark (Tk. 103000) was chosen randomly. The probability of NI per ha of *Boro* showed that medium farmer had 23% likelihood of achieving NI per ha above the lower benchmark total imputed cost per ha of *T. Aman*, meaning that it could cover the cost of owned resources including use of family labour. The chance of receiving NI per ha above this threshold decreased to 5% for large farmer and 0.5% for small farmer (Figure 10.63(a)). The small farmers were found riskier in *T. Aman* rice production in submergence ecosystem since higher probability of NI per ha in *T. Aman* become negative. The lower benchmark (Tk. 58000) was selected based on the total paid out cost per ha for medium farmer, while the upper benchmark (Tk. 141000) was chosen randomly. The likelihood of GR per ha of *T. Aman* showed that large farmer had about 86% chance of achieving GR per ha above the lower benchmark total paid out cost per ha meaning that it could cover the cost of all cash costs. The chance of receiving GR per ha above this threshold slightly decreased to 67% for medium farmer and 50% for small farmer (Figure 10.63(b).

The lower benchmark (Tk. 30000) was selected based on total imputed cost per ha for large farmer in *Boro* under submergence, while the upper benchmark (Tk. 152000) was chosen randomly. The probability of achieving NI per ha from *Boro* showed that large farmer had about 78% chance of gaining NI per ha above the lower benchmark, meaning that it could cover the cost of owned resources including family labour of *Boro* rice production. The chance of receiving NI per ha above this threshold decreased to 29% for large farmer and 63% for small farmer (Figure 10.64(a)). The lower benchmark (Tk. 62000) was selected based on total paid out cost for medium farmer, while the upper benchmark (Tk. 193000) was chosen randomly. The cumulative probability of GR per ha from *Boro* showed that large farmer and small farmer had about 95% chance of gaining GR per ha, respectively above the lower benchmark, respectively meaning that it could cover the cost of all cash costs. The chance of receiving GR per ha above this threshold slightly decreased to 91% for medium farmer (Figure 10.64(b)).

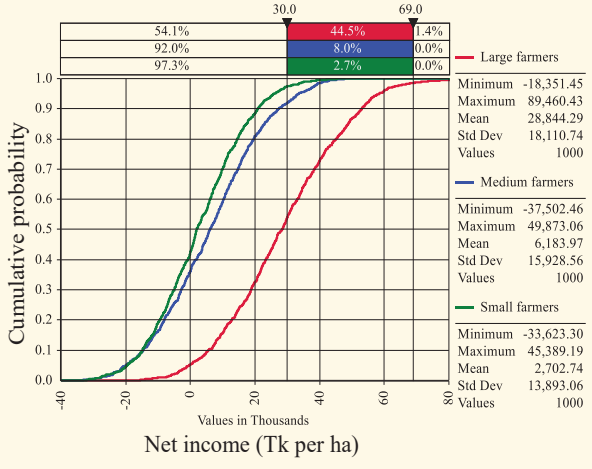


Figure 10.62(a): Cumulative probability of net-income (Tk per ha) of *T. Aus* rice cultivation in submergence ecosystem

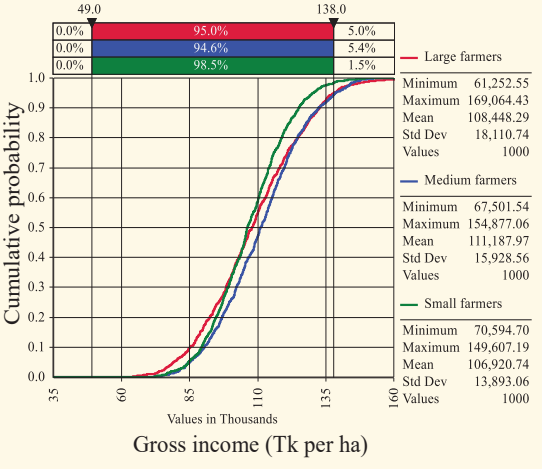


Figure 10.62(b): Cumulative probability of gross income (Tk per ha) of *T. Aus* rice cultivation in submergence ecosystem

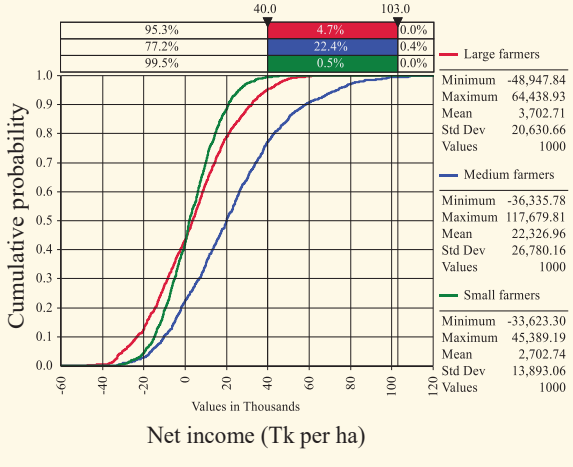


Figure 10.63(a): Cumulative probability of net-income (Tk per ha) of *T. Aman* rice cultivation in submergence ecosystem

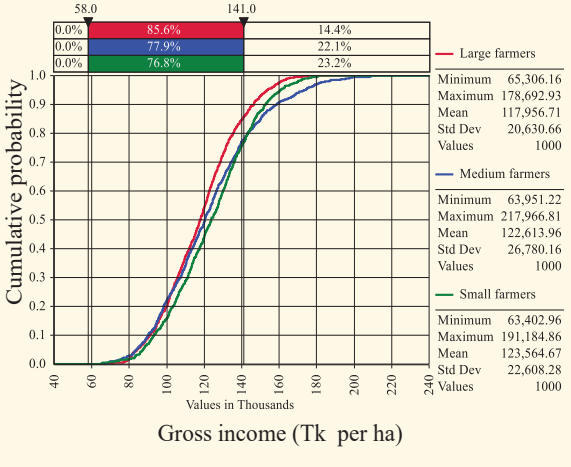
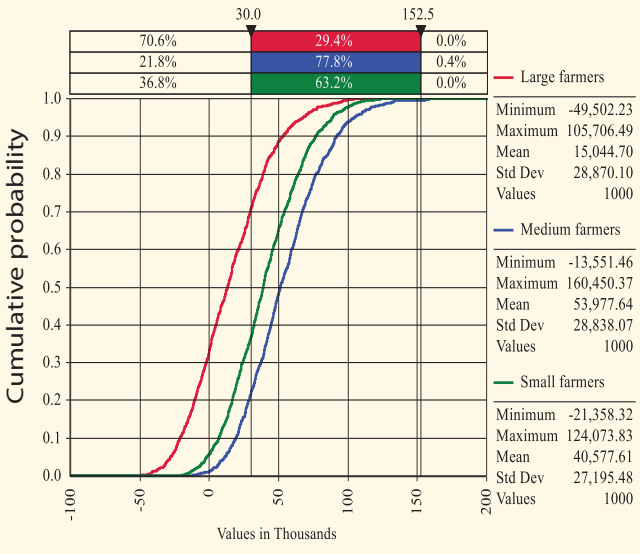
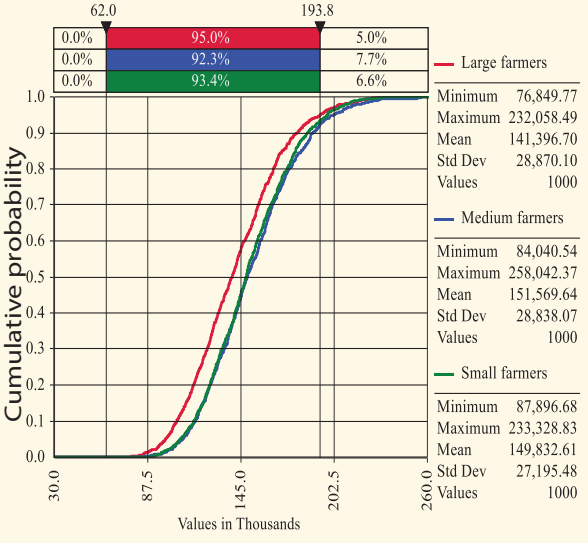


Figure 10.63(b): Cumulative probability of gross income (Tk per ha) of *T. Aman* rice cultivation in submergence ecosystem



Net income (Tk per ha)

Figure 10.64(a): Cumulative probability of net-income (Tk per ha) of *Boro* rice cultivation in submergence ecosystem



Gross income (Tk per ha)

Figure 10.64(b): Cumulative probability of gross income (Tk per ha) of *Boro* rice cultivation in submergence ecosystem

The outcome of submergence environment and market uncertainty is major risk on the gross return and net-income (NI) of seasonal rice cultivation. This uncertainty was taken into consideration in order to assess the economic viability based on farmers' perceived variation in yield and market price (lower/worse, moderate/average and best case). The result revealed that variability in the yield of rice in the Barisal had influence on farm profit with current market price. Figure 10.65 shows that, with all variables being constant other than yield, straw value and price, the fluctuation in rice yield and straw value contributed to the variability of the NI per ha by little more than 60% of total variation in NI under *T. Aman*, *T. Aus and Boro* for all categories of farmers. Risk in *T. Aman* for large farmer appeared due to both yield and straw value, higher than that in both *T. Aman* and *T. Aus*. small farmer experienced extreme effect of price variation (more than 40%) on NI in *T. Aus* followed by medium farmer in *T. Aman* (39%). However, the fluctuation in the price of rice was found to be relatively lower than the combined effect of yield and straw value. The variability in the NI per ha from yield and straw value was higher for medium farmer and small farmer than for large farmer. Similar pattern of variation was observed in GR for large farmer, medium farmer and small farmer across the seasons under submergence ecosystem. The analysis also revealed that the rice production was economically viable at current price and average seasonal yields, but yield and price variation can affect the profitability of the crop which was aroused by adverse weather, flash flood and market distortion in this ecosystem (Figure 10.66).

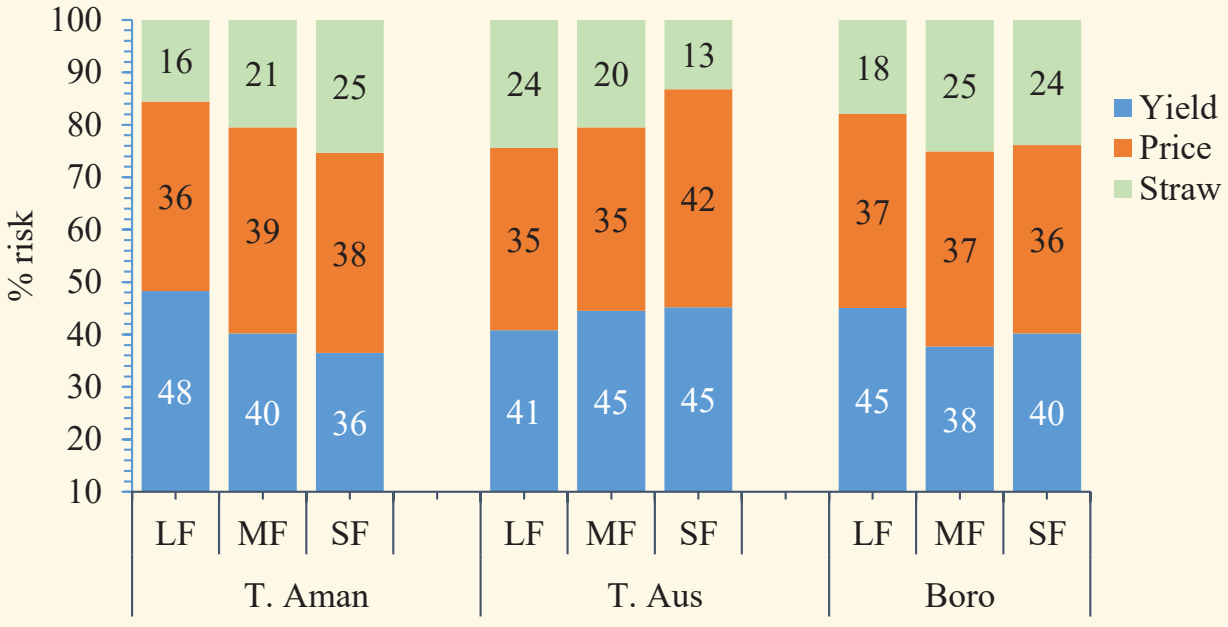


Figure 10.65: Inputs' effect ranked on NI for *T. Aman*, *T. Aus* and *Boro* rice in submergence ecosystem

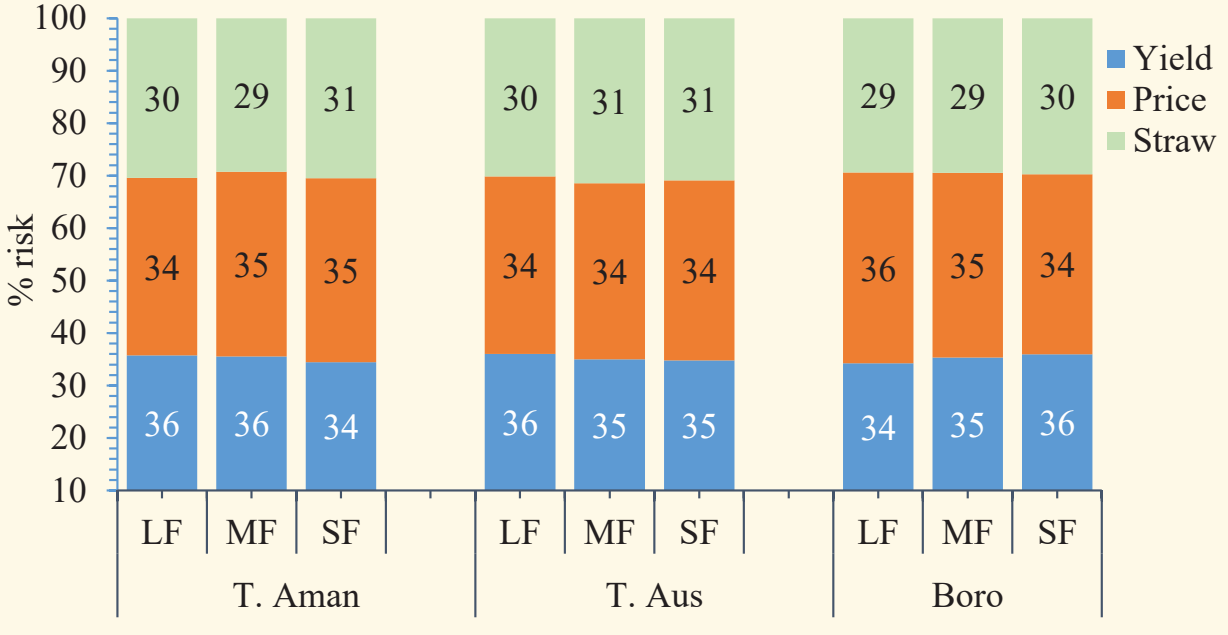


Figure 10.66: Inputs' effect ranked on GR for *T. Aman*, *T. Aus* and *Boro* rice in submergence ecosystem

10.7 Financial and risk analysis of rice production under low lying ecosystem

Representative farm budgets for seasonal rice production were computed with the market prices in 2020 for the average/moderate/typical value of all farm categories. Based on average value from sample survey, was estimated and cross checked with focus group discussion (FGD) as well as key informant survey (KIS). Representative farm budget, variation in both yield and price under weather and market variability were finally developed.

10.7.1 Input use pattern and productivity of rice under low lying ecosystem

Data in table 10.19 displayed the pattern of inputs use in seasonal rice cultivation by three farm types in low lying ecosystem. Large farmer spent fewer man-days of family labor and mostly used 86%, 92% and 85% hired labor for *T. Aman*, *T. Aus* and in *Boro* rice production respectively, for all kind of operation. On the contrary, small farmer used nearly 42% family labour in rice cultivation and decreased to 21% in *T. Aman*, 27% in *T. Aus* and 26% in *Boro* for medium farmer. Contractual costs for large farmer were found to be higher than medium farmer and small farmer in all rice growing seasons because large farmer used to hire more contractual labour. It can be viewed that per hectare inputs use in *Boro* season by small farmer was relatively higher than that by large farmer and medium farmer in low-lying ecosystem. In some case, magnitude of inputs use seems to be close for medium farmer and small farmer in rice cultivation. Per hectare man-days used for rice cultivation varied widely among the seasons as well as farmers' types.

Large farmer used considerably lower seed rate of 33 kg/ha in *T. Aman* and 41kg/ha in *T. Aus* and 25 kg/ha in *Boro* whereas small farmer used seed rate of 41 kg/ha in *T. Aman* and 26 kg/ha in T. *Aus* and 28kg/ha in *Boro*. In practice, 28-32 days old seedlings were used when transplanting *T. Aman* up to second weeks of August, *T. Aus* seedlings up to third week of May, *Boro* seedlings up to second week of December. All farmers used to buy HYV rice seed from market because they did not like to do maintenance operation of seed storage. Even though farmers' practice was higher than recommended seed rate, seed rate did not vary much among different farmers' categories.

Only large farmer applied about 2% and 12% more urea in *T. Aman* and *Boro* season, respectively than the recommended dose (185kg/ha), while medium farmer applied 2% and 25% higher urea in *T. Aman* and *Boro* season. Urea application in *T. Aus* season for large, medium and small farmer is found to be lower than the recommended rate. In addition, small farmer used to apply more TSP and MOP than that of large and small farmer. Rate of other fertilizer such DAP, Gypsum, Zinc and theovit was found almost same among the farmers' types. Average yield (ton/ha), straw value (Tk./ha) and market price (Tk./ton) under moderate case were considered as average point estimation. Average yield of medium farmer and small farmer (6.59 t/ha) in *Boro* season is considerably higher than large farmer (5.27 t/ha); In case of *T. Aman*, yield performance was found to be same (4.94t/ha) for large farmer, medium farmer and small farmer; in *T. Aus* season, average yield for small farmer (4.29 t/ha) was higher than that for medium farmer (3.99 t/ha) and small farmer (3.95 t/ha) in low lying ecosystem.

Table 10.19 Input use pattern, productivity and price of seasonal rice in low-lying ecosystem

Cost items (Tk/ha)	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Seed (kg/ha)	41	33	25	33	41	41	26	41	28
Land preparation	7410	7410	8233	5880	9880	7940	5640	7410	7410
Human labour (man-days/ha)									
Hired	61	49	67	61	68	69	44	46	63
Family	5	8	12	23	19	25	33	34	40
Contractual	14467	14171	16858	9173	16347	15583	9350	9880	14700

Cost items (Tk/ ha)	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Fertilizer (Kg/ha)									
Urea	91	190	208	110	190	232	120	167	182
TSP	82	53	73	66	57	60	82	60	73
MOP	82	113	132	124	101	110	124	83	122
DAP	0	38	199	82	135	141	165	106	133
Gypsum	0	30	38	82	34	37	41	52	36
Sulpher	0	8	8	8	8	8	8	8	8
Zinc	0	0	8	8	8	8	8	8	8
Mg	0	0	0	8	8	8	8	8	8
Theovit	0	8	8	8	8	8	8	8	8
Irrigation	2587	2834	6057	1647	1976	9076	2470	2600	9025
Herbicides	474	748	494	988	412	371	494	1647	371
Insecticides	290	1411	1235	823	618	823	823	1235	1235
Yield (ton/ha)	4.29	4.94	5.27	3.99	4.94	6.59	3.95	4.94	6.59
Straw (Tk/ha)	8982	11227	13473	115988	11227	13473	11227	11227	7485

Source: Authors' estimation based on field survey, 2019-2021.

10.7.2 Scenario of cost and return of rice production in low-lying ecosystem

Table 10.20 show that per ha total cost of *Boro* season for medium farmer was higher by Tk. 11260 and Tk. 13819 than that for large farmer and small farmer, respectively due to differences in the man-days of hired labor and irrigation costs. Per ha total cost of *T. Aman* seasons was relatively higher for medium farmer than that for large farmer by Tk. 10720 and small farmer by Tk.15109, because of differences in the man days of hired labor, contractual cost and fertilizers application. In addition, per ha total cost of medium farmer and small farmer in *T. Aus* season was almost same which was slightly higher than that for large farmer by Tk. 7700, because of differences in family labor and fertilizer application. It is important to mention that wages and market price of input did not vary across the season among farmer's categories.

The actual total paid out cost usually includes seed, land preparation, hired labor, fertilizers, herbicides, insecticides, and power thresher representing 75%, 77% and 66% of total cost in *T. Aman* for large farmer, medium farmer and small farmer, respectively. On the contrary, the total imputed cost of land rent and family labor shared 33% of total cost for small farmer and 24% for large farmer, and stood at 22% of total cost for medium farmer. The total paid out cost of large farmer in *T. Aus* shared 74% of total cost, and stood at 63-67% of total cost for medium farmer and small farmer. The total imputed cost of small farmer and medium farmer shared 33-37% of total cost and stood at 26% of total cost for large farmer. Similarly, the total paid out cost in *Boro* season shared 76% of total cost for medium farmer and stood at 74% for large farmer and 68% for small farmer, respectively. In *Boro* season, the imputed cost shared 32% of total cost for small farmer, large farmer (26%) and small farmer (24 %). The BCR on cash cost and full cost basis in all seasons in had more than one and the positive net return, denoting that return outyielded total investment in rice production (Table 10.20).

Table 10.20 Production cost and return in rice production in different seasons in low-lying ecosystem

Cost and income (Tk/ ha)	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Paid out cost (A)	64635	75202	88088	63621	85661	98757	60667	63331	77636
Seed	1557	2140	2033	1254	2188	2962	988	2241	3176
Land preparation	7410	7410	8233	5880	9880	7940	5640	7410	7410
Hired labour	27450	28800	29700	27450	36900	40500	19800	19800	27900
Contractual	14467	14171	16858	9173	16347	15583	14653	14653	14653
Power thresher	5450	7057	8233	5233	6175	8233	3200	3200	1544
Fertilizer	4950	10631	15245	11173	11165	13269	12599	10545	12322
Irrigation	2587	2834	6057	1647	1976	9076	2470	2600	9025
Herbicides	474	748	494	988	412	371	494	1647	371
Insecticides	290	1411	1235	823	618	823	823	1235	1235
Imputed cost (B)	22755	24187	31522	31470	24448	32113	35946	31671	39415
Seedbed	1846	1840	3734	2470	2014	2436	2470	1773	2714
Family labour	2250	3600	5400	10350	3600	7200	14850	11250	14400
Land rent	18120	18120	21654	18120	18120	21654	18120	18120	21654
IOC at 4% for 5 months	539	627	734	530	714	823	506	528	647
Total cost (A+B)	87390	99389	119610	95091	110109	130870	96613	95002	117051
Gross return	110948	110027	132033	106409	122377	169906	105087	110027	155685
Net-income	23558	10639	12422	11318	12268	39037	8474	15025	38634
BCR (Cash cost)	1.72	1.46	1.5	1.67	1.43	1.72	1.73	1.74	2.01
BCR (Full cost)	1.27	1.11	1.1	1.12	1.11	1.3	1.09	1.16	1.33

Source: Authors' estimation based on field survey, 2019-2021.

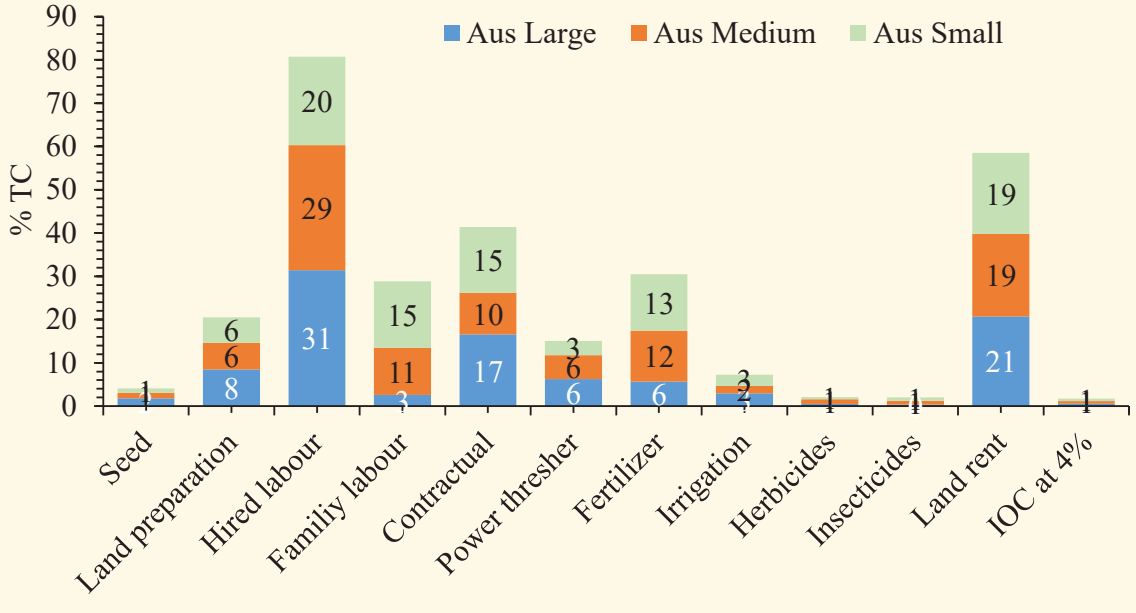


Figure 10.67: Share of per hectare inputs cost to total cost of *T. Aus* cultivation in low-lying ecosystem

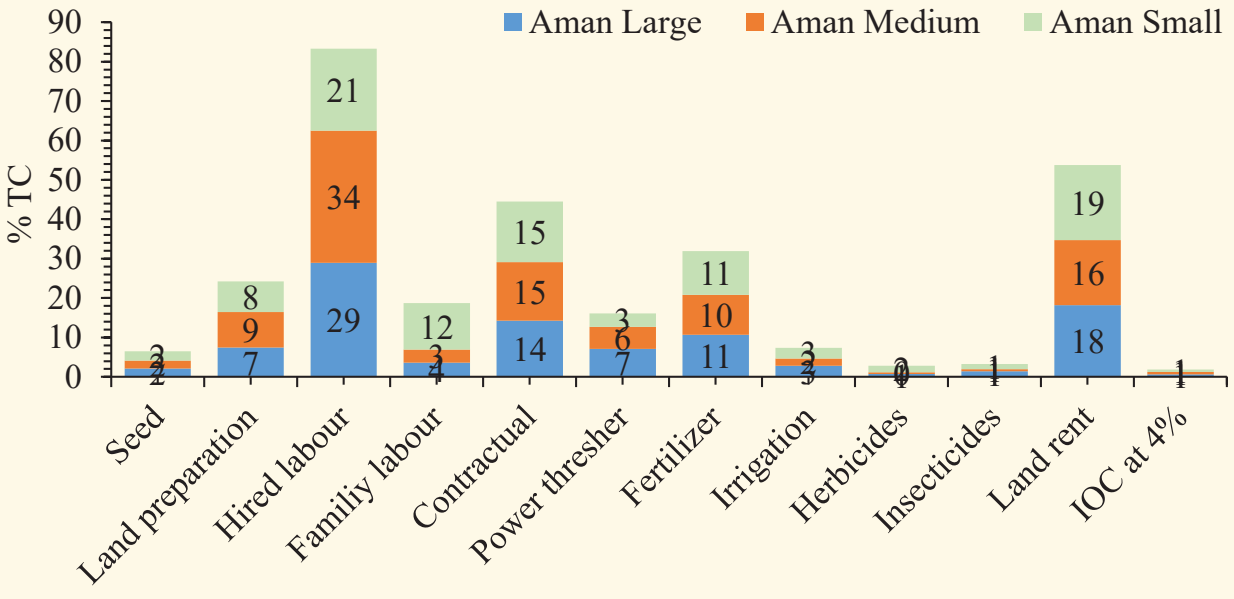


Figure 10.68: Share of per hectare inputs cost to total cost of *T. Aman* cultivation in low-lying ecosystem

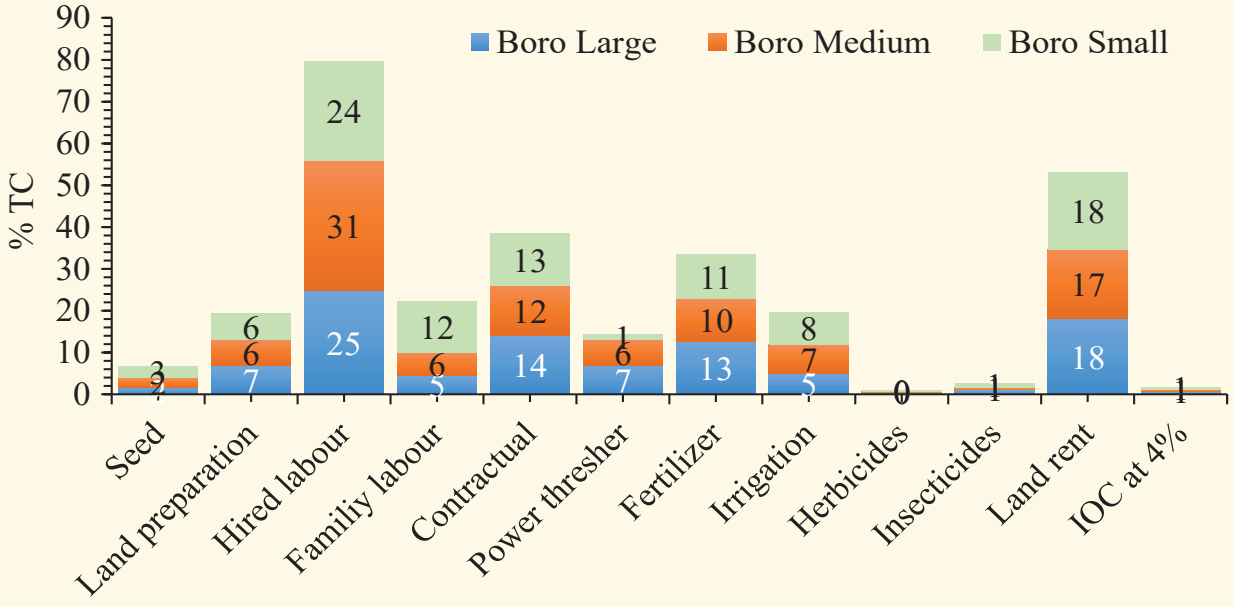


Figure 10.69: Share of per hectare inputs cost to total cost of *Boro* cultivation in low-lying ecosystem

10.7.3 Risk analysis of rice production under low-lying ecosystem

In assessing economic viability of rice cultivation at the reported market price, the variability of yield of rice and straw value in the low-lying ecosystem on farm profit was synthesized based on the households' survey and key informants survey.

The average/moderate/typical value of rice yield, straw value, inputs use and market price of rice estimated from household survey of low-lying ecosystem were crosschecked with the key informant survey to get more standard data. Moreover, farmers offered to supply their produces in at a higher price than that in the worst case. The gross return (GR) of rice was computed by multiplying

rice yields by the reported price (Table 10.21). In constructing the stochastic budgeting of rice production in submergence ecosystems, production cost and profitability of this ecosystem was taken into risk analysis (Table 10.21). Stochastic budgets were eventually constructed for seasonal rice cultivation considering farmers' perceived variation in yield and market price by different farm types. The stochastic budget analysis displayed that seasonal rice cultivation was economically viable at the reported average/typical market price and yield. Likewise, triangular distribution was adopted by worst, typical/average, and best yields, straw value and price for different farm types across the seasons. In addition, the distribution of the collected data based on farmers' observations fully buttressed with the triangle algorithm of risk prediction. Figure 10.70-10.73 showed that rice production in all seasons for large, medium and small farmers was found to be more profitable in the farmers' perceived typical and best case than that in the worst case. However, farmers always suffer from negative net-income in the worst case caused by weather stress (unpredictive climatic factor such as erratic temperature and rainfall, and flash flood).

Table 10.21 Stochastic budgeting of rice production by farm types in lowlying ecosystem

Items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Yield (ton per ha)									
Worse case	2.62	2.97	4.49	2.99	2.99	4.49	2.99	2.4	4.49
Typical case	4.49	4.89	6.99	4.49	4.86	5.99	3.99	4.94	6.59
Best case	5.99	6.92	8.98	5.37	7.48	9.14	4.94	5.99	9.88
Straw (Tk per ha)									
Worse case	6736	3742	4491	6736	11227	3742	1497	7485	3742
Typical case	14970	18712	8982	13473	14970	11227	12227	22455	11227
Best case	18712	22455	14970	18712	22455	14970	14970	29939	14970
Price (Tk per ton)									
Worse case	16250	15000	12500	16250	12500	15000	18750	15000	15000
Typical case	22000	21500	17500	24500	20000	20000	24750	25000	20000
Best case	27000	26250	28000	28000	30000	30000	30000	30000	25000
Paid out cost (Tk/ha) (A)	49107	73549	97198	70472	58261	62105	59567	51952	64894
Imputed cost (Tk/ha) (B)	30497	40705	29154	34532	42026	35487	44651	41403	44361
Total cost (Tk/ha) (A+B)	79604	114254	126352	105004	100287	97592	104218	93355	109255
Net return (Tk per ha)									
Worse case	-30293	-65962	-65736	-49681	-51685	-26500	-46659	-49870	-38163
Typical case	34146	9593	4955	18474	11883	33435	6762	52600	33772
Best case	100838	89851	140058	64068	146568	191578	58952	116284	152715

Source: Authors' estimation based on field survey, 2019-2021.

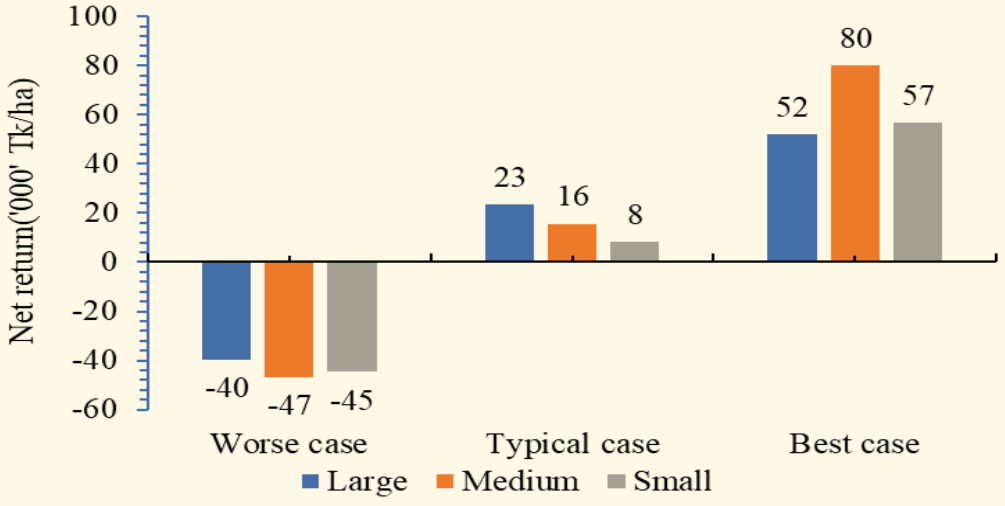


Figure 10.70: Farm types and case wise comparison in net-income (Tk per ha) for *T. Aus* in low-lying ecosystem

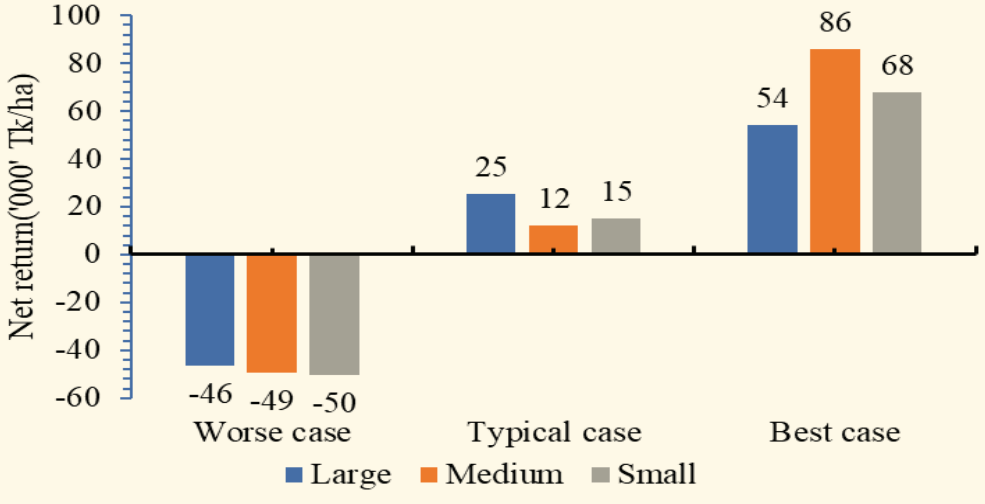


Figure 10.71: Farm types and case wise comparison in net-income (Tk per ha) for *T. Aman* in low-lying ecosystem

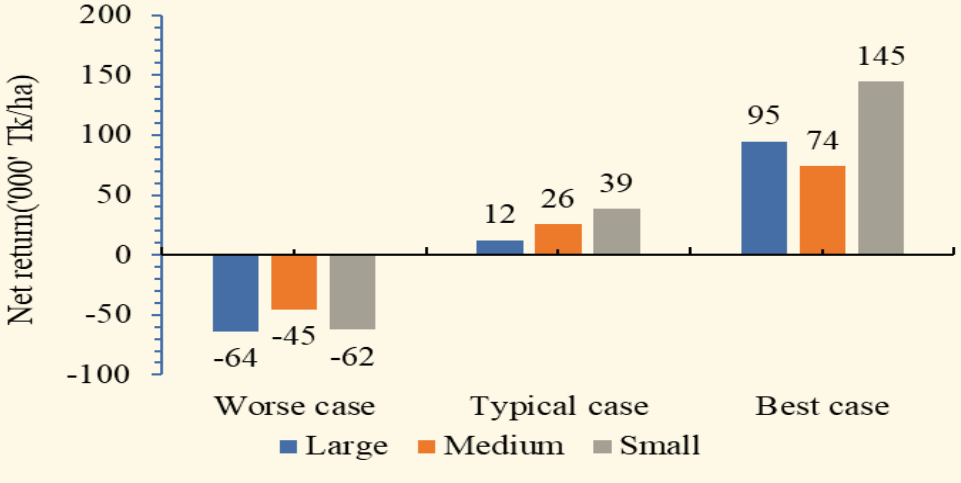
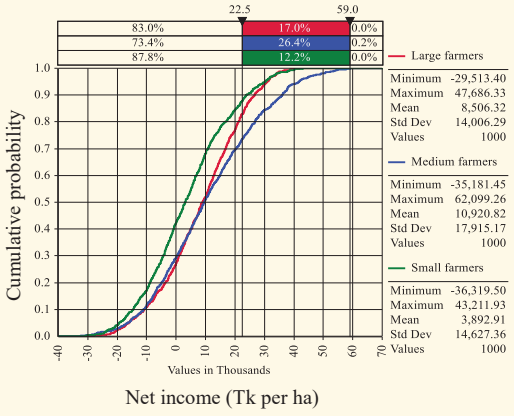


Figure 10.72: Farm types and case wise comparison in net-income (Tk per ha) for *Boro* in low-lying ecosystem

The lower benchmark (Tk. 22,000) was selected based on total imputed cost per ha in *T. Aus* under low-lying ecosystem, while the upper benchmark (Tk. 59,000) was chosen randomly. The probability of achieving NI per ha showed that medium farmer had about 26% chance of achieving NI per ha above the lower benchmark total imputed cost per ha, meaning that it could cover the cost of farm owned resources including family labour. The chance of receiving NI per ha above this threshold decreased to 17% for large farmer and 12% for small farmer (Figure 10.73(a)). The lower benchmark (Tk. 77,000) was selected based on total paid out cost for medium farmer, while the upper benchmark (Tk. 1,25,000) was chosen randomly. The cumulative probability of achieving GR per ha from *T. Aus* showed that large farmer and small farmer had about 99 and 94% chance of achieving GR per ha above the lower benchmark total paid out cost per ha in *T. Aus,* meaning that it could cover the cost of all cash costs. The chance of receiving GR per ha above this threshold slightly decreased to 84% for medium farmer (Figure10.73(b)).

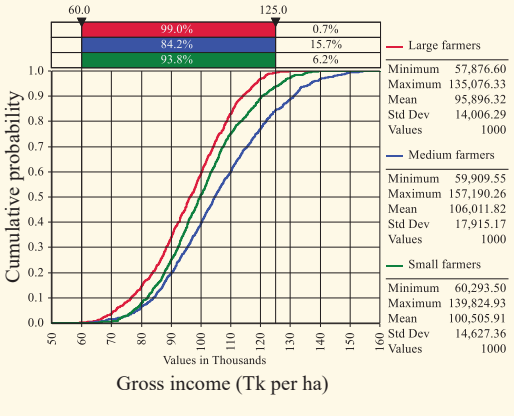
The lower benchmark (Tk. 24000) was selected based on total imputed cost per ha for large farmer, while the upper benchmark (Tk. 62,000) was chosen randomly. The cumulative probability of NI per ha from *T. Aman* showed that medium farmer had about 23% chance of achieving NI per ha above the lower benchmark, denoting that the probability to recover the cost of owned resources including family labour under low-lying ecosystem. The chance of receiving NI per ha above this threshold decreased to 13% for both large farmer and small farmer (Figure 10.74(a)). The lower benchmark (Tk. 64,000) was selected based on the paid-out costs (total paid out cost per ha) for medium farmer, while the upper benchmark (Tk. 1,37,000) was chosen randomly. The probability of achieving GR per ha showed that large farmer and small farmer had about 99% chance of achieving GR per ha above the lower benchmark total paid out cost per ha in *T. Aman*, respectively meaning that it could cover the cost of all cash costs. The chance of receiving GR per ha above this threshold decreased to 80% for medium farmer (Figure 10.74(b)). However, the cumulative probability of gaining NI indicated the higher probability to become negative in *T. Aman*.

The lower benchmark (Tk. 31,000) was selected based on total imputed cost per ha for large farmer in *Boro* under low-lying while the upper benchmark (Tk. 1,00,000) was chosen randomly. The cumulative probability of NI per ha from *Boro* showed that small farmer had about 46% chance of achieving NI per ha above the lower benchmark total imputed cost per ha in *Boro* under low-lying ecosystem, meaning that it could cover the cost of owned resources including family labour. The chance of receiving NI per ha above this threshold decreased to 17% for medium farmer and 20% for small farmer (Figure 10.75(a)). The lower benchmark (Tk. 77,000) was selected based on the total paid out cost per ha for medium farmer, while the upper benchmark (Tk. 1,89,000) was chosen randomly. The cumulative probability of achieving GR per ha showed that large farmer and medium farmer had 99% chance of achieving GR per ha, respectively above the lower benchmark total paid out cost per ha in this season, respectively meaning that it could cover the cost of all cash costs. The chance of receiving GR per ha above this threshold slightly decreased to 89% for small farmer (Figure 10.75(b)).



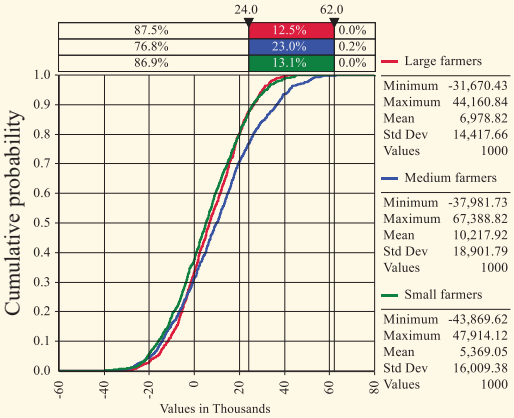
Net income (Tk per ha)

Figure 10.73(a): Cumulative probability of net-income (Tk per ha) of *T. Aus* rice cultivation in low-lying ecosystem



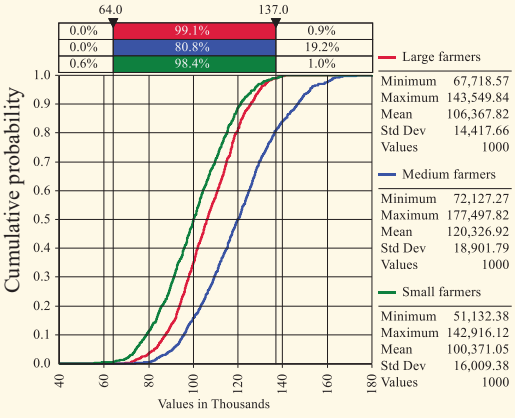
Gross income (Tk per ha)

Figure 10.73(b): Cumulative probability of gross income (Tk per ha) of *T. Aus* rice cultivation in low-lying ecosystem



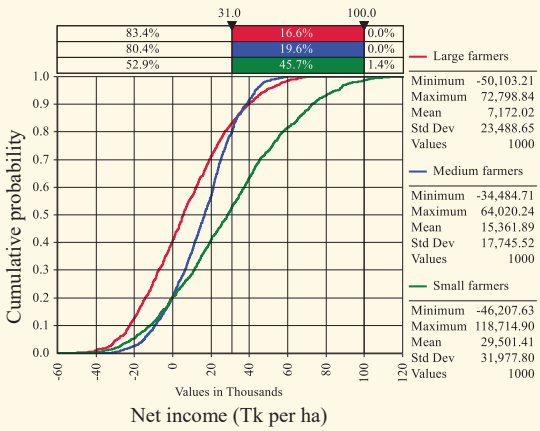
Net income (Tk per ha)

Figure 10.74(a): Cumulative probability of net-income (Tk per ha) of *T. Aman* rice cultivation in low-lying ecosystem



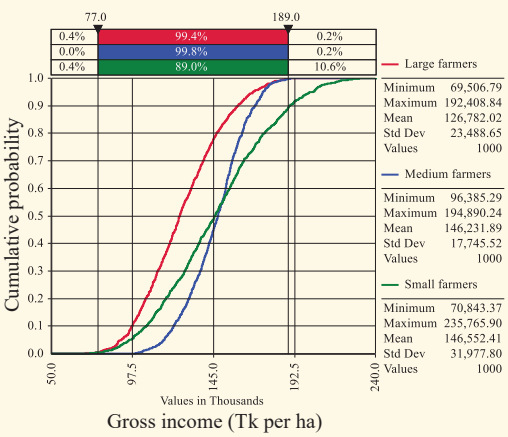
Gross income (Tk per ha)

Figure 10.74(b): Cumulative probability of gross income (Tk per ha) of *T. Aman* rice cultivation in low-lying ecosystem



Net income (Tk per ha)

Figure 10.75(a): Cumulative probability of net-income (Tk per ha) of *Boro* rice cultivation in low-lying ecosystem



Gross income (Tk per ha)

Figure 10.75(b): Cumulative probability of gross income (Tk per ha) of *Boro* rice cultivation in low-lying ecosystem

In assessing seasonal variation on economic viability of rice cultivation at current price, the variability in the yield of seasonal rice and straw value in the low-lying ecosystem had influence on farm profit with the reported market price. Figure 10.76 showed that, with all variables being constant other than yield, straw value and price, rice yield and straw value contributed together to the risk occurrence ranging from 55 to 65% in getting NI per ha above benchmark total imputed cost cost in *T. Aman* while more than 70% risk was induced by both yield and straw value in both *T. Aus* and *Boro* seasons. small farmer experienced higher risk of price variation on achievement of NI per above the lower benchmark total imputed cost per ha in both *T. Aman* (46%) followed by medium and small farmers, respectively in the same season. However, the risk of marker price volatility of rice was found relatively lower in *T. Aus* and *Boro* under low-lying ecosystem. The risk occurred in getting the NI per ha above benchmark cost of owned resources from yield and straw value was higher for both medium farmer and small farmer than that for large farmer in low-lying ecosystem. Similar pattern of risk (65-70% arose from yield and straw value) was observed in getting GR per ha above benchmark cash cost for all farm types across the seasons. The analysis revealed that the rice production was economically viable at current price and average seasonal yields, but yield and price have outmost effect on the profitability of the rice cultivation which was aroused by erratic climate (temperature, heat wave and rainfall), water logging, occurrence of casual flood and market distortion in low-lying ecosystem (Figure 10.77).

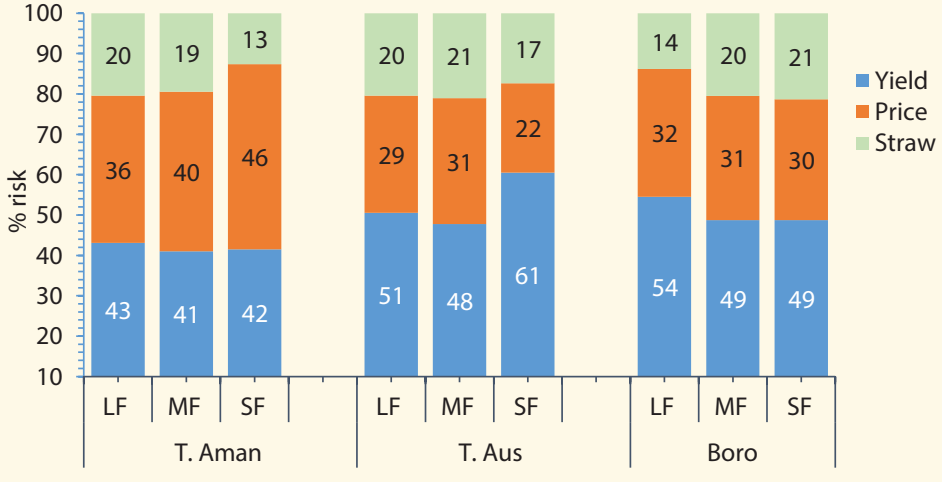


Figure 10.76: Inputs' effect ranked on NI for *T. Aman*, *T. Aus* and *Boro* rice in low-lying ecosystem

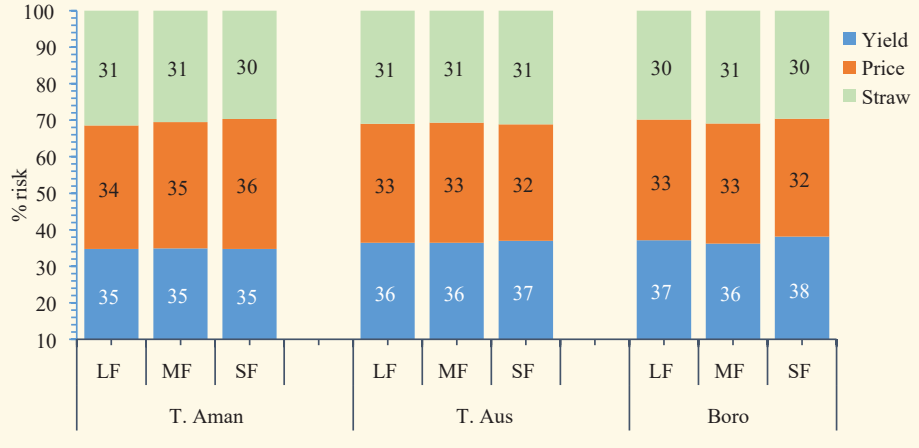


Figure 10.77: Inputs' effect ranked on GR for *T. Aman*, *T. Aus* and *Boro* rice in low-lying ecosystem

10.8 Financial and risk analysis of rice production in hilly ecosystem

Representative farm budgets for seasonal rice production were computed with the market prices in 2020 for the average/moderate/typical value of all farm categories. Based on average value from sample survey, was estimated and cross checked with focus group discussion (FGD) as well as key informant survey (KIS). Representative farm budget, variation in both yield and price under weather and market variability were finally developed.

10.8.1 Input use pattern and productivity of rice in hilly ecosystem

The pattern of inputs use in seasonal rice cultivation by three farm types in hilly ecosystem can be viewed in table 10.22. The level of per ha inputs use in *Boro* season by small farmer was relatively higher than that of large farmer and medium farmer in hilly ecosystem. In some case, magnitude of inputs use seems to be same for large, medium and small farmer in *T. Aman* and *T. Aus* season.

Large farmer used 52 kg/ha seed for producing *T. Aus* rice which is 28 kg higher than medium farmer and more than double small farmer. Contractual costs for large, medium and small farmer didn't vary much extent, it was quite same in all the seasons. Seed rate was not quite higher than recommended rate among different farmers' categories. Large farmer used considerably seed rate of 25 kg/ha in *T. Aman* 45 kg/ha in *Boro* whereas small farmer used seed rate of 46 kg/ha in *T. Aman* and 24 kg/ha in *T. Aus* and 42 kg/ha in *Boro*.

Table 10.22: Input use pattern, productivity and price of seasonal rice in hilly ecosystem

Input items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Seed (kg/ha)	52	25	45	24	46	42	45	48	37
Land preparation	3450	5250	2850	3150	6450	2850	3150	4575	4275
Human labour (man-days/ha)									
Hired	64	69	52	45	48	56	60	57	51
Family	20	42	22	28	25	36	36	32	38
Contractual	10366	12450	12258	13560	12150	9870	9680	12236	12148
Fertilizer (Kg/ha)									
Urea	77	124	123	119	118	123	141	138	136
TSP	46	96	106	57	103	106	41	101	102
MOP	46	70	38	42	86	38	42	61	57
DAP	22	25	14	8	18	14	19	10	33
Gypsum	16	10	21	6	12	20	13	18	18
Sulpher	0	0	0	0	0	0	0	0	0
Zinc	0	0	0	0	0	0	0	0	0
Mg	0	0	0	0	0	0	0	0	0
Theovit	2	5	7	0	5	6	0	5	5
Irrigation	624	487	3176	450	553	3706	450	1169	3220
Herbicides	224	236	745	210	268	843	268	340	952
Insecticides	1204	3088	2264	1328	1807	2034	1622	2261	3044
Yield (ton/ha)	4.36	4.9	5.6	4.76	4.4	5.3	4.7	4.5	5.2
Straw (Tk/ha)	3845	2845	5423	3063	4732	3288	1903	4425	4313

Source: Authors' estimation based on field survey, 2019-2021.

All categories of the farmers used lower amount of urea than the recommended dose and that was the reason for lower yield. In addition, large, medium and small farmer applied moderate amount of TSP in both *T. Aus* and *Boro* season, but the situation was different in case of T. *Aman* season where they used more than the recommended dose (56 kg/ha). Average yield of large farmer (5.6 t/ha) in *Boro* season was considerably higher than medium farmer (5.3 t/ha) and small farmer (5.2 t/ha). In *T. Aman*, yield performance of large farmer was also (4.9 t/ha) higher compared to medium farmer (4.4 t/ha) and small farmer (4.7 t/ha). On the contrary, average yield of medium farmer (4.76 t/ha) in *T. Aus* found higher than small farmer (4.7t/ha) and large farmer (4.36 t/ha) (Table 10.22).



Picture 6: Rice field in hilly ecosystem

10.8.2 Scenario of cost and return of rice production in hilly ecosystem

Data in table 10.23 show that per ha total cost of *Boro* season for small farmer was higher by Tk. 6756 and Tk. 2950 than that for large farmer and medium farmer, respectively due to differences in the man-days of hired labor and irrigation costs. Per ha total cost of *T. Aman* season was relatively higher for large farmer than that for medium farmer by Tk. 6933 and small farmer by Tk.2610 because of differences in the man days of hired labor, contractual cost and fertilizers application. In addition, per ha total cost of *T. Aus* season was relatively higher for small farmer than that for large farmer by Tk. 3591 and medium farmer by Tk.7443 because of differences in family labor and fertilizer application. It is important to mention that wages and market price of input did not vary across the season among farmer's categories.

The actual total paid out cost usually includes seed, land preparation, hired labour, fertilizers, herbicides, insecticides, and power thresher representing 67%, 67% and 68% of total cost in *T. Aman* for large, medium and small farmer, respectively. On the contrary, the total imputed cost of medium farmer and large farmer shared 32% of total cost and stood at 31% of total cost for small farmer. The total paid out cost of large farmer in *T. Aus* shared 76% of total cost, and stood at 70% of total cost for medium farmer and small farmer. The total imputed cost of small farmer and medium farmer shared 29% of total cost and stood at 23% of total cost for large farmer. Similarly, the total paid out cost in *Boro* season shared 72% of total cost for large farmer and stood at 68% for small farmer and 67% for medium farmer, respectively. In *Boro* season, the imputed cost was 32%, 31% and 27% of total cost for medium, small and large farmer, respectively. The BCR found more

than one on cash cost and full cost basis in all rice season and the positive net return denoting that return outyielded total investment in rice production (Table 10.23).

Table 10.23 Production cost and return in rice production in different seasons in hilly ecosystem

Cost and income (Tk/ha)	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	T. *Aman*	Boro	*T. Aus*	T. *Aman*	Boro	*T. Aus*	T. *Aman*	Boro
Paid out cost (A)	51967	56910	55537	45126	52642	54427	49947	56469	57017
Seed	1300	625	1125	600	1150	1050	1125	1200	925
Land preparation	3450	5250	2850	3150	6450	2850	3150	4575	4275
Hired labour	28800	31050	23400	20250	21600	25200	27000	25650	22950
Contractual	10366	12450	12258	13560	12150	9870	9680	12236	12148
Power thresher	2186	1254	2633	1025	1547	2578	1625	2245	2236
Fertilizer	3813	2470	7086	4553	7117	6297	5027	6793	7267
Irrigation	624	487	3176	450	553	3706	450	1169	3220
Herbicides	224	236	745	210	268	843	268	340	952
Insecticides	1204	3088	2264	1328	1807	2034	1622	2261	3044
Imputed cost (B)	15618	27637	21044	18608	24972	25960	21229	25468	26320
Seedbed	1935	3088	3266	2182	4909	3267	1866	2908	2718
Family labour	7000	14700	7700	9800	8750	12600	12600	11200	13300
Land rent	6250	9375	9615	6250	10875	9639	6348	10890	9827
IOC at 4% for 5 months	433	474	463	376	439	454	416	471	475
Total cost (A+B)	67585	84547	76581	63733	77614	80387	71176	81937	83337
Gross return	100280	120050	119000	109480	101200	110903	99288	103500	108810
Net-income	32695	35503	42419	45747	23586	30516	28111	21563	25473
BCR (Cash cost)	1.93	2.11	2.14	2.43	1.92	2.04	1.99	1.83	1.91
BCR (Full cost)	1.48	1.42	1.55	1.72	1.3	1.38	1.39	1.26	1.31

Source: Authors' estimation based on field survey, 2019-2021.

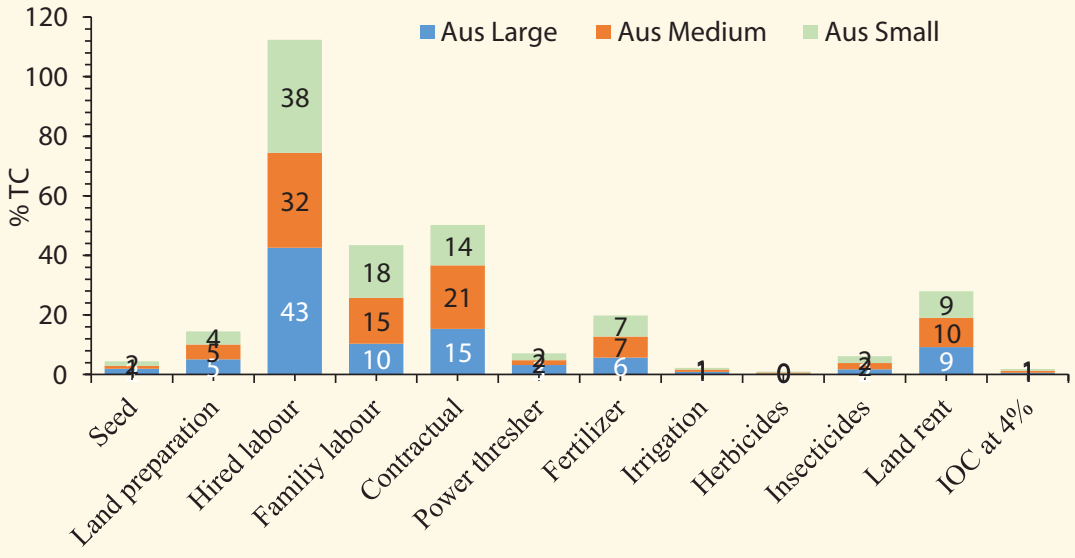


Figure 10.78: Share of per hectare inputs cost to total cost of *T. Aus* cultivation in hilly ecosystem

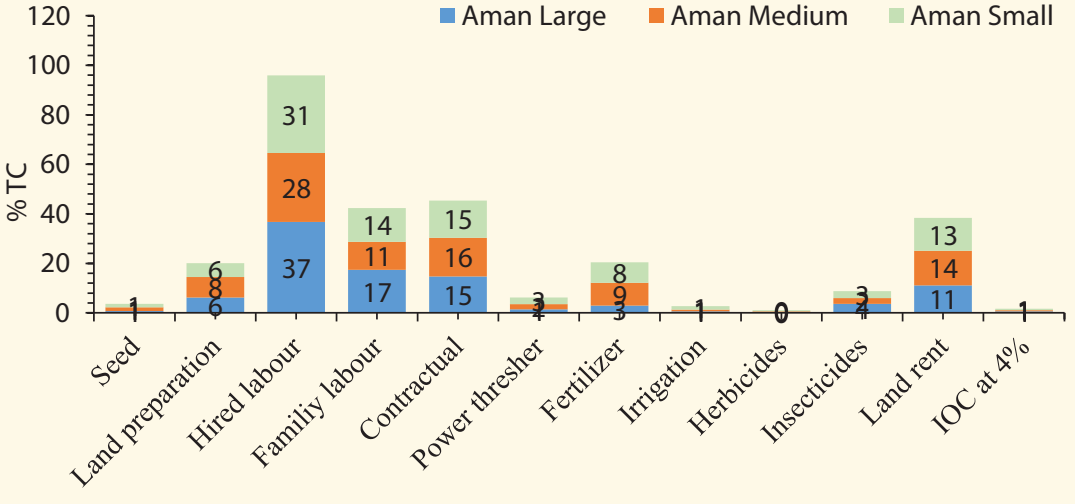


Figure 10.79: Share of per hectare inputs cost tototal cost of *T. Aman* cultivation in hilly ecosystem

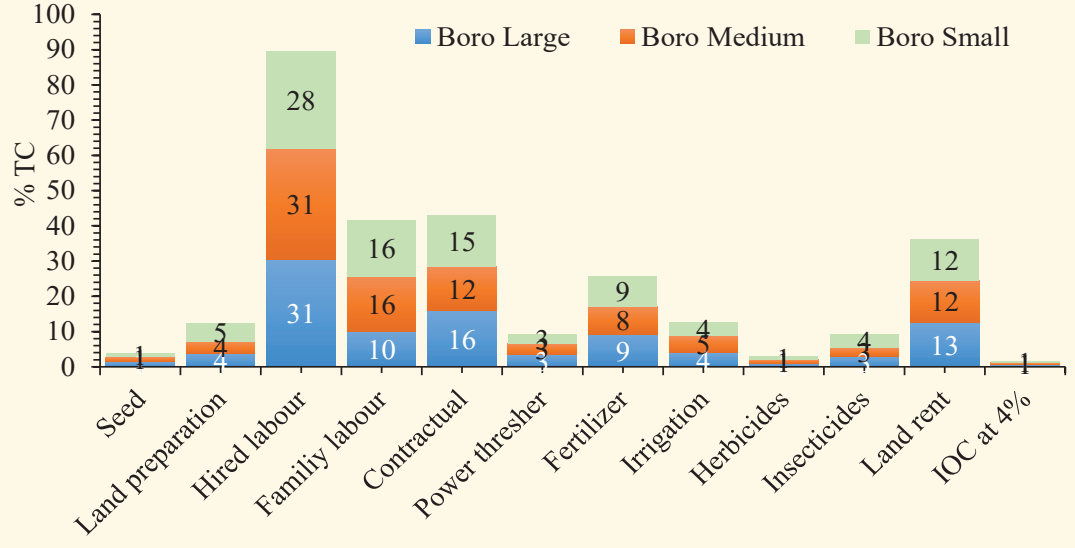


Figure 10.80: Share of per hectare inputs cost to total cost of *Boro* cultivation in hilly ecosystem

10.8.3 Risk analysis of rice production under hilly ecosystem

In assessing economic viability of rice cultivation at the reported market price, the variability of yield of rice and straw value in the hilly ecosystem on farm profit was synthesized based on the households' survey and key informants survey.

The average/moderate/typical value of rice yield, straw value, inputs use and market price of rice estimated from household survey of hilly ecosystem were crosschecked with the key informant survey to get more standard data. Moreover, farmers offered to supply their produces in at a higher price than that in the worst case. The gross return (GR) of rice was computed by multiplying rice yields by the reported price (Table 10.24). In constructing the stochastic budgeting of rice production in submergence ecosystems, production cost and profitability of this ecosystem was taken into risk analysis (Table 10.24). Stochastic budgets were eventually constructed for seasonal rice cultivation considering farmers' perceived variation in yield and market price by different farm types. The stochastic budget analysis displayed that seasonal rice cultivation was economically viable at the reported average/typical market price and yield. Likewise, triangular distribution was adopted by worst, typical/average, and best yields, straw value and price for different farm types across the seasons. In addition, the distribution of the collected data based on farmers' observations fully buttressed with the triangle algorithm of risk prediction. Figure 10.81-10.83 showed that rice production in all seasons for large, medium and small farmers was found to be more profitable in the farmers' perceived typical and best case than that in the worst case. However, farmers always suffer from negative net-income in the worst case caused by weather stress (unpredictive climatic factor such as erratic temperature and rainfall, and drought).

Table 10.24 Stochastic budgeting of rice production by farm types in hilly ecosystem

Items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Yield (ton per ha)									
Worse case	2.8	2.2	3.2	2.3	3.1	3.38	2.1	2.24	2.08
Typical case	4.36	4.9	5.6	4.76	4.4	5.3	4.7	4.5	5.2
Best case	5.28	5.64	8.47	5.87	6.25	7.62	5.064	5.08	7.25
Straw (Tk per ha)									
Worse case	1380	1256	3268	1523	2200	1428	1200	2214	2436
Typical case	3845	2845	5423	3063	4732	3288	1903	4425	4313
Best case	5634	4586	6800	8547	5469	6586	4035	6870	8045
Price (Tk per ton)									
Worse case	17500	15250	15250	17750	15625	15000	17250	15250	15125
Typical case	23000	24500	21250	23000	23000	20925	21125	23000	20925
Best case	23750	25250	25000	24000	25250	23750	25625	24500	25250

Items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Paid out cost (Tk/ha) (A)	51967	56910	55537	45126	52642	54427	49947	56469	57017
Imputed cost (Tk/ha) (B)	15618	27637	21044	18608	24972	25960	21229	25468	26320
Total cost (Tk/ha) (A+B)	67585	84547	76581	63733	77614	80387	71176	81937	83337
Net return (Tk per ha)									
Worse case	-17205	-49741	-24513	-21385	-26977	-28259	-33751	-45563	-49441
Typical case	36540	38348	47842	48810	28318	33804	30015	25988	29786
Best case	63449	62449	141969	85694	85668	107174	62624	49393	107771

Source: Authors' estimation based on field survey, 2019-2021.

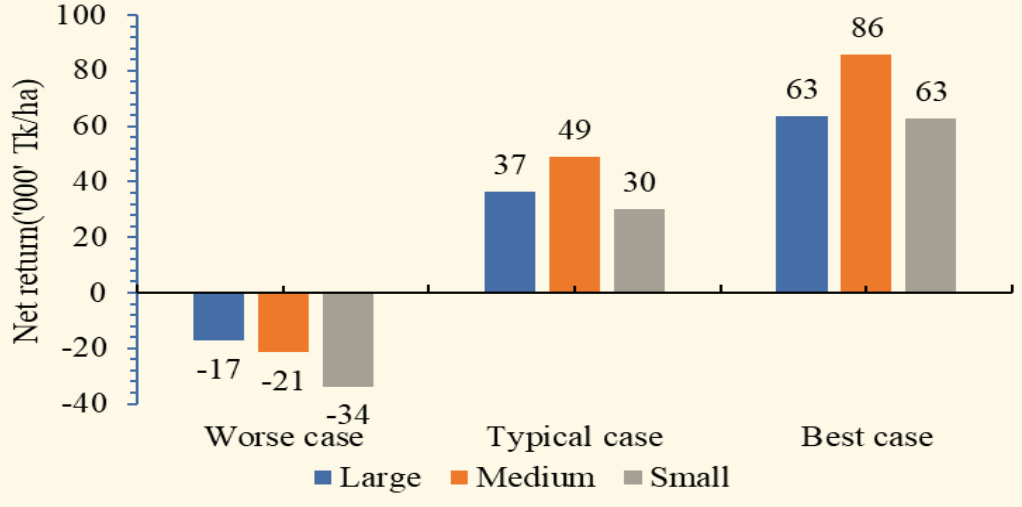


Figure 10.81: Farm types and case wise comparison in net-income (Tk per ha) for *T. Aus* in hilly ecosystem

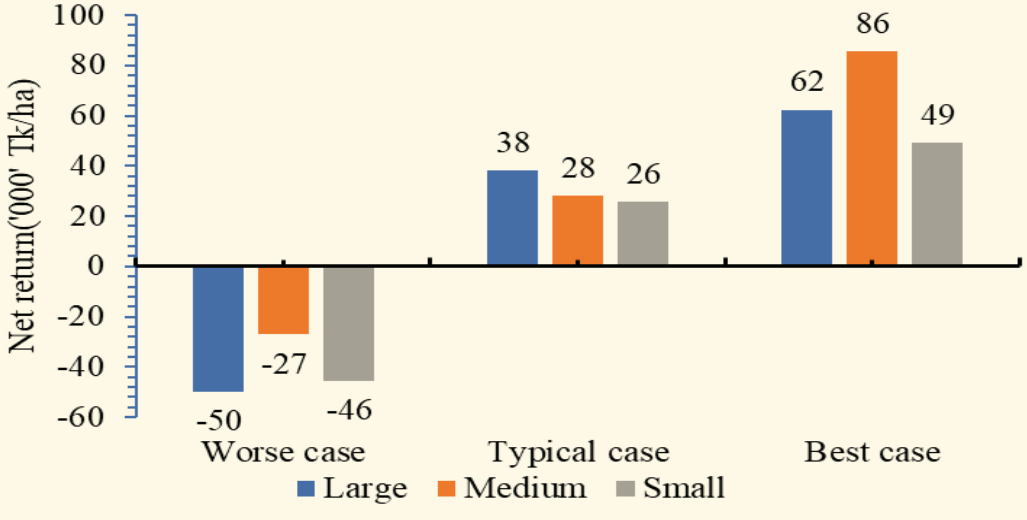


Figure 10.82: Farm types and case wise comparison in net-income (Tk per ha) for *T. Aman* in hilly ecosystem

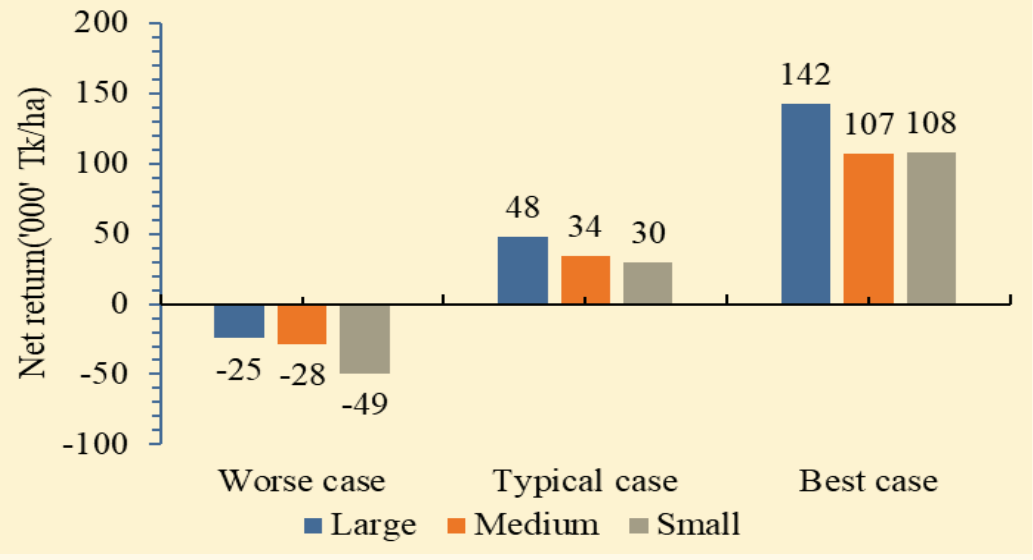


Figure 10.83: Farm types and case wise comparison in net-income (Tk per ha) for *Boro* in hilly ecosystem

The lower benchmark (Tk. 15000) was selected based on total imputed cost per ha of *T. Aus* under hilly ecosystem, while the upper benchmark (Tk. 63000) was chosen randomly. The cumulative probability of obtaining NI per ha showed that large farmer and medium farmer had about 77 and 81% chance of obtaining NI per ha, respectively above the lower benchmark total imputed cost per ha, meaning that it could cover the cost of owned resources including family labour. The chance of receiving NI per ha above this threshold substantially decreased to 54% for small farmer (Figure 10.84(a)). The lower benchmark (Tk. 71000) was selected based on total paid out cost for medium farmer of *T. Aus* in hilly ecosystem, while the upper benchmark (Tk. 111000) was chosen randomly. The cumulative probability of GR per ha showed that large farmer had 96% chance of GR per ha above the lower benchmark total paid out cost per ha meaning that it could cover the cost of all cash costs. The chance of receiving GR per ha above this threshold substantially decreased to 69 and 77% for medium farmer and small farmer, respectively (Figure 10.84(b)).

The lower benchmark (Tk. 21000) was selected based on total imputed cost per ha for large farmer in *T. Aman* under hilly ecosystem, while the upper benchmark (Tk. 62000) was chosen randomly. The cumulative probability of getting NI per ha showed that medium farmer had about 54% chance of achieving NI per ha above the lower benchmark total imputed cost per ha, denoting that the probability to recover the cost of owned resources including family labour. The chance of receiving NI per ha above this threshold decreased to 29% for large farmer and 16% for small farmer (Figure 10.83(a)). The lower benchmark (Tk. 52000) was selected based on the paid-out costs (total paid out cost per ha) for medium farmer, while the upper benchmark (Tk. 125000) was chosen randomly. The cumulative probability of gaining GR per ha showed that large farmer and small farmer had about 99 and 94% chance of achieving GR per ha above the lower benchmark total paid out cost per ha, respectively meaning that it could cover the cost of all cash costs in *T. Aman* rice production. The chance of receiving GR per ha above this threshold decreased to 91% for medium farmer (Figure 10.83(b)). However, chance of probability of obtaining NI per ha indicated the higher probability to become negative in *T. Aman*.

The lower benchmark (Tk. 21000) was selected based on total imputed cost per ha for large farmer of *Boro* under hilly ecosystem, while the upper benchmark (Tk. 98000) was chosen randomly. The cumulative probability of obtaining NI per ha showed that large farmer had about 82% chance of gaining NI per ha above the lower benchmark total imputed cost per ha, meaning that it could cover the cost of farm owned resources including family labour. The chance of receiving NI per ha above this threshold considerably decreased to 68% for medium farmer and 50% for small farmer (Figure 10.86(a)). The lower benchmark (Tk. 54000) was selected based on the total paid out cost per ha of *Boro* for medium farmer under hilly ecosystem, while the upper benchmark (Tk. 165000) was chosen randomly. The cumulative probability of obtaining GR per ha showed that medium farmer and small farmer had 99% chance of obtaining GR per ha of *Boro* under this ecosystem, respectively above the lower benchmark total paid out cost per ha, respectively meaning that it could cover the cost of all cash costs. The chance of receiving GR per ha above this threshold slightly decreased to 94% for large farmer (Figure 10.86(b)).

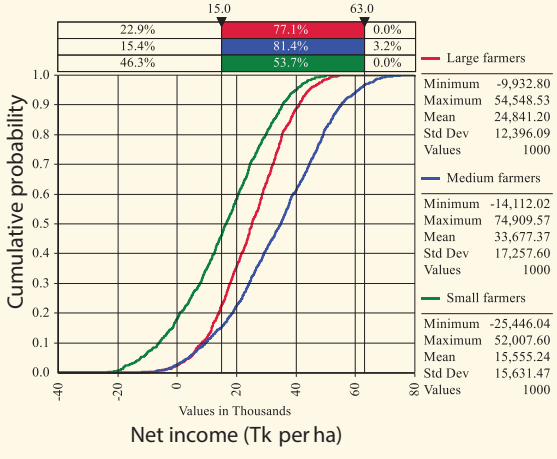


Figure 10.84(a): Cumulative probability of net-income (Tk per ha) of *T. Aus* rice cultivation in hilly ecosystem

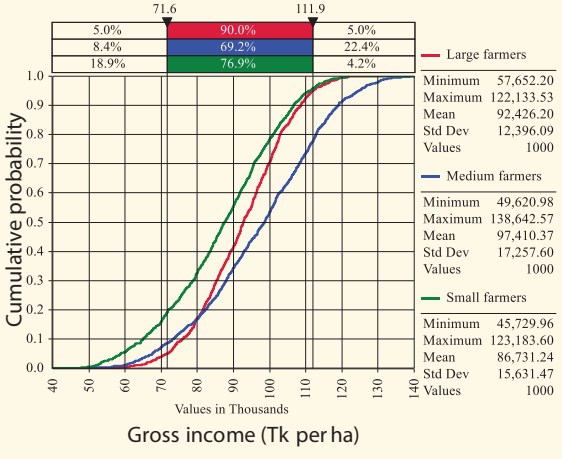


Figure 10.84(b): Cumulative probability of gross income (Tk per ha) of *T. Aus* rice cultivation in hilly ecosystem

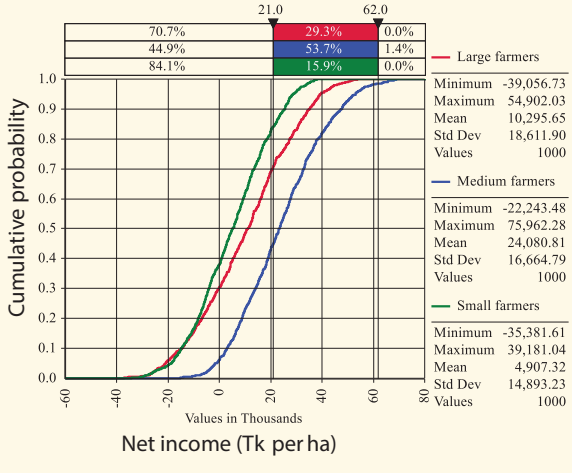


Figure 10.85(a): Cumulative probability of net-income (Tk per ha) of *T. Aman* rice cultivation in hilly ecosystem

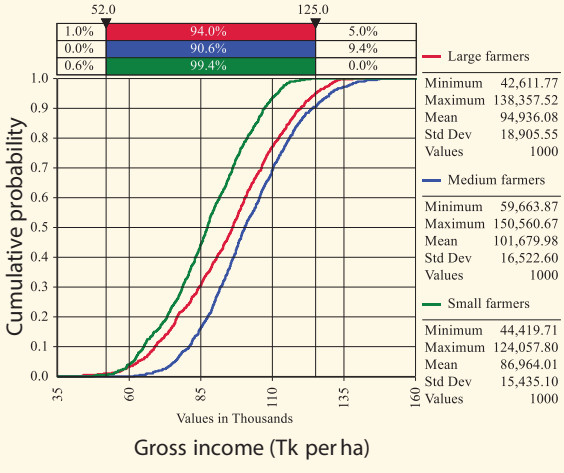


Figure 10.85(b): Cumulative probability of gross income (Tk per ha) of *T. Aman* rice cultivation in hilly ecosystem

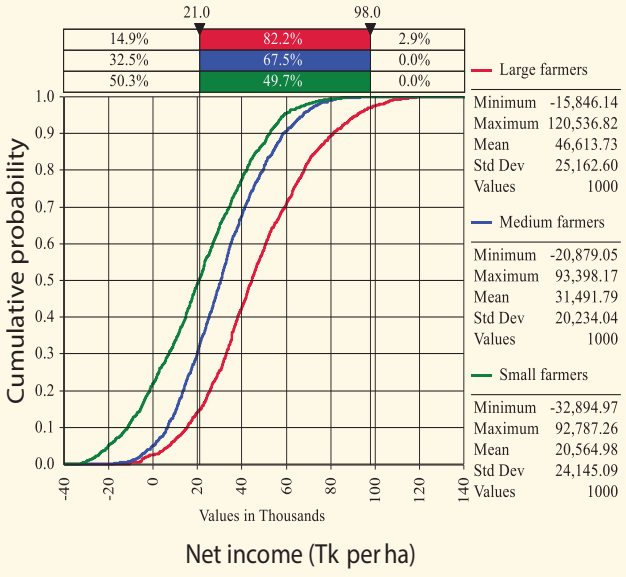


Figure 10.86(a): Cumulative probability of net-income (Tk per ha) of *Boro* rice cultivation in hilly ecosystem

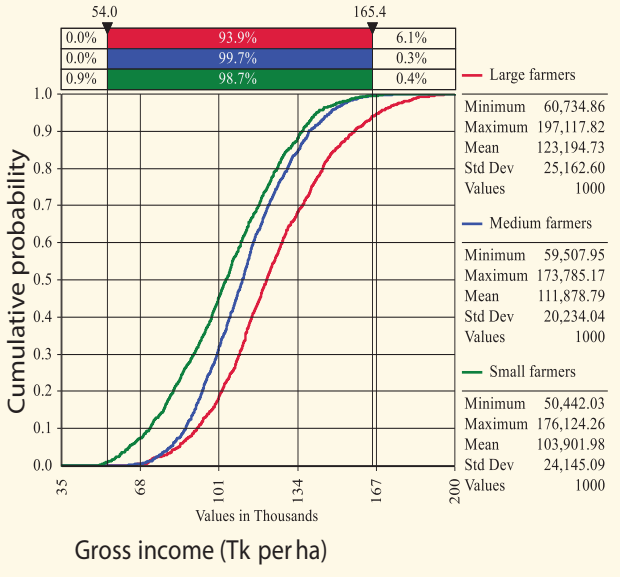


Figure 10.86(b): Cumulative probability of gross income (Tk per ha) of *Boro* rice cultivation in hilly ecosystem

In assessing seasonal variation on economic viability of rice cultivation at current price, the variability in the yield of seasonal rice and straw value in the hilly ecosystem had influence on farm profit with the reported market price. Figure 10.87 showed that, with all variables being constant other than yield, straw value and price, rice yield and straw value contributed together to the risk occurrence ranging from 66 to 70% in getting NI per ha above benchmark total imputed cost cost in all seasons. large farmer and small farmer experienced relatively more risk of price variation on achievement of NI per above the lower benchmark total imputed cost per ha in both *T. Aus* (32%) and *Boro* (34%) rice production (46%) followed by medium and small farmers, respectively in the same season. However, the risk of marker price volatility of rice was found relatively lower in *T. Aus* and *Boro* under low lying ecosystem. The risk occurred in getting the NI per ha above benchmark cost of owned resources from yield and straw value was higher for both medium farmer and small farmer than that for large farmer in low-lying ecosystem. Similar pattern of risk (66-70% arose from yield and straw value) was observed in getting GR per ha above benchmark cash cost for all farm types across the seasons. The analysis revealed that the rice production was economically viable at current price and average seasonal yields, but yield and price have outmost effect on the profitability of the rice cultivation which was aroused by erratic climate (temperature, heat wave and rainfall), water logging, occurrence of casual flood and market distortion in hill ecosystem (Figure 10.88).

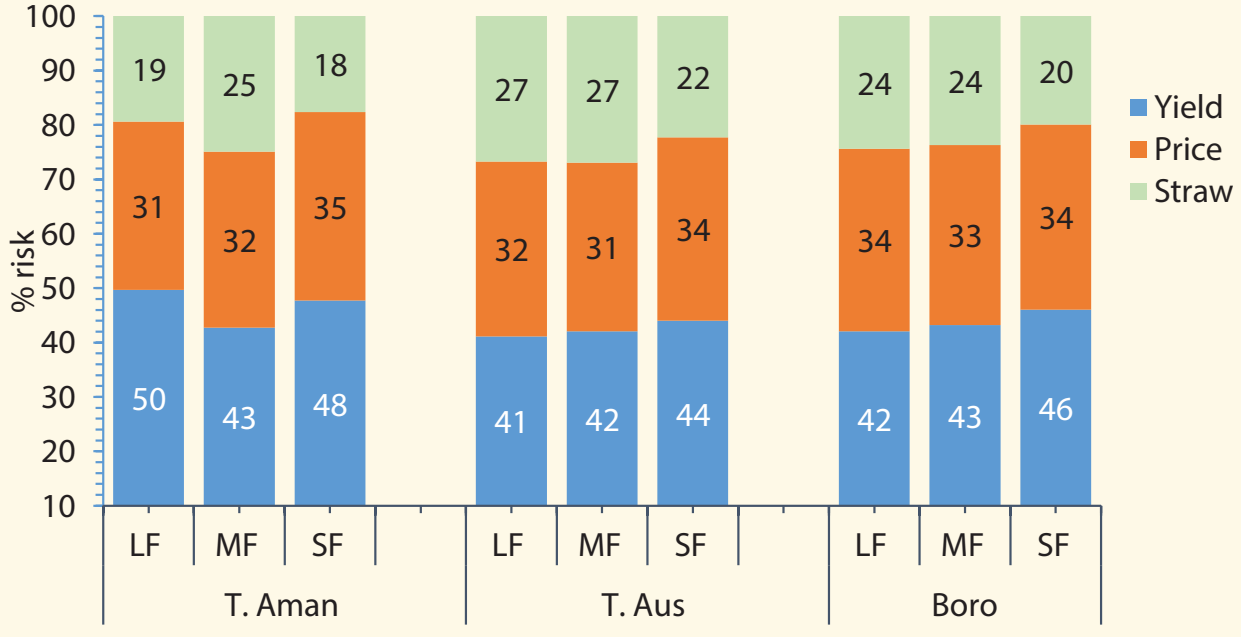


Figure 10.87: Inputs' effect ranked on NI for *T. Aman*, *T. Aus* and *Boro* rice in hilly ecosystem

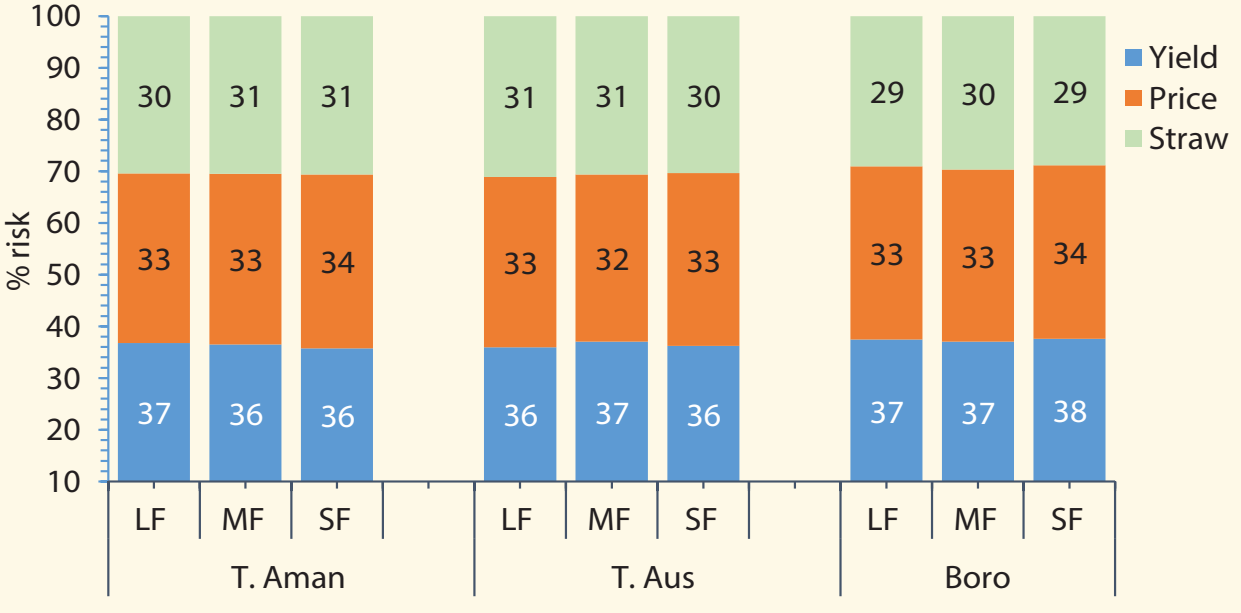


Figure 10.88: Inputs' effect ranked on GR for *T. Aman*, *T. Aus* and *Boro* rice in hilly ecosystem

10.9 Financial and risk analysis of rice production under pool data

Representative farm budgets for seasonal rice production were computed with the market prices in 2020 for the average/moderate/typical value of all farm categories. Based on average value from sample survey, was estimated and cross checked with focus group discussion (FGD) as well as key informant survey (KIS). Representative farm budget, variation in both yield and price under weather and market variability were finally developed.

10.9.1 Input use pattern and productivity of rice under pooled data

The pattern of inputs use in seasonal rice cultivation by three farm types can be viewed in table 10.25. Large farmer used more than 80% hired labour among *T. Aman*, *T. Aus* and *Boro*, respectively for all kind of production activities. On the contrary, small farmer used nearly 50% family labour among *T. Aman*, *T. Aus* and *Boro*, respectively in rice cultivation and medium farmer used little nearly 70% hired labour in *T. Aman* and *Boro* and 89% hired labour in *T. Aus* to carry out the production activities of seasonal rice. Contractual costs for large farmer were much higher than that for small and medium farmer in all rice growing seasons. They opined that farmer purchased HYV rice quality seed from market and most of them did not treat the rice seed to control diseases before sowing. Seed rate was moderately higher than recommended rate. large farmer used seed rate of 30-37 kg/ha in *T. Aman*, *T. Aus* and *Boro* whereas medium farmer used seed rate of about 37 kg/ha among the seasons. Small farmer used seed rate of 37 kg/ha in *T. Aman* and *T. Aus* and 41kg/ha in *T. Aus*.

Only all farmers applied about 3% and 34% more urea in *T. Aman* and *Boro* season than the moderate recommended dose (185 kg/ha), but they used 19-30% lower amount of urea in *T. Aus* (BRRI Adhunik Dhaner Chas 2020). In addition, large farmer used to apply more TSP and MOP, than that of medium and small farmer even more than recommended rate. All types of farmers applied lower rate of DAP, Gypsum, Zinc and theovit in rice cultivation than recommended rate (Table 23). Average yield is 5.99 t/ha for the farmers in *Boro* season. In *T. Aman*, yield of small farmer (5.95 t/ha) was higher than large farmer (4.95t/ha) and medium farmer (4.59 t/ha), in *T. Aus* season, yield of small farmer (4.74 t/ha) was higher than that of medium and small farmer (4.95 t/ha) appeared to be higher than large farmer (4.09 t/ha) (Table 10.25).

Table 10.25: Input use pattern, productivity and price of seasonal rice cultivation of pooled data

Items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Seed	30	37	37	37	41	37	41	37	37
Land preparation	7485	8233	5988	8233	5988	5988	7410	8233	6988
Human labour (man-days/ha)									
Hired	51	62	41	57	72	74	44	42	44
Family	10	13	8	7	22	34	35	47	42
Contractual	11467	21978	18712	19064	18712	7712	10350	11612	20712
Fertilizer (Kg/ha)									
Urea	150	190	247	110	190	247	140	190	247
TSP	75	82	112	75	56	124	82	82	124
MOP	75	112	75	112	112	82	124	82	75
DAP	34	75	49	112	75	82	82	75	75
Gypsum	75	75	37	37	37	37	41	37	75
Sulpher	7	8	8	8	8	8	8	8	8
Zinc	0	7	7	8	7	7	8	7	7
Mg	2	16	16	8	16	16	8	16	16

Items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Theovit	6	7	8	8	7	7	8	8	7
Irrigation	1871	2994	14970	6175	2245	14970	1470	2470	14970
Herbicides	23	374	374	374	748	247	823	1235	374
Insecticides	814	1123	2994	1123	2245	1123	2470	1123	1123
Yield (ton/ha)	4.09	4.95	5.99	4.59	4.95	5.99	4.95	5.94	5.99
Straw (Tk/ha)	14970	22455	18712	11227	20958	11227	11227	14970	18712

Source: Authors' estimation based on field survey, 2019-2021.

10.9.2 Scenario of cost and return of rice production under pooled data

Table 10.26 shows that total cost per ha of *Boro* season for medium farmer was higher by almost Tk. 19000 than that for large farmer and small farmer, respectively due to differences in the man-days of hired labour, fertilizer costs and irrigation. Per ha total cost in *T. Aman* season for medium farmer was relatively higher than that for large farmer by Tk. 7857 and for small farmer by Tk. 32667, due mainly to differences in hired labour, contractual cost and fertilizer application. In addition, per ha total cost of medium farmer in *T. Aus* seasons was also higher than that for large farmer and small farmer by nearly Tk. 30000.

The actual paid-out costs includes seed, land preparation, hired labour, fertilizers, herbicides, insecticides, and power thresher which were the major items for rice cultivation standing for more than 70% of total cost in three rice growing seasons for large farmer and medium farmer, respectively, and decreased to slightly more than 60% for small farmer. On the contrary, the imputed cost of land rent and family labour showed almost 22-24% of total cost for large farmer and increased to 32-38 for small farmer. The imputed cost in both *T. Aman* and *T. Aus* showed nearly 26 and 18% of total cost for medium farmer, increased to 30% of total cost for small farmer in *Boro* season. Net return of small farmer in all seasons showed higher than that for large farmer and medium farmer. The BCR found more than one on cash cost and full cost basis in all rice seasons and the positive net return denoting that return outyielded total investment in rice production

Table 10.26: Production cost and return in rice production in different seasons of pooled data

Items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Paid out cost (A)	56720	81370	80705	77566	80325	83151	60572	60219	84400
Seed	1500	1850	1850	1850	2050	1850	2050	1850	1850
Land preparation	7485	8233	5988	8233	5988	5988	7410	8233	6988
Hired labour	22185	26970	17835	24795	31320	32190	19140	18270	19140
Contractual	11467	21978	18712	19064	18712	7712	10350	11612	20712
Power thresher	2245	3800	3742	3293	4117	3742	4233	2245	3742

Items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Fertilizer	9130	14048	14240	12659	12899	15329	12625	13180	15501
Irrigation	1871	2994	14970	6175	2245	14970	1470	2470	14970
Herbicides	23	374	374	374	748	247	823	1235	374
Insecticides	814	1123	2994	1123	2245	1123	2470	1123	1123
Imputed cost (B)	20938	26848	28667	20430	30978	39810	32469	41686	43488
Seedbed	1846	2245	2245	2470	2470	2058	2470	2470	2245
Family labour	4350	5655	3480	3045	9570	14790	15225	20445	18270
Land rent	14269	18269	22269	14269	18269	22269	14269	18269	22269
IOC at 4% for 5 months	473	678	673	646	669	693	505	502	703
Total cost (A+B)	77658	108217	109372	97996	111303	122961	93040	101905	127888
Gross return (Tk/ha)	86561	132637	123500	103082	119998	139967	110027	133770	144458
Net return (Tk/ha)	8903	24419	14128	5086	8694	17006	16987	31865	16570
BCR (Cash cost)	1.53	1.63	1.53	1.33	1.49	1.68	1.82	2.22	1.71
BCR (Full cost)	1.11	1.23	1.13	1.05	1.08	1.14	1.18	1.31	1.13

Source: Authors' estimation based on field survey, 2019-2021.

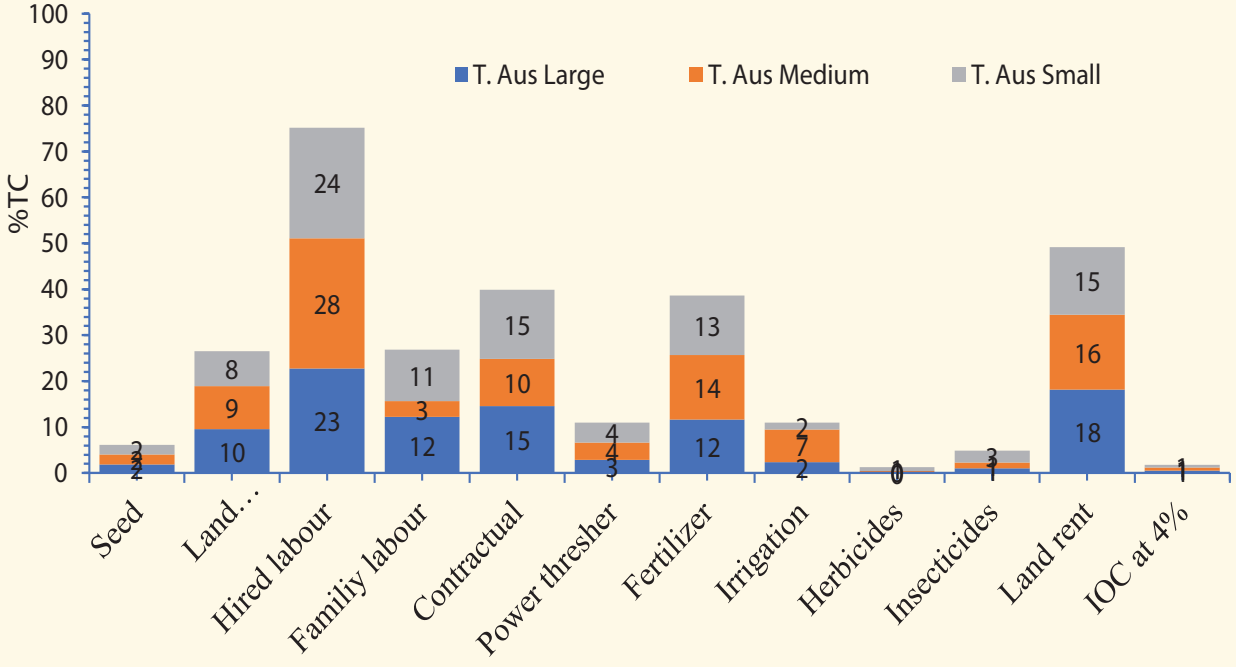


Figure 10.89: Share of per hectare inputs cost to total cost of *T. Aus* cultivation in pooled data

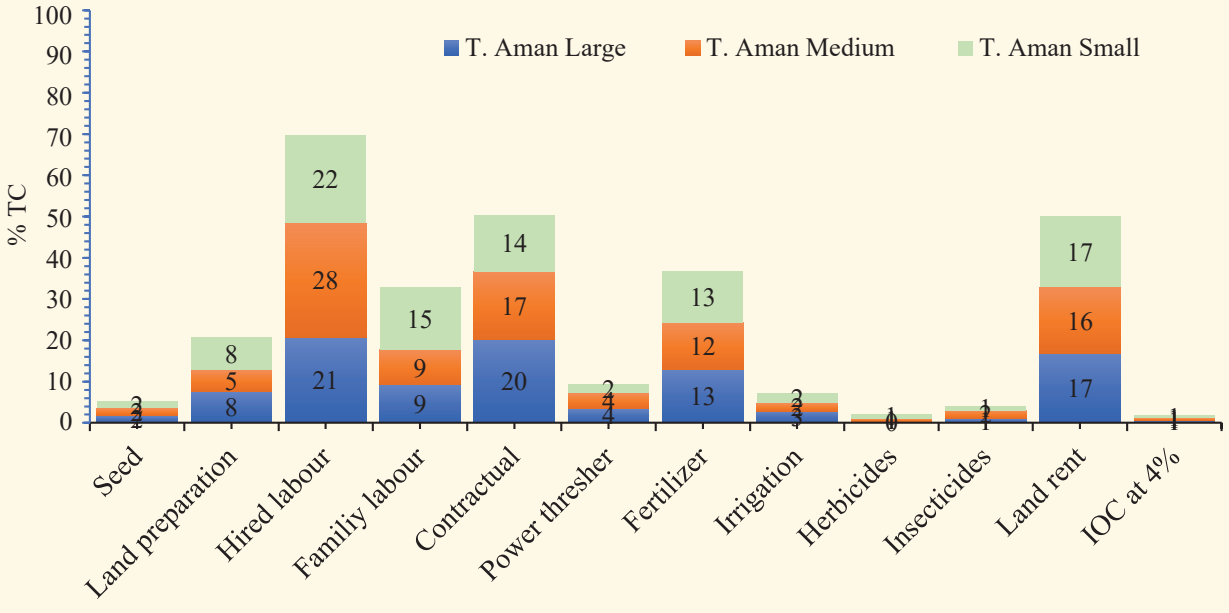


Figure 10.90: Share of per hectare inputs cost to total cost of *T. Aman* cultivation in pooled data

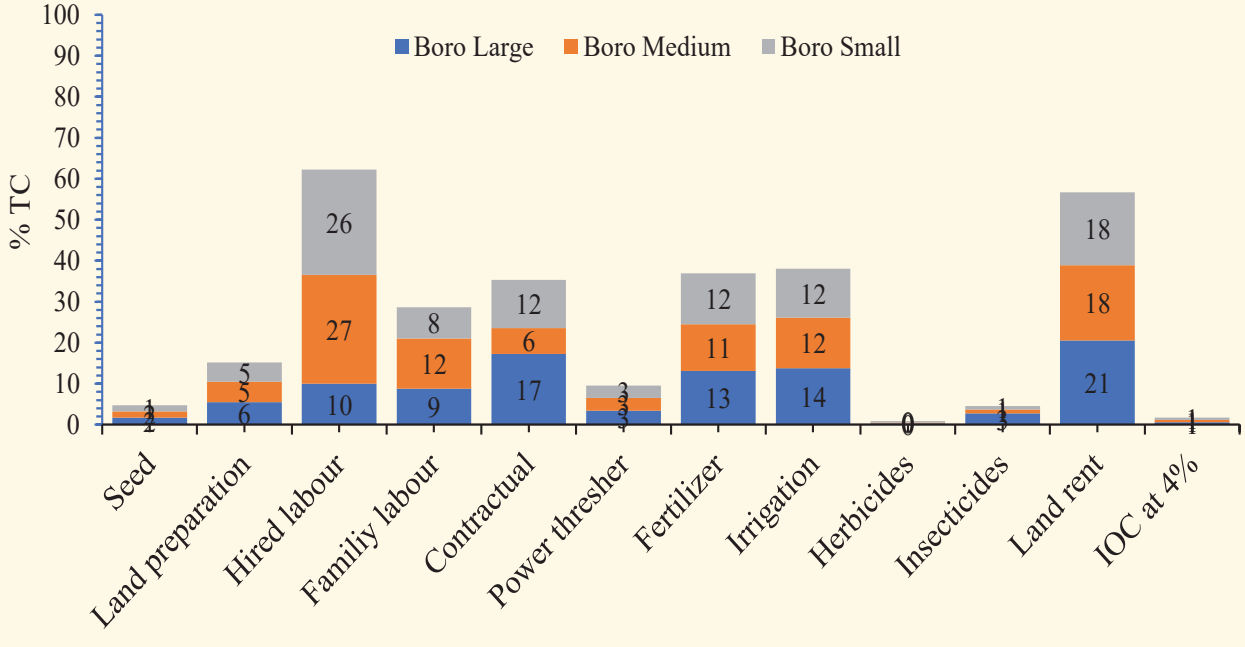


Figure 10.91: Share of per hectare inputs cost to total cost of *Boro* cultivation in pooled data

10.9.3 Risk analysis of rice production of pooled data

In order to assess the seasonal variation on economic viability of rice cultivation at current prices, the result revealed that variability in the yield of rice in the pooled data had influence on farm profit with current market price. The gross return (GR) of rice was computed by multiplying rice yields and the reported prices (Table 10.27). The modal value of every item from sample survey such inputs and outputs for worse and best value were crosschecked with key informant opinion. Average/typical value of yield and price was estimated from survey data. After all that, the dataset was prepared for triangle distribution. Farmers opined that they sold their produces for moderate/

average/typical case at a higher price than in the worst and best seasons. Figure 10.92-10.94 showed that rice production in all seasons for large farmer, medium farmer and small farmer was found to be more profitable in the farmers' perceived best case than average and worse case. However, farmers always suffer from negative NI in the worst case caused from weather and abiotic stress (unpredictive temperature, rainfall, salinity and drought). Stochastic budgets were constructed for seasonal rice cultivation considering farmers' perceived variation in yield and market price for large farmer, medium farmer and small farmer. The stochastic budget analysis displayed that seasonal rice cultivation was economically viable at current prices and average yields. In this analysis, triangular distribution was constructed based on three different points of worst, typical/ average, and best yields and prices for large farmer, medium farmer and small farmer.

Table 10.27: Stochastic budgeting of rice production by farm types in pooled data

Items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Yield (ton per ha)									
Worse case	2.99	2.97	4.49	2.99	3.99	4.49	2.47	3.29	4.49
Typical case	4.49	4.95	5.99	3.59	4.95	5.99	4.94	4.94	5.99
Best case	5.99	6.74	7.48	5.39	6.99	7.48	5.97	6.59	7.48
Straw (Tk per ha)									
Worse case	7485	11227	6736	7485	14970	7485	11227	7485	7485
Typical case	14970	22455	18712	11227	20958	11227	11227	14970	18712
Best case	18712	29939	22455	14970	29939	14970	14970	22455	22455
Price (Tk per ton)									
Worse case	10000	12500	12500	12500	10000	12500	12500	15000	20000
Typical case	17500	22250	17500	20000	20000	17500	20000	20000	25000
Best case	25000	25000	25000	25000	25000	25000	25000	25000	25000
Paid out cost (Tk/ ha) (A)	58031	77020	77909	67096	80325	81630	61922	71669	86450
Imputed cost (Tk/ ha) (B)	27214	27808	34380	20526	27625	39062	28313	34078	34037
Total cost (Tk/ha) (A+B)	85245	104828	112289	87622	107950	120692	90234	105746	120487
Net-income (Tk per ha)									
Worse case	-47821	-56483	-49416	-42713	-53040	-57071	-48132	-48861	-23184
Typical case	8315	27809	11211	15460	12048	12823	19793	8023	47922
Best case	83164	93521	97287	62125	96687	81399	73965	81375	89089

Source: Authors' estimation based on field survey, 2019-2021.

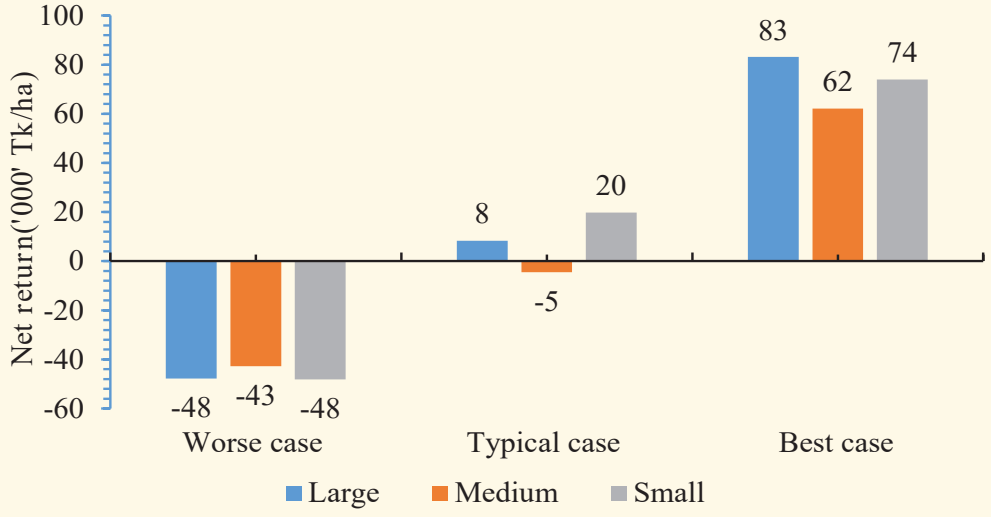


Figure 10.92: Farm and case wise comparison in net-income (Tk/ha) for *T. Aus* in pooled data

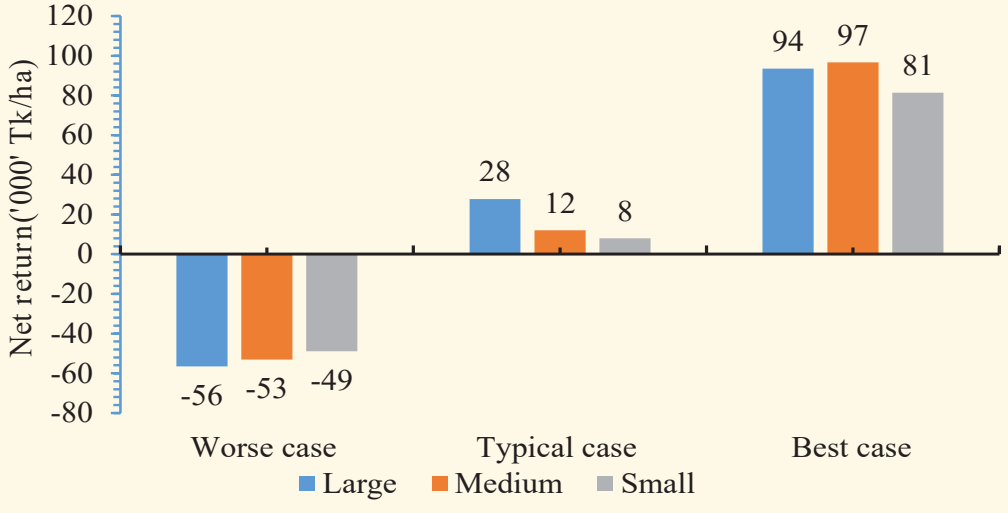


Figure 10.93: Farm and case wise comparison in net-income (Tk/ha) for *T. Aman* in pooled data

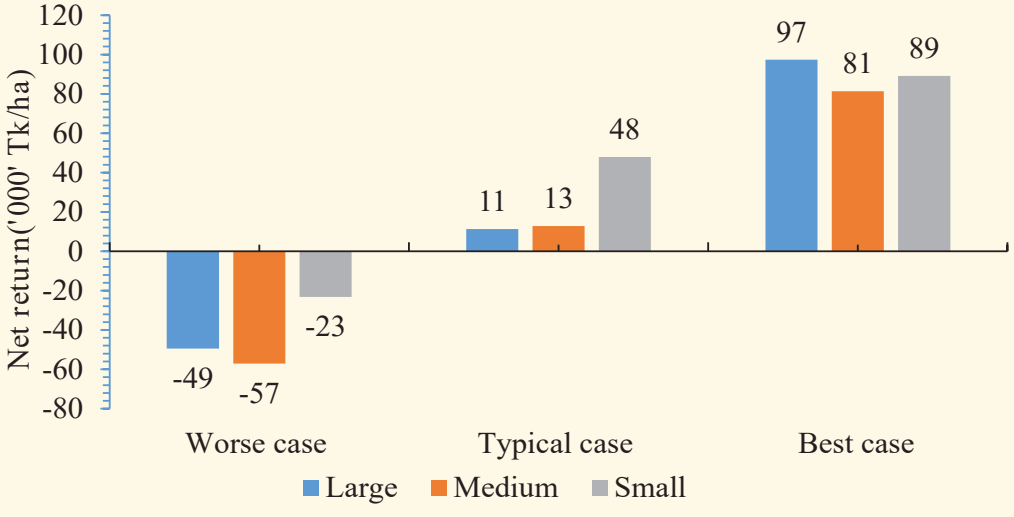


Figure 10.94: Farm and case wise comparison in net-income (Tk/ha) for *Boro* in pooled data

The lower benchmark (Tk. 20000) was selected based on total imputed costs (TIC/ha) for large farmer, while the upper benchmark (Tk. 50000) was chosen randomly. The CDF of NI/ha from *T. Aus* showed that large farmer had about 33% chance of NI per ha above the lower benchmark, meaning it could cover the cost of farm owned resources including labour. The chance of receiving NI per ha above this threshold decreased to 19% for medium farmer and 29% for small farmer, respectively (Figure 10.95(a)). The lower benchmark (Tk. 58000) was selected based on the paid-out costs (TPC/ha) for medium farmer, while the upper benchmark (Tk. 110000) was chosen randomly. The CDF of GR/ha from *T. Aus* showed slightly more than 93% chance of GR per ha for medium farmer above the lower benchmark, respectively meaning it could cover the cost of all cash costs. The chance of receiving GR per ha above this threshold decreased to 82% for large farmer and 73% for small farmer, respectively (Figure 10.95(b)). However, the probability of NI for all farm types indicated the higher to become negative in *T. Aus*.

The lower benchmark (Tk. 26000) was selected based on total imputed costs (TIC/ha) for large farmer, while the upper benchmark (Tk. 60000) was chosen randomly. The CDF of NI/ha from *T. Aman* showed that large farmer had about 25% chance of NI per ha above the lower benchmark, meaning it could cover the cost of farm owned resources including labour. The chance of receiving NI per ha above this threshold decreased to 24 and 15% for medium farmer and small farmer, respectively (Figure 10.96(a)). The lower benchmark (Tk. 71000) was selected based on the paid-out costs (TPC/ha) for medium farmer, while the upper benchmark (Tk. 119000) was chosen randomly. The CDF of GR/ha from *T. Aman* showed that medium farmer had about 82% chance of GR per ha above the lower benchmark, respectively meaning it could cover the cost of all cash costs. The chance of receiving GR per ha above this threshold decreased to 53% for large farmer and 39% for small farmer, respectively (Figure 10.96(b)). However, chance of probability of NI for medium farmer and small farmer indicated the higher probability to become negative in *T. Aman* whereas more chance of getting higher GR was obtained.

The lower benchmark (Tk. 31000) was selected based on total imputed costs (TIC/ha) for large farmer, while the upper benchmark (Tk. 91000) was chosen randomly. The CDF of NI/ha from *Boro* showed that small farmer had about 47% chance of NI per ha above the lower benchmark, meaning it could cover the cost of farm owned resources including labour. The chance of receiving NI per ha above this threshold decreased to 42% for large farmer and 41% for medium farmer (Figure 10.97(a)). The lower benchmark (Tk. 67000) was selected based on the paid-out costs (TPC/ha) for medium farmer, while the upper benchmark (Tk. 174000) was chosen randomly. The CDF of GR/ha from *Boro* showed 80% chance of GR per ha for large farmer whereas decreased to 78% for large farmer and 58% for medium farmer, respectively above the lower benchmark, respectively meaning it could cover the cost of all cash costs (Figure 10.97(b)). Relatively higher risk in net return of *T. Aman* season was found compared to that of *T. Aus* and *Boro*.

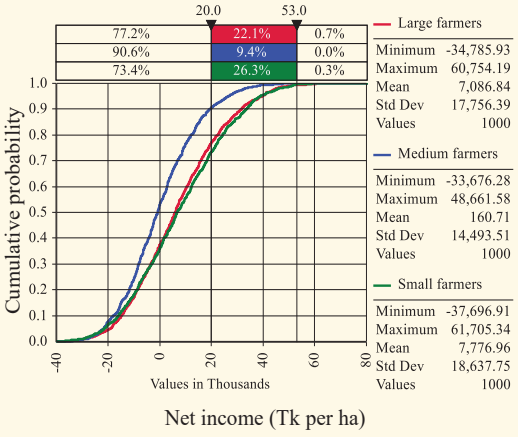


Figure 10.95(a): Cumulative probability of net-income (Tkperha) of *T. Aus* rice cultivation in pooled data

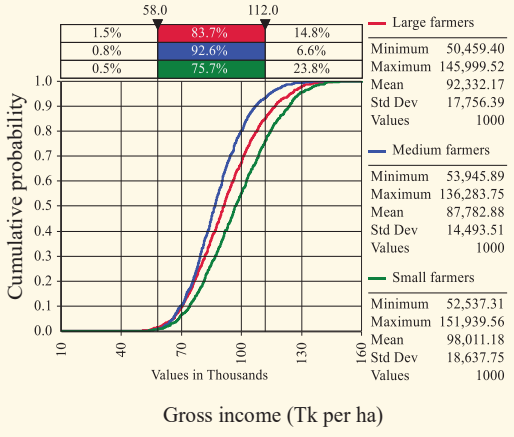


Figure 10.95(b): Cumulative probability of gross income (Tkperha) of *T. Aus* rice cultivation in pooled data

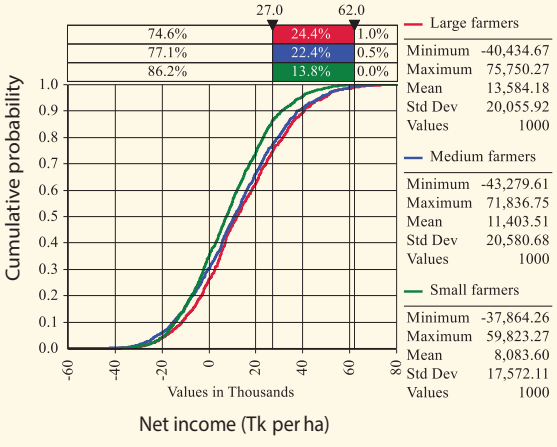


Figure 10.96(a): Cumulative probability of net-income (Tkperha) of *T. Aman* rice cultivation in pooled data

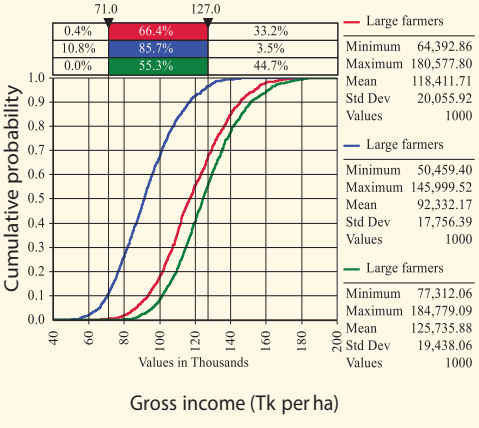


Figure 10.96(b): Cumulative probability of gross income (Tkperha) of *T. Aman* rice cultivation in pooled data

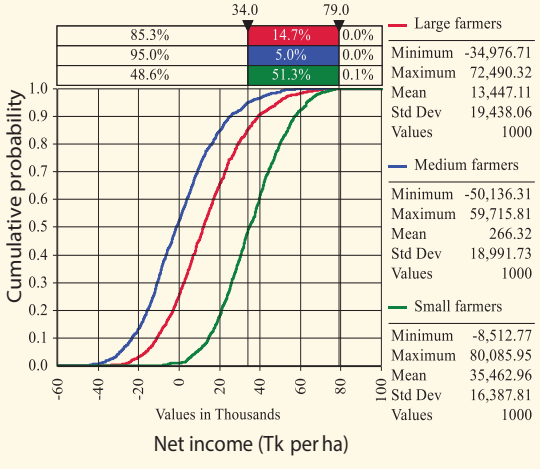


Figure 10.97(a): Cumulative probability of net-income (Tk per ha) of *Boro* rice cultivation in pooled data

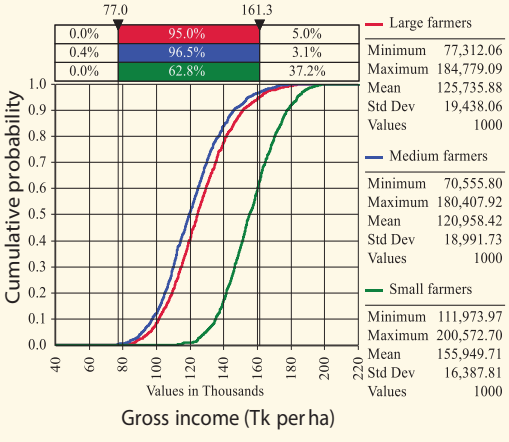


Figure 10.97(b): Cumulative probability of gross income (Tk per ha) of *Boro* rice cultivation in pooled data

Figure 10.98-10.99 shows that, with all variables being constant other than yield, straw value and prices, it was the fluctuation in rice yield and straw value contributed to the variability of the NI/ha by nearly 60% of total variation in NI from *T. Aman*, *T. Aus* and *Boro* for all farmers. large farmer and medium farmer has gotten more risk in price (about 41% from market risk) compared to that for medium farmer and small farmer. However, the fluctuation in the price of rice was found to be relatively lower contribution than the combine effect of yield and straw value. Similar pattern of variation was observed in GR for large farmer, medium farmer and small farmer.

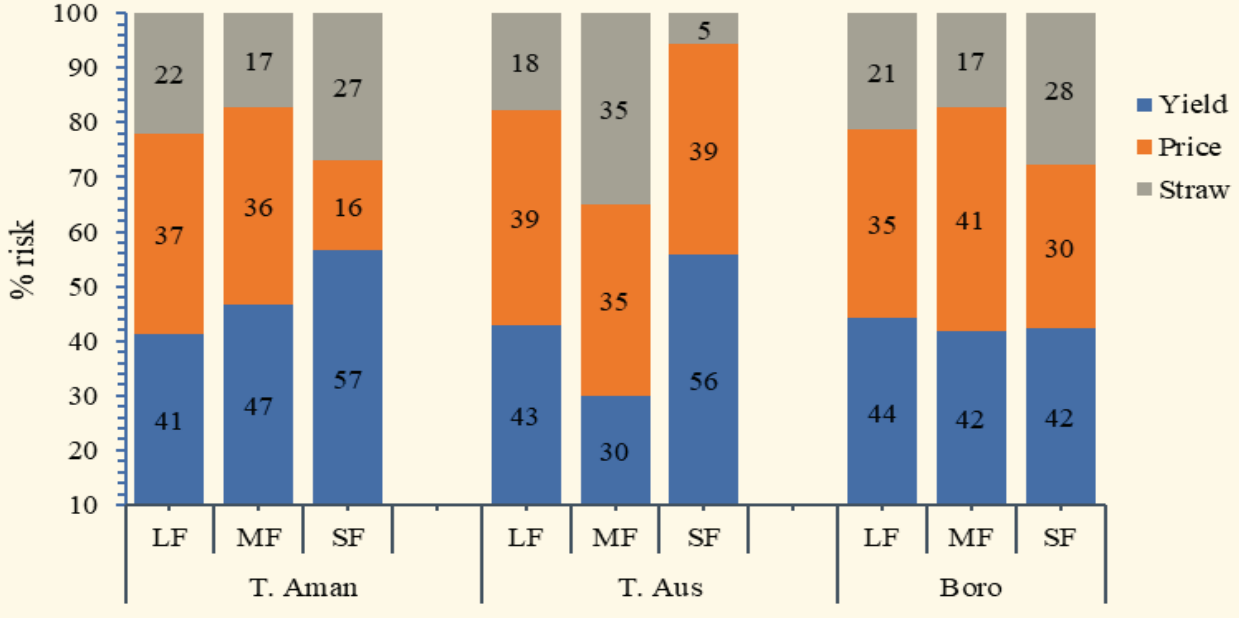


Figure 10.98: Inputs' effect ranked on NI for *T. Aman*, *T. Aus* and *Boro* rice in pooled data

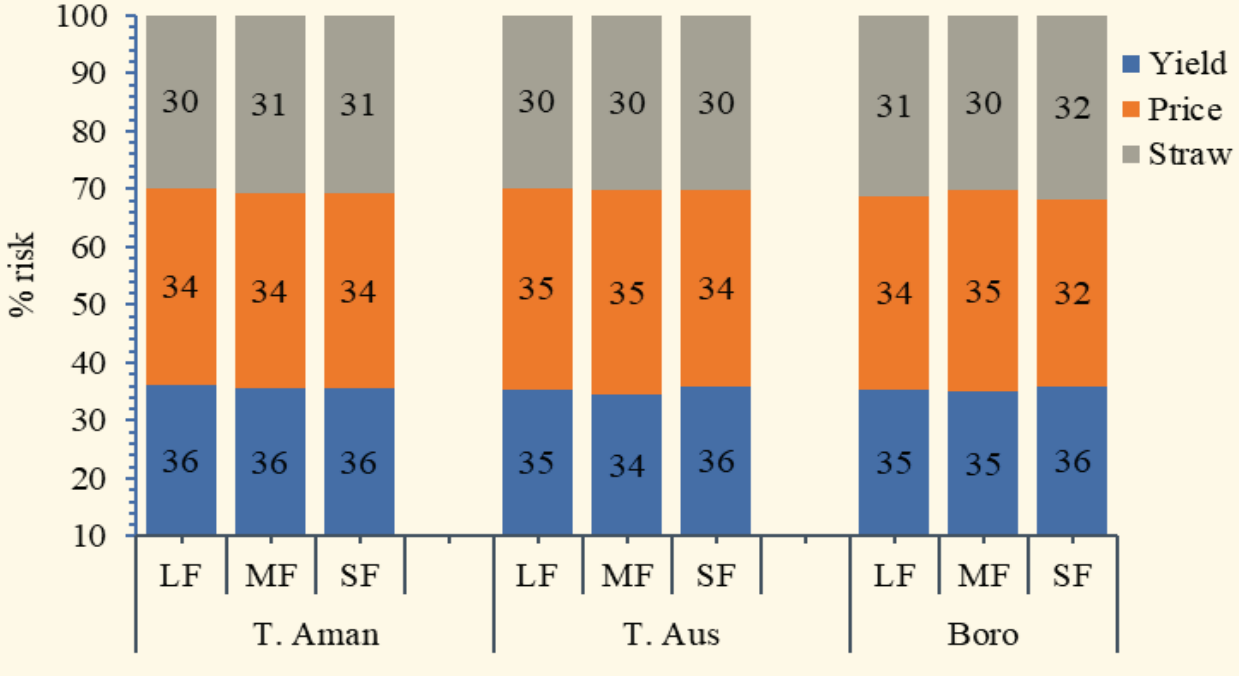


Figure 10.99: Inputs' effect ranked on GR for *T. Aman*, *T. Aus* and *Boro* rice in pooled data

In concluding remarks, it could be worth repeating that rice cultivation appeared riskier in both submergence and drought followed by *haor* ecosystem than other ecosystem. The *T. Aus* rice cultivation was found riskier in submergence, drought and *Haor* ecosystems than any other ecosystems. The cumulative probability of obtaining NI per ha above the benchmark imputed cost of seasonal rice cultivation was found higher tendency to become negative. In most case, small farmers experienced more risk from yield variation by environment and market distortion and incurred in lower profitability of rice cultivation in three different seasons.

10.10 Technical efficiency of rice farmers in different seasons in different ecosystems

10.10.1 Descriptive statistics of all variables used in the models

Ecosystem wise descriptive statistics of the sample variables by different farm size and season were given table 10.28. **In favorable ecosystem**, mean of *Boro* rice (5586 kg/ha) yield was higher for compared to *T. Aman* (4432 kg/ha) and *T. Aus* (3816 kg/ha).) Average rice land area was also higher for *Boro* rice production (310 dec) compared to *T. Aman* (265 dec) and *T. Aus* (100 dec). Average number of hired labor used by the *T. Aman, T. Aus* and *Boro* farmers were 109, 118 and 110 man-days, respectively in favorable ecosystem. In case of seed rate, average seed usage was higher for *T. Aman* (35 kg/ha) production compared to *T. Aus* (33 kg/ha) and *Boro* (31 kg/ha) rice. Mean of NPK (Urea, TSP and MoP) application for the cultivation of *T. Aman, T. Aus* and *Boro* were 349, 352 and 405 kg/ha with a standard deviation of 79, 300 and 109 kg/ha in favorable ecosystem. In addition, *Boro* rice incurred higher irrigation cost (7963 Tk/ha) compared to *T. Aus* (7657 Tk/ha) and *T. Aman* (1733 Tk/ha) rice.

In *haor* ecosystem, mean of *Boro* rice (6428 kg/ha) yield was higher for compared to *T. Aman* (4626 kg/ha) and *T. Aus* (5004 kg/ha).) Average rice land area was also higher for *Boro* rice production (480 dec) compared to *T. Aman* (445 dec) and *T. Aus* (339 dec). Average number of hired labor used by the *T. Aman, T. Aus* and *Boro* farmers were 99, 93 and 112 man-days, respectively in *haor* ecosystem. In case of seed rate, average seed usage was higher for *T. Aman* (39 kg/ha) production compared to *T. Aus* and *Boro* (38 kg/ha) rice. Mean of NPK (Urea, TSP and MoP) application for the cultivation of *T. Aman, T. Aus* and *Boro* were 333, 292 and 359kg/ha with a standard deviation of 53, 50 and 82 kg/ha in *haor* ecosystem. In addition, *Boro* rice incurred higher irrigation cost (11148 Tk/ha) compared to *T. Aus* (2446 Tk/ha) and *T. Aman* (480 Tk/ha).

In salinity ecosystem, mean of *Boro* rice (6028 kg/ha) yield was higher for compared to *T. Aman* (4771 kg/ha) and *T. Aus* (4489 kg/ha).) Average rice land area was higher for *T. Aus* rice production (252 dec) compared to *T. Aman* (240 dec) and *Boro* (217 dec). Average number of hired labor used by the *T. Aman, T. Aus* and *Boro* farmers were 90, 88 and 100 man-days, respectively in salinity ecosystem. In case of seed rate, average seed usage was higher for *T. Aman* (33 kg/ha) production compared to *T. Aus* (31 kg/ha) and *Boro* (29 kg/ha) rice. Mean of NPK (Urea, TSP and MoP) application for the cultivation of *T. Aman, T. Aus* and *Boro* were 423, 292 and 573 kg/ha with a standard deviation of 78, 57 and 65 kg/ha in salinity ecosystem. In addition, *Boro* rice incurred higher irrigation cost (14068 Tk/ha) compared to *T. Aus* (2180 Tk/ha) and *T. Aman* (1192 Tk/ha).

In drought ecosystem, mean of *Boro* rice (6226 kg/ha) yield was higher for compared to *T. Aman* (4867 kg/ha) and *T. Aus* (5003 kg/ha).) Average rice land area was higher for *T. Aman* rice production (305 dec) compared to *T. Aus* (260 dec) and *Boro* (257 dec). Average number of hired labor used by the *T. Aman, T. Aus* and *Boro* farmers were 101, 103 and 99 man-days, respectively in drought ecosystem. In case of seed rate, average seed usage was higher for *T. Aus* (39 kg/ha)

production compared to *T. Aman* (38 kg/ha) and *Boro* (35 kg/ha) rice. Mean of NPK (Urea, TSP and MoP) application for the cultivation of *T. Aman, T. Aus* and *Boro* were 316, 273 and 404 kg/ha with a standard deviation of 64, 54 and 113 kg/ha in salinity ecosystem. In addition, *Boro* rice incurred higher irrigation cost (13213 Tk/ha) compared to *T. Aus* (3442 Tk/ha) and *T. Aman* (2553 Tk/ha) rice.

In tidal submergence ecosystem, mean of *Boro* rice (5641 kg/ha) yield was higher for compared to *T. Aman* (4137 kg/ha) and *T. Aus* (4809 kg/ha).) Average rice land area was also higher for *Boro* rice production (240 dec) compared to *T. Aman* (222 dec) and *T. Aus* (160 dec). Average number of hired labor used by the *T. Aman, T. Aus* and *Boro* farmers were 91, 95 and 98 man-days, respectively in tidal submergence ecosystem. In case of seed rate, average seed usage was higher for *T. Aman* (49 kg/ha) production compared to *T. Aus* (36 kg/ha) and *Boro* (35 kg/ha) rice. Mean of NPK (Urea, TSP and MoP) application for the cultivation of *T. Aman, T. Aus* and *Boro* were 352, 300 and 311 kg/ha with a standard deviation of 63, 71 and 115 kg/ha in tidal submergence ecosystem. In addition, *Boro* rice incurred higher irrigation cost (12611 Tk/ha) compared to *T. Aus* (2822 Tk/ha) and *T. Aman* (1513 Tk/ha) rice.

In submergence ecosystem, mean of *Boro* rice (5897 kg/ha) yield was higher for compared to *T. Aman* (4463 kg/ha) and *T. Aus* (4875 kg/ha).) Average rice land area was higher for *T. Aman* rice production (273 dec) compared to *Boro* (272 dec) and *T. Aus* (121 dec). Average number of hired labor used by the *T. Aman, T. Aus* and *Boro* farmers were 113, 97 and 130 man-days, respectively in submergence ecosystem. In case of seed rate, average seed usage was 31 Kg/ha for *T. Aman* as well as *T. Aus* production and on the other hand, it was 35 kg/ha for *Boro* rice. Mean of NPK (Urea, TSP and MoP) application for the cultivation of *T. Aman, T. Aus* and *Boro* were 347, 312 and 333 kg/ha with a standard deviation of 67, 76 and 38 kg/ha in submergence ecosystem. In addition, *Boro* rice incurred higher irrigation cost (12513 Tk/ha) compared to *T. Aus* (2628 Tk/ha) and *T. Aman* (3075 Tk/ha) rice.

In low lying ecosystem, mean of *Boro* rice (6108 kg/ha) yield was higher for compared to *T. Aman* (4707 kg/ha) and *T. Aus* (4875 kg/ha).) Average rice land area was also higher for *Boro* rice production (291 dec) compared to *T. Aman* (260 dec) and *T. Aus* (177 dec). Average number of hired labor used by the *T. Aman, T. Aus* and *Boro* farmers were 120, 125 and 134 man-days, respectively in low lying ecosystem. In case of seed rate, average seed usage was 36 Kg/ha for *T. Aman* as well as *T. Aus* production and on the other hand, it was 35 kg/ha for *Boro* rice. Mean of NPK (Urea, TSP and MoP) application for the cultivation of *T. Aman, T. Aus* and *Boro* were 350, 307 and 478 kg/ha with a standard deviation of 68, 56 and 137 kg/ha in low lying ecosystem. In addition, *Boro* rice incurred higher irrigation cost (15045 Tk/ha) compared to *T. Aus* (4610 Tk/ha) and *T. Aman* (2421 Tk/ha) rice.

In hilly **ecosystem**, mean of *Boro* rice (4901 kg/ha) yield was higher for compared to *T. Aman* (4149 kg/ha) and *T. Aus* (4176 kg/ha).) Average rice land area was higher for *T. Aman* rice production (89 dec) compared to *Boro* (71 dec) and *T. Aus* (75 dec). Average number of hired labor used by the *T. Aman* as well as *T. Aus* farmers was 106 man-days and on the other hand, it was 110 man-days for *Boro* farmers in hilly ecosystem. In case of seed rate, average seed usage was higher for *T. Aman* (53 kg/ha) production compared to *T. Aus* (38 kg/ha) and *Boro* (43 kg/ha) rice. Mean of NPK (Urea, TSP and MoP) application for the cultivation of *T. Aman, T. Aus* and *Boro* were 254, 233 and 339 kg/ha with a standard deviation of 113, 115 and 159 kg/ha in hilly ecosystem. In addition, *T. Aus* rice incurred higher irrigation cost (8528 Tk/ha) compared to *Boro* (8269 Tk/ha) and *T. Aman* (382 Tk/ha) rice.

Table 10.28: Descriptive statistics of variable used in technical efficiency model of seasonal rice production in different ecosystems

Particulars		Yield	Rice area	Labor	NPK	Seed	Irrigation	Power tiller	Experience	Education	Farm size	Extension service	Access to credit	Training
Favorable ecosystem														
T. Aus	Min	1482	12	26	29	14	0	2245	2	0	16	0	0	0
	Max	7904	300	583	1630	49	16467	10978	60	20	624	1	1	1
	Mean	3816	100	118	352	33	7657	5999	25	8	171	1	0	1
	STDV	1079	82	95	300	10	5426	2369	16	6	144	0	1	1
T. Aman	Min	2395	67	53	188	12	0	2558	2	0	101	0	0	0
	Max	6314	863	771	638	49	4985	12425	53	17	645	1	1	1
	Mean	4432	265	109	349	35	1733	8037	23	7	257	1	1	1
	STDV	820	147	95	79	9	1617	1904	14	5	107	0	1	1
Boro	Min	2683	38	55	209	11	2470	2077	2	0	60	0	0	0
	Max	7464	900	772	795	50	15464	11115	48	17	497	1	1	1
	Mean	5586	310	110	405	31	7963	6893	23	7	243	1	1	1
	STDV	1103	151	96	109	9	3592	1767	13	5	85	0	0	0.5
***Haor* ecosystem**														
T. Aus	Min	3293	30	58	164	16	0	3952	4	0	85	0	0	0
	Max	7026	1044	149	387	49	16467	26347	60	17	1215	1	1	1
	Mean	5004	339	93	292	38	2446	8220	27	4	205	1	0	0
	STDV	746	208	22	50	6	3168	3101	14	4	173	0	0	1
T. Aman	Min	2470	114	56	208	20	0	3420	2	0	133	0	0	0
	Max	5886	1485	164	471	49	4757	9880	62	21	747	1	1	1
	Mean	4626	445	99	333	39	480	7686	31	4	286	1	1	0
	STDV	750	247	22	53	5	1145	1262	15	5	104	0	1	0
Boro	Min	2800	36	54	198	8	4117	3522	3	0	45	0	0	0
	Max	7992	5657	194	580	49	25043	17509	63	16	788	1	1	1
	Mean	6428	480	112	359	38	11148	7901	29	5	263	1	0	1
	STDV	1191	753	34	82	8	5668	1961	14	4	113	0	1	1

Particulars		Yield	Rice area	Labor	NPK	Seed	Irrigation	Power tiller	Experience	Education	Farm size	Extension service	Access to credit	Training
Salinity ecosystem														
T. Aus	Min	1192	33	67	137	16	0	4491	3	5	40	0	0	0
	Max	7186	632	118	374	47	8970	7736	40	18	319	1	1	1
	Mean	4489	252	88	292	31	2180	5891	23	10	152	1	0	0
	STDV	1661	158	17	57	6	1415	940	12	4	76	1	1	0
T. Aman	Min	1737	25	52	267	17	0	3742	4	0	59	0	0	0
	Max	7350	655	213	661	49	6584	16280	55	17	701	1	1	1
	Mean	4771	240	90	423	33	1192	6638	26	8	231	1	1	1
	STDV	1199	128	29	78	7	1916	2006	12	4	100	1	0	0
Boro	Min	2984	11	23	217	9	4940	2807	2	0	59	0	0	0
	Max	8608	512	259	2459	47	33144	23204	64	18	512	1	1	1
	Mean	6028	217	100	573	29	14068	7389	25	7	215	1	0	0
	STDV	1145	115	44	65	9	4493	3705	15	5	88	1	0	0
Drought ecosystem														
T.Aus	Min	2668	10	25	147	20	0	2021	2	0	20	0	0	0
	Max	8084	5412	202	396	50	20163	11179	55	18	1037	1	1	1
	Mean	5003	260	103	273	39	2928	7021	20	7	167	1	0	0
	STDV	992	637	35	54	7	3442	1509	12	5	129	0	0	0
T. Aman	Min	2682	13	30	175	15	0	2069	2	0	22	0	0	0
	Max	7336	3154	206	486	50	12602	10500	55	22	857	1	1	1
	Mean	4867	305	101	316	38	2290	7036	23	7	228	1	0	0
	STDV	972	429	34	64	8	2553	1660	13	6	136	0	0	0
Boro	Min	1927	18	41	148	14	1860	1862	2	0	35	0	0	0
	Max	9576	1196	198	640	50	28068	18638	60	33	2437	1	1	1
	Mean	6226	257	99	404	35	13213	6886	23	8	273	1	0	0
	STDV	1280	194	31	113	7	6202	2477	13	5	282	0	0	1

Particulars		Yield	Rice area	Labor	NPK	Seed	Irrigation	Power tiller	Experience	Education	Farm size	Extension service	Access to credit	Training
Tidal submergence ecosystem														
T. Aus	Min	1729	40	49	169	25	0	3040	4	0	21	0	0	0
	Max	9880	380	247	458	49	19760	19297	60	16	463	1	1	1
	Mean	4809	160	95	300	36	2822	8013	26	5	169	1	1	1
	STDV	1941	75	39	71	7	3969	3038	14	4	87	1	1	1
T. Aman	Min	1433	46	48	227	20	0	1915	4	0	64	0	0	0
	Max	7904	672	208	497	49	8337	28302	58	16	750	1	1	1
	Mean	4137	222	91	352	35	1513	8616	29	6	284	1	1	1
	STDV	1620	132	31	63	7	1960	4826	15	4	137	1	1	1
Boro	Min	1400	25	44	97	16	4529	2079	2	0	94	0	0	0
	Max	10703	670	222	619	49	27788	49400	68	29	654	1	1	1
	Mean	5641	240	98	311	35	12611	9955	27	6	261	1	1	1
	STDV	1926	133	38	115	9	6035	8271	16	4	105	1	1	1
Submergence ecosystem														
T. Aus	Min	1976	10	45	156	14	0	3705	5	0	50	0	0	0
	Max	6904	297	153	484	49	8233	9880	54	18	295	1	1	1
	Mean	4283	121	97	312	31	2628	6342	26	6	125	1	0	0
	STDV	1302	79	24	76	9	1581	1371	14	5	65	0	0	0
T. Aman	Min	1277	22	49	218	18	0	1284	3	0	49	0	0	0
	Max	6859	908	201	573	47	20210	11725	58	20	726	1	1	1
	Mean	4463	273	113	347	31	3075	6066	26	7	251	1	0	0
	STDV	1253	195	28	67	9	3484	1498	14	6	133	0	1	1
Boro	Min	1638	35	67	99	8	4529	2347	3	0	39	0	0	0
	Max	11362	1181	244	585	47	22455	43225	55	34	793	1	1	1
	Mean	5897	272	130	333	27	12513	6670	28	7	238	1	1	1
	STDV	1754	169	38	106	9	4221	3777	14	6	105	0	1	1

Particulars		Yield	Rice area	Labor	NPK	Seed	Irrigation	Power tiller	Experience	Education	Farm size	Extension service	Access to credit	Training
Low lying ecosystem														
T. Aus	Min	2635	27	69	183	14	0	1853	1	0	19	0	0	0
	Max	7465	600	283	504	49	24700	11856	75	22	382	1	1	1
	Mean	4875	177	125	307	36	3636	7094	27	5	105	1	0	0
	STDV	967	114	29	56	8	4610	1687	16	4	66	0	0	1
T. Aman	Min	1709	12	58	200	13	0	2470	3	0	26	0	0	0
	Max	7081	678	242	630	49	11270	15232	70	15	559	1	1	1
	Mean	4707	260	120	350	36	2421	7646	28	5	217	1	0	0
	STDV	911	145	34	68	8	2251	2185	15	4	91	0	0	0
Boro	Min	2305	32	67	133	14	2882	2162	3	0	20	0	0	0
	Max	9880	822	231	870	49	24014	15232	60	41	724	1	1	1
	Mean	6108	291	134	478	35	15045	6801	30	6	246	1	0	1
	STDV	1228	175	31	137	9	3558	1950	14	5	111	0	0	0
Hilly **ecosystem**														
T. Aus	Min	494	16	12	6	6	20	2	2	0	494	0	0	0
	Max	9880	320	284	494	124	17290	70	15	14	9880	1	1	1
	Mean	4176	75	110	233	38	8528	20	5	2	4176	1	0	1
	STDV	1700	57	55	115	24	5484	15	4	4	1700	0	0	0
T. Aman	Min	706	20	10	31	6	0	354	2	1	25	0	0	0
	Max	8892	500	305	498	147	8645	17702	60	18	600	1	1	1
	Mean	4149	89	106	254	53	382	9766	23	2	126	1	0	1
	STDV	1319	68	45	113	22	1288	4398	13	3	94	0	0	0
Boro	Min	1400	20	19	25	15	100	450	2	0	20	0	0	0
	Max	9880	280	375	951	185	37050	20583	60	12	840	1	1	1

Particulars		Yield	Rice area	Labor	NPK	Seed	Irrigation	Power tiller	Experience	Education	Farm size	Extension service	Access to credit	Training
							Hilly **ecosystem**							
Boro	Mean	4901.04	71	106	339	43	8269	10724	23	2	110	1	0	0
	STDV	1490.52	41	37	159	25	9281	3531	12	3	86	0	0	0
							Pooled data							
T. Aus	Min	1198	16	34	139	9	0	1729	2	0	24	0	0	0
	Max	9880	2250	307	1034	50	17964	20583	73	25	1205	1	1	1
	Mean	4589	386	103	361	33	1479	7499	28	7	368	1	0	0
	STDV	1172	242	34	93	9	2211	2455	14	5	165	0	0	1
T. Aman	Min	2787	11	32	148	0	0	2245	4	0	38	0	0	0
	Max	9880	1584	219	1441	49	29939	32933	60	22	1584	1	1	1
	Mean	4680	424	104	310	36	3623	7835	27	6	383	1	0	0
	STDV	1059	286	32	123	7	4870	3346	13	5	175	0	0	1
Boro	Min	1796	76	48	179	8	4411	3293	1	0	196	0	0	0
	Max	9880	3210	201	707	49	25204	29939	63	20	2445	1	1	1
	Mean	6017	869	109	416	32	13543	7249	30	10	1051	1	0	1
	STDV	1348	599	34	113	10	5425	3139	17	5	418	0	0	0

Source: Authors' estimation based on field survey, 2019-2021.

10.10.2 Log-likelihood (LR) test of inefficiency model for different ecosystems

In spite of the magnitude and significance of the variance parameter, , it is also important to examine various null hypotheses. For this purpose, various restrictions were imposed on the original model defined in equations 6. To test the validity of these restrictions, the generalized likelihood ratio tests are performed. The results of these tests of hypotheses for parameters of the translog stochastic frontier and inefficiency model only are shown in table 10.29

The first null hypothesis is concerned with technical inefficiency effects. It states that technical inefficiency effects are absent i.e.

H_0: $\gamma = \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = \delta_7 = \delta_8 = 0$ 6

On the basis of the generalized log-likelihood ratio test, we find test statistics for different ecosystems of the farmers in *T. Aman*, *T. Aus* and *Boro* season which were significantly higher from the respective critical values, suggesting that the null hypothesis of no technical inefficiency effects was rejected. Therefore, the average (OLS) production function was not suitable for the sample data.

Table 10.29 LR test of inefficiency model for different ecosystems

Season	Model without inefficiency	Model with inefficiency	Test statistics	Chisq Pr(>Chisq)	Critical value	Decision
Favorable ecosystem						
T. Aus	20.64	31.939	22.597	0.007649 ***	6.21	No inefficiency Rejected
T. Aman	-53.667	50.338	208.01	2.2e-16 ***	48.28	No inefficiency Rejected
Boro	48.167	88.386	80.439	1.79e-13 ***	6.21	No inefficiency Rejected
***Haor* ecosystem**						
T. Aus	42.39	83.776	82.773	6.189e-14 ***	33.4	No inefficiency rejected
T. Aman	31.309	46.09	29.562	0.0675 *	24.69	No inefficiency rejected
Boro	-51.788	3.883	111.34	2.2e-16 ***	33.4	No inefficiency rejected
Salinity ecosystem						
T. Aus	-1.417	49.833	102.5	2.2e-16 ***	48.27	No inefficiency rejected
T. Aman	7.132	25.393	56.522	3.664e-05 ***	41.33	No inefficiency rejected
Boro	132.52	192.67	120.31	2.2e-16 ***	48.27	No inefficiency rejected

Season	Model without inefficiency	Model with inefficiency	Test statistics	Chisq Pr(>Chisq)	Critical value	Decision
Drought ecosystem						
T. Aus	49.877	96.113	92.472	7.285e-16 ***	48.27	No inefficiency rejected
T. Aman	147.5	295.54	296.09	2.2e-16 ***	48.27	No inefficiency rejected
Boro	-93.145	31.001	248.29	2.2e-16 ***	24.76	No inefficiency rejected
Tidal submergence ecosystem						
T. Aus	35.093	59.312	48.438	2.551e-07 ***	33.4	No inefficiency Rejected
T. Aman	6.62	32.031	50.822	9.191e-08 ***	27.58	No inefficiency Rejected
Boro	-50.721	-30.412	40.618	6.846e-06 ***	33.4	No inefficiency Rejected
Submergence ecosystem						
T. Aus	23.991	38.002	28.021	0.001038*	36.74	No inefficiency Rejected
T. Aman	-2.634	47.69	100.65	2.2e-16 ***	44.27	No inefficiency Rejected
Boro	-33.557	69.133	205.38	2.2e-16 ***	41.33	No inefficiency Rejected
Low lying ecosystem						
T. Aus	29.592	38.685	18.186	0.03448 *	16.96	No inefficiency Rejected
T. Aman	-184.054	-89.135	189.84	2.2e-16 ***	21.67	No inefficiency Rejected
Boro	-79.78	41.942	243.45	2.2e-16 ***	21.67	No inefficiency Rejected
Hilly ecosystem						
T. Aus	7.132	25.393	36.522	3.664e-05 ***	21.67	No inefficiency Rejected
T. Aman	-108.808	-97.809	21.998	0.005316 **	6.21	No inefficiency Rejected
Boro	-37.112	-17.449	39.325	1.167e-05 ***	21.67	No inefficiency Rejected
Pooled data						
T. Aus	23.914	30.706	13.583	0.096**	6.21	No inefficiency Rejected
T. Aman	23.990	43.702	39.424	94.8e-06 ***	6.21	No inefficiency Rejected
Boro	1.250	19.831	37.162	1.26e-05 ***	6.21	No inefficiency Rejected

Source: Authors' estimation based on field survey, 2019-2021.

10.10.3 LR test of functional form for different ecosystems

Diagnostically, the generalized likelihood ratio test was used to determine whether the Cobb–Douglas or translog functional form fits the data collected from the survey in this study. The test allows evaluation of a restricted model with respect to an adopted model. The second null hypothesis is concerned with selection of functional form with Generalized likelihood ratio (LR) test. Generalized likelihood ratio (LR) test is used to decide the function form as under:

Where, from Cobb-Doulas and from Translog model are log likelihood value, respectively. The maximum likelihood estimates of the parameters of the Cobb-Douglas and translog stochastic frontier production function and inefficiency effects model was estimated for Generalized likelihood ratio test. Before going to discussion of ML estimates, selection of functional form. Selection of functional form is summarized in table 10.30. Results can be considerably affected by the choice of functional form in an empirical study. Most popular functional two forms, Cobb Douglas and translog are used in the empirical studies. Translog or flexible functional form is generally preferred to Cobb Douglas since it usually avoids the general restrictions on the parameters (Kebede, 2001). In this research, both Cobb Douglas and translog functional form have been used to estimate stochastic frontier production function and inefficiency effect model.

The value of LR test was found in different ecosystems, which were greater than the critical Chi square table value at 1 and 5 percent level of significance. So, we reject null hypothesis and thus, translog functional form is preferred over Cobb Douglas functional form.

Table 10.30 LR test of functional form for different ecosystems

Season	SFA CD form	SFA Translog form	Test statistics	Chisq Pr(>Chisq)	Critical value	Decision
Favorable ecosystem						
T. Aus	14.302	31.939	35.273	0.02635 **	27.58	CD Rejected
T. Aman	23.143	50.338	54.389	8.674e-05 ***	33.41	CD Rejected
Boro	58.475	88.386	59.821	1.359e-05 ***	33.4	CD Rejected
***Haor* ecosystem**						
T. Aus	65.629	83.776	36.294	0.02026 **	44.27	CD rejected
T. Aman	19.739	46.09	52.703	0.0001517 ***	37.91	CD rejected
Boro	-12.312	3.883	32.391	0.05343*	44.27	CD rejected
Salinity ecosystem						
T. Aus	28.934	49.833	41.798	0.00446 **	27.58	CD rejected
T. Aman	-14.576	25.394	79.94	1.706e-10 ***	33.4	CD rejected
Boro	164.89	192.67	55.559	5.857e-05 ***	33.4	CD rejected

Season	SFA CD form	SFA Translog form	Test statistics	Chisq Pr(>Chisq)	Critical value	Decision
Drought ecosystem						
T. Aus	80.768	96.113	30.689	0.07899*	24.76	CD rejected
T. Aman	266.2	295.54	58.692	2.011e-05 ***	33.4	CD rejected
Boro	-18.969	31.001	99.941	2.957e-12 ***	33.4	CD rejected
Tidal submergence ecosystem						
T. Aus	11.45	59.312	95.724	1.633e-11 ***	46.93	CD rejected
T. Aman	12.132	32.031	39.799	0.007867 ***	36.74	CD rejected
Boro	-71.556	-30.412	82.288	3.335e-09 ***	46.93	CD rejected
Submergence ecosystem						
T. Aus	15.346	38.002	45.312	0.001576 **	27.58	CD rejected
T. Aman	-20.234	47.69	135.85	2.2e-16 ***	33.4	CD rejected
Boro	13.74	69.133	110.79	3.399e-14 ***	33.4	CD rejected
Low lying ecosystem						
T. Aus	24.857	38.685	27.656	0.03474 *	24.76	CD rejected
T. Aman	-115.18	-89.135	52.089	1.06e-05 ***	31.41	CD rejected
Boro	23.847	41.942	36.19	0.002723 ***	31.41	CD rejected
Hilly ecosystem						
T. Aus	-14.576	25.394	79.94	1.706e-10 ***	33.4	CD rejected
T. Aman	-53.47	214.32	135.85	2.2e-12 ***	46.93	CD rejected
Boro	-34.725	-17.449	34.552	0.04313 **	24.76	CD rejected
Pooled data						
T. Aus	30.706	48.470	41.485	0.003***	37.57	CD rejected
T. Aman	43.702	62.063	36.722	0.012**	31.57	CD rejected
Boro	19.832	49.476	59.290	9.1e-06***	37.57	CD rejected

Source: Authors' estimation based on field survey, 2019-2021.

10.10.4 Technical efficiency (TE) of rice farmers in different seasons in favorable ecosystem

The estimated value of γ for both models (gamma γ =0.977***, γ =0.994 *** and γ =0.999***) for models 1,2 and 3, respectively allows us to reject the hypothesis (H0: γ=0) of no significant technical inefficiency among seasonal rice growers. The results showed that the variance ratio parameter (γ) is greater than zero with statistically significant at 1 percent level, implying that the variation in *T. Aman, T. Aus* and *Boro* yield of favorable ecosystem from frontier yield was obtained among the farmers mainly arose by the differences in technological and management practices of seasonal rice yield rather than random variability.

The strong statistical significance of Sigma-squared (σ2) on both models indicated that technical efficiency analysis can explain the differences between farms 'technical efficiency and the technical efficiency locus (points on the frontier). Moreover, the significance of σ2 confirms that the frontier model is stochastic rather than deterministic.

The aforesaid factors are under the control of the farmers and the influence of which can be altered to enhance their technical efficiency. The result shows that the coefficient of NPK (Kg/ha) was positive and statistically significant at 1 percent level for *T. Aman* yield, on the other hand it was statistically not significant for *Boro* yield meaning that increase in the magnitude of this input increased *T. Aman* yield substantially while there is slim influence of NPK to increase *Boro* yield. The result also shows that the coefficient of land preparation and irrigation was positive and statistically significant at 1 percent and 10 percent level for *T. Aus* yield implying that land preparation and irrigation has influential effect on yield in favorable ecosystem. The coefficient of interaction between seed and irrigation was positive and significant for *Boro* rice production but in case of *T. Aus* rice interaction between labor and seed was negative and significant, implying that increased the application of seed and irrigation would increase the yield of *Boro* yield but decrease the yield of *T. Aus* rice. The coefficient of interaction between labor and irrigation was positive and significant for *T. Aus* rice production, indicating that application of these inputs has positive effect on *T. Aus* rice yield.

Table 10.31presents the determinants of technical inefficiency of farmer's specific rice cultivation. It denoted that in the stochastic frontier estimation, the parameter for inefficiency level usually enters the inefficiency effects component of the model (second stage) as the dependent variable. In addition, a negative sign on the coefficient variable is interpreted as a positive influence on efficiency (i.e., decrease in inefficiency). Conversely, a positive coefficient is treated as a negative influence on efficiency (an increase in inefficiency) (Brummer and Loy 2000; Coelli *et al.* 2005).

The estimated determinants of technical inefficiency of the rice growers in favorable ecosystem are given in Table 10.31. The coefficient of education, training and access to media was negative and significant at 1 percent level for *T. Aman* rice growers indicating that if the farmers had received higher education, extension service and training in the season that would decrease inefficiency of rice cultivation. On the other hand, the coefficient of credit of *T. Aus* growers was positive and significant at 1 percent level, implying that provision of credit on rice cultivation would reduce technical inefficiency in favorable ecosystem. The coefficient of extension service, training, credit and access to media of *Boro* rice cultivars was negative but not statistically significant indicating that those inputs can influence to reduce the inefficiency.

Table 10.31: Maximum likelihood estimates of Translog TE model for favorable ecosystem

Variables	Parameters	Translog TE model		
		T. Aus	*T. Aman*	*Boro*
		n=335	n=892	n=873
Intercept	β_0	-11.67***	21.00***	9.408*
Log RA	β_1	-0.038	-0.513	0.23
Log labour	β_2	1.299	-0.569	0.959
Log seed	β_3	0.082	-0.589	-0.401
Log NPK	β_4	-0.467	1.657*	0.2
Log LP	β_5	2.91***	-0.596	-0.207
Log irrigation	β_6	1.125*	-0.467	-0.656
Log RA^2	β_{11}	0.037	-0.02	0.019
Log labour^2	β_{22}	-0.145	-0.022	-0.058**
Log seed^2	β_{33}	0.462**	-0.272***	0.044
Log NPK^2	β_{44}	-0.009	0.204*	0.029
Log LP^2	β_{55}	-0.39***	-0.0148	0.022
Log irrigation^2	β_{66}	-0.12***	0.042*	0.103***
Log RA x Log labour	β_{12}	-0.097	0.102*	-0.03
Log RA x Log seed	β_{13}	0.012	-0.108**	-0.029
Log RA x Log NPK	β_{14}	0.006	0.123*	0.113*
Log RA x Log LP	β_{15}	0.169*	0.055	-0.056
Log RA x Log irri	β_{16}	-0.079	-0.02	-0.064
Log labour x Log seed	β_{23}	-0.859***	0.168	-0.129
Log labour x Log NPK	β_{24}	0.286*	-0.062	-0.159
Log labour x Log LP	β_{25}	-0.317*	0.0287	-0.045
Log labour x Log irri	β_{26}	0.405***	0.0447	0.051
Log seed x Log NPK	β_{34}	-0.103	0.111	-0.03
Log seed x Log LP	β_{35}	-0.002	0.189	-0.017
Log seed x Log irri	β_{36}	-0.053	0.034	0.149***
Log NPK x Log LP	β_{45}	0.279	0.074	0.107
Log NPK x Log irri	β_{46}	-0.236*	0.009	-0.134
Inefficiency model				
Intercept	δ_0	0.075	-0.799***	-24.709
Farm size	δ_1	-0.0001	0.0002	0.01
Education	δ_2	0.0174	-0.077***	-0.771
Age	δ_3	-0.0025	-0.0067	0.029
Experience	δ_4	0.0063	0.003	0.033
Extension	δ_5	-0.171	-0.39***	-5.755
Training	δ_6	0.087	-0.086*	-1.451
Credit received	δ_7	-0.39***	-0.096	-4.273
Access to media	δ_8	0.115	-0.37***	-12.166
Sigma Square	σ^2	0.095***	0.16***	4.579
Gamma	γ	0.99***	0.98***	0.99***
log likelihood		31.93	50.33	88.38

Source: Authors' estimation based on field survey, 2019-2021.
* '10% level', ** '5% level', ***'1% level' significant.

10.10.5 Technical efficiency of rice farmers in different seasons in *haor* ecosystem

The results show that the variance ratio parameter (γ) is greater than zero (0.999***,0.986*** and 0.956 ***) for models 1,2 and 3, respectively allows us to reject the hypothesis (H0: γ=0) of no significant technical inefficiency among seasonal rice growers. The results showed that the variance ratio parameter (γ) is greater than zero with statistically significant at 1 percent level, implying that the variation in *T. Aman, T. Aus* and *Boro* yield of *haor* ecosystem from frontier yield was obtained among the farmers mainly arose by the differences in technological and management practices of seasonal rice yield rather than random variability.

The strong statistical significance of Sigma-squared (σ2) on both models indicated that technical efficiency analysis can explain the differences between farms 'technical efficiency and the technical efficiency locus (points on the frontier). Moreover, the significance of σ2 confirms that the frontier model is stochastic rather than deterministic.

The aforesaid factors are under the control of the farmers and the influence of which can be altered to enhance their technical efficiency. The result shows that the coefficient of the area, labor, NPK and irrigation for *T. Aman* as well as *T. Aus* yield was positive and significant at 1 percent level; implying that increase of area, labor, seed and NPK has positive effect on yield increase in *haor* ecosystem. The coefficient of seed was positive and statistically significant in *Boro* season while the coefficient of seed under *T. Aus* rice cultivation (ha) was found negative and statistically significant at 1% level, meaning that no further opportunities exist in the frontier to increase yield by the increased use of seed in *T. Aus* rice cultivation. The coefficient of area under *Boro* rice cultivation (ha) was negative and statistically significant at 10% level, implying that there are no further opportunities to increase yield by increasing land area under *Boro* rice cultivation in this ecosystem. The coefficient of interaction between seed and irrigation was positive and significant for *T. Aman* and *T. Aus* rice production but in case of *Boro* rice, it was negative and significant, implying that increased the application of seed and irrigation would increase the yield of *T. Aman* and *T. Aus* yield but decrease the yield of *Boro* rice in *haor* ecosystem. The coefficient of interaction between seed and NPK was positive and significant for *T. Aus* rice production indicating that application of these inputs has positive effect on *T. Aus* rice yield.

The estimated determinants of technical inefficiency of the rice growers in *haor* ecosystem are given in Table 10.32. The coefficient of extension contact and access to media was negative and significant at 1percent level for *T. Aman* as well as *T. Aus* rice growers; indicating that if the farmers had received extension service and technological information in the seasons that would decrease inefficiency of rice cultivation. On the other hand, the coefficient of education and training of *Boro* growers was negative and significant at 5 percent level, implying that higher education and imparting more training on rice cultivation would reduce technical inefficiency in *haor* ecosystem.

Table 10.32 Maximum likelihood estimates of Translog TE model for *haor* ecosystem

Variables	Parameters	Translog TE model		
		T. Aus	***T. Aman***	***Boro***
		n=115	**n=295**	**n=640**
Intercept	β_0	8.14***	-478.89***	3.77
Log RA	β_1	2.87***	4.70***	-1.016**
Log labour	β_2	3.23***	14.15***	0.758
Log seed	β_3	-6.10***	7.06***	1.981*
Log NPK	β_4	6.56***	52.22***	-0.105
Log LP	β_5	0.04	58.28***	-0.074
Log irrigation	β_6	1.87***	3.587***	0.628
Log RA^2	β_{11}	-0.04	-0.0197	0.0141
Log labour^2	β_{22}	-1.01**	0.591	0.057
Log seed^2	β_{33}	-1.56*	5.79***	0.055
Log NPK^2	β_{44}	-1.235*	0.276	-0.05
Log LP^2	β_{55}	0.411	-1.894***	0.074
Log irrigation^2	β_{66}	0.035*	-0.126*	-0.082***
Log RA x Log labour	β_{12}	0.051	-0.042	-0.059
Log RA x Log seed	β_{13}	0.04	-1.067**	-0.074
Log RA x Log NPK	β_{14}	-0.521**	0.38	0.169*
Log RA x Log LP	β_{15}	-0.311	-0.562***	0.048
Log RA x Log irri	β_{16}	-0.008	-0.29***	0.107*
Log labour x Log seed	β_{23}	2.165**	-4.87***	0.19
Log labour x Log NPK	β_{24}	1.165	-0.35	-0.157
Log labour x Log LP	β_{25}	-0.09	-1.56**	-0.101
Log labour x Log irri	β_{26}	0.217*	0.027	-0.025
Log seed x Log NPK	β_{34}	1.716**	-1.41*	-0.074
Log seed x Log LP	β_{35}	0.01	-3.02***	-0.187
Log seed x Log irri	β_{36}	0.421*	0.94**	-0.289**
Log NPK x Log LP	β_{45}	-0.965	-10.38***	-0.045
Log NPK x Log irri	β_{56}	0.133	-1.24***	0.135
		Inefficiency model		
Intercept	δ_0	0.467*	0.411**	-0.045
Farm size	δ_1	-0.0003	-0.0004***	0.0001
Education	δ_2	0.004	-0.028**	-0.107***
Age	δ_3	0.005	0.0001	0.003
Experience	δ_4	-0.004	0.0008	-0.002
Extension	δ_5	-0.235**	-0.437***	0.029
Training	δ_6	-0.099	-0.058	-0.244**
Credit received	δ_7	-0.155	-0.191**	0.153
Access to media	δ_8	-0.349***	-0.127*	-0.279
Sigma Square	σ^2	0.032***	0.020***	0.239***
Gamma	γ	0.986***	0.999***	0.956 ***
log likelihood		83.776	46.09	3.883

Source: Authors' estimation based on field survey, 2019-2021.
* '10% level', ** '5% level', ***'1% level' significan

10.10.6 Technical efficiency of rice farmers in different seasons in salinity ecosystem

The result shows that the variance ratio parameter (γ) is greater than zero (0.999***,0.999*** and 0.999 ***) for models 1,2 and 3, respectively allows us to reject the hypothesis (H0: γ=0) of no significant technical inefficiency among seasonal rice growers. The results showed that the variance ratio parameter (γ) is greater than zero with statistically significant at 1 percent level, implying that the variation in *T. Aman, T. Aus* and *Boro* yield of salinity ecosystem from frontier yield was obtained among the farmers mainly arose by the differences in technological and management practices of seasonal rice yield rather than random variability. The significance of sigma square of the model models of seasonal rice yield indicated the existence of output variation among the farmers across the seasons in this ecosystem.

The aforesaid factors are under the control of the farmers and the influence of which can be altered to enhance their technical efficiency. The result shows that the coefficient of the labor for *T. Aman* as well as *T. Aus* and *Boro* yield was positive and significant at 1, 10 and 5 percent level; implying that increase of labor has positive effect on yield increase in salinity ecosystem. The coefficient of NPK was also positive and statistically significant at 1 percent level in *T. Aman* as well as *T. Aus* season meaning that increase in the magnitude of this input increased yield substantially. The coefficient of land preparation of *T. Aman* rice was negative and statistically significant at 1 percent level, while it was positive and statistically significant at 1 percent level under *T. Aus* yield implying that increase in the magnitude of this input decreased *T. Aman* yield and increased *T. Aus* yield substantially. The coefficient of interaction between seed and NPK was positive and significant for *T. Aman* rice production but in case of *T. Aus* rice, it was negative and significant, implying that increased the application of seed and NPK would increase the yield of *T. Aman* and but decrease the yield of *T. Aus* rice in salinity ecosystem. The coefficient of interaction between area and seed was positive and significant for *T. Aman* rice production, indicating that application of these inputs has positive effect on *T. Aman* rice yield. The coefficient of interaction between labor and land preparation of *T. Aman* and *Boro* yield was negative and statistically significant revealed that there is slim influence of labor and land preparation to increase yield in salinity ecosystem.

The estimated determinants of technical inefficiency of the rice growers in salinity ecosystem are given in Table 10.33. The coefficient of education was negative and significant at 5 percent level for *T. Aman* as well as *Boro* rice growers; indicating that if the farmers had received higher education in the seasons that would decrease inefficiency of rice cultivation. The coefficients of age of *T. Aman* growers was positive and significant at 1 percent level indicated that inefficiency effect increased with the increase of age level of the *Aman* farmers. On the other hand, the coefficients of extension service, credit received and access to media was negative and significant of *T. Aman, T. Aus* and *Boro* rice cultivars; indicating that these inputs have vital influence on intervention in inefficiency in salinity ecosystem.

Table 10.33 Maximum likelihood estimates of Translog TE model for salinity ecosystem

Variables	Parameters	Translog TE model		
		T. Aus	*T. Aman*	*Boro*
		n=232	n=626	n=542
Intercept	β_0	-55.000***	65.149***	3.651
Log RA	β_1	0.825	-2.927***	-0.373
Log labour	β_2	1.669*	5.807***	2.426**
Log seed	β_3	-0.27	-9.306***	1.27
Log NPK	β_4	15.838***	7.268***	0.076
Log LP	β_5	2.541***	-5.808***	0.492
Log irrigation	β_6	0.781	0.332	-0.991
Log RA^2	β_{11}	-0.03	0.074	0.029
Log labour^2	β_{22}	-0.019	-0.198	0.304***
Log seed^2	β_{33}	-0.224	-0.289	-0.169**
Log NPK^2	β_{44}	-1.081	0.541	0.156
Log LP^2	β_{55}	0.045	0.286	0.047
Log irrigation^2	β_{66}	0.022	0.077	0.11
Log RA x Log labour	β_{12}	-0.392	-0.292	0.140*
Log RA x Log seed	β_{13}	0.055	0.889**	0.017
Log RA x Log NPK	β_{14}	0.206	-0.045	0.077
Log RA x Log LP	β_{15}	-0.179	0.253	0.009
Log RA x Log irri	β_{16}	0.086	0.141	0.054
Log labour x Log seed	β_{23}	-0.289	-0.666	-0.118
Log labour x Log NPK	β_{24}	0.385	0.064	-0.297*
Log labour x Log LP	β_{25}	0.231	-0.409*	-0.464***
Log labour x Log irri	β_{26}	-0.574	-0.362**	-0.028
Log seed x Log NPK	β_{34}	-1.539*	1.412**	-0.223
Log seed x Log LP	β_{35}	1.230**	1.135*	-0.145
Log seed x Log irri	β_{36}	0.061	0.074	0.166
Log NPK x Log LP	β_{45}	-1.868**	0.551	0.108
Log NPK x Log irri	β_{46}	-0.003	-0.203	-0.119
Inefficiency model				
Intercept	δ_0	0.705	0.018	-495.96
Farm size	δ_1	-9E-05	-0.0003	-0.056
Education	δ_2	0.042	-0.023**	-0.375**
Age	δ_3	-0.003	0.023***	1.195
Experience	δ_4	-0.008	-0.017***	-0.0568***
Extension	δ_5	-0.935**	-0.228	-27.253
Training	δ_6	-0.512	-0.185	-118.92
Credit received	δ_7	0.166	-0.350***	295.37
Access to media	δ_8	-0.195	-0.182*	-1.187
Sigma Square	σ^2	0.163***	0.048***	46.926
Gamma	γ	0.999***	0.999***	0.999***
log likelihood		49.832	79.943	192.67

Source: Authors' estimation based on field survey, 2019-2021.
* '10% level', ** '5% level', ***'1% level' significant.

10.10.7 Technical efficiency of rice farmers in different seasons in submergence ecosystem

The results show that the variance ratio parameter (γ) is greater than zero (0.988***,0.994*** and 0.989***) for models 1,2 and 3, respectively allows us to reject the hypothesis (H0: γ=0) of no significant technical inefficiency among seasonal rice growers. The results showed that the variance ratio parameter (γ) is greater than zero with statistically significant at 1 percent level, implying that the variation in *T. Aman, T. Aus* and *Boro* yield of submergence ecosystem from frontier yield was obtained among the farmers mainly arose by the differences in technological and management practices of seasonal rice yield rather than random variability. The significance of sigma square of the model models of seasonal rice yield indicated the existence of output variation among the farmers across the seasons in this ecosystem.

The aforesaid factors are under the control of the farmers and the influence of which can be altered to enhance their technical efficiency. The result shows that the coefficient of seed and labor for *T. Aman* and *Boro* yield was positive and significant at 1 percent and 5 percent level implying that these inputs has positive influence on yield in submergence ecosystem. The result also shows that the coefficients of NPK for *T. Aus* as well as *Boro* yield was positive and significant at 1percent level, indicating that increase in the application of NPK could increase yield. The coefficient of land preparation and irrigation of *T. Aman* as well as *T. Aus* yield was positive and significant at 1 percent level which implies that if the application of these inputs is increased, the yield of rice would be increased. The coefficient of interaction between area and land preparation was positive and significant at 5 percent level for *Boro* rice production but in case of *T. Aman* rice, it was negative and significant at 1 percent level, implying that increased the area and land preparation would increase the yield of *Boro* and but decrease the yield of *T. Aman* rice in submergence ecosystem. The coefficient of interaction between labor and land preparation was positive and significant for *Boro* rice production, indicating that application of these inputs has positive effect on *Boro* rice yield. The coefficient of interaction between seed and NPK was positive and significant at 1 percent level for *T. Aman* rice production on the other hand, it was negative and statistically significant at 5 percent level under *Boro* yield, implying that increased the application of seed and NPK would increase the yield of *T. Aman* and decrease the yield of *Boro* rice in submergence ecosystem.

The estimated determinants of technical inefficiency of the *T. Aman, T. Aus* and *Boro* rice growers in submergence ecosystem are presented in Table 10.34. The coefficient of experience and extension service was negative and significant at 5 percent for *T. Aman* as well as *T. Aus* and *Boro* rice growers; indicating that if the farmers had higher experience and received higher education in the seasons that would decrease inefficiency of rice cultivation. Magnitudes of all other coefficients (training, credit and access to media) was also negative, implying that all of the included variables of the model have more or less contribution to reduce the technical inefficiency of *T. Aman, T. Aus* and *Boro* rice growers in the submergence ecosystem.

10.34 Maximum likelihood estimates of Translog TE model for submergence ecosystem

Variables	Parameters	Translog TE model		
		T. Aus	*T. Aman*	*Boro*
		n=148	n=432	n=470
Intercept	β_0	2.966***	19.300**	-7.363*
Log RA	β_1	0.337	1.788***	-0.029
Log labor	β_2	1.177	-0.536	1.222**
Log seed	β_3	-1.227	4.720***	0.744
Log NPK	β_4	12.350***	1.353	3.263***
Log LP	β_5	6.924***	4.232***	0.28
Log irrigation	β_6	2.378***	1.586***	1.051*
Log RA^2	β_{11}	-0.045	0.01	0.016
Log labour^2	β_{22}	-0.58	0.125**	0.152***
Log seed^2	β_{33}	-0.493	-0.081	0.195**
Log NPK^2	β_{44}	1.141	-0.024	0.166*
Log LP^2	β_{55}	-1.551***	0.748***	-0.086
Log irrigation^2	β_{66}	-0.498	-0.059**	0.113**
Log RA x Log labour	β_{12}	-0.034	-0.047	-0.075*
Log RA x Log seed	β_{13}	-0.358	-0.031	-0.017
Log RA x Log NPK	β_{14}	0.411	0.057	-0.154**
Log RA x Log LP	β_{15}	-0.109	0.314***	0.154**
Log RA x Log irri	β_{16}	-0.028	0.126***	-0.016
Log labour x Log seed	β_{23}	0.859	0.170*	-0.086
Log labour x Log NPK	β_{24}	-0.762	0.181	-0.022
Log labour x Log LP	β_{25}	0.732	-0.149	0.311***
Log labour x Log irri	β_{26}	-0.343	-0.013	-0.068
Log seed x Log NPK	β_{34}	-1.198	0.905***	-0.263**
Log seed x Log LP	β_{35}	1.334*	0.515	0.007
Log seed x Log irri	β_{36}	-0.108	-0.075	-0.09
Log NPK x Log LP	β_{45}	1.164	-0.558**	-0.15
Log NPK x Log irri	β_{56}	0.856	-0.193*	-0.555***
Inefficiency model				
Intercept	δ_0	0.417	-8.98	-5.761
Farm size	δ_1	0.0002	0.0005	0.004
Education	δ_2	0.016	0.156	-0.241
Age	δ_3	0.004	0.123	0.106
Experience	δ_4	-0.007*	-0.103*	-0.131**
Extension	δ_5	-0.309**	-1.198**	-4.665**
Training	δ_6	-0.086	-8.798**	-2.629**
Credit received	δ_7	-0.319	-5.450***	-4.832**
Access to media	δ_8	-0.065	-4.787*	0.891
Sigma Square	σ^2	0.071***	1.836	1.678
Gamma	γ	0.994***	0.988***	0.989
log likelihood		38.0018	47.6896	69.1334

Source: Authors' estimation based on field survey, 2019-2021.
* '10% level', ** '5% level', ***'1% level' significant.

10.10.8 Technical efficiency of rice farmers in different seasons in tidal submergence ecosystem

The results show that the variance ratio parameter (γ) is greater than zero (1.000***,1.000*** and 0.954***) for models 1,2 and 3, respectively allows us to reject the hypothesis (H0: γ=0) of no significant technical inefficiency among seasonal rice growers. The results showed that the variance ratio parameter (γ) is greater than zero with statistically significant at 1 percent level, implying that the variation in *T. Aman, T. Aus* and *Boro* yield of tidal submergence ecosystem from frontier yield was obtained among the farmers mainly arose by the differences in technological and management practices of seasonal rice yield rather than random variability.

The aforesaid factors are under the control of the farmers and the influence of which can be altered to enhance their technical efficiency. The result shows that the coefficient of land area was positive and statistically significant at 1percent and 5 percent level respectively for *T. Aman* as well as *T. Aus* yield while the coefficient of this input under *Boro* yield was found negative but statistically significant at 5 percent level, meaning that optimum land area has positive effect on *T. Aman* as well as T Aus yield increase and no further opportunities exist in the frontier to increase yield by the increased land area input in *Boro* season in tidal submergence ecosystem. The coefficient of labor and seed was positive and significant under *T. Aman*, *T. Aus* and *Boro* yield respectively; indicating that sufficient labor and good quality could increase yield remarkably. The result also shows that the coefficient of fertilizers (NPK) of T. Amam yield was positive and significant at 1 percent level while the coefficient of this input under *T. Aus* yield was found negative but statistically significant at 1 percent level indicating that increased application of fertilizers could increase *T. Aman* yield and decrease *T. Aus* yield. The coefficient of interaction between area and land preparation was positive and significant for *Boro* rice production but in case of *T. Aus* rice the coefficient of interaction between area and land preparation was negative and significant, implying that increased the application of optimum area and land preparation would increase the yield of *Boro* yield but decrease the yield of *T. Aus* rice in tidal submergence ecosystem. The coefficient of interaction between labor and seed was positive and significant for *T. Aus as* well as *Boro* rice production, indicating that application of these inputs has positive effect on *T. Aus as* well as *Boro* rice yield. In case of *Boro* rice yield, the coefficients of interaction between labor, irrigation and land preparation were negative and significant at 1 percent level implying that unnecessary additional labor, irrigation and land preparation decreased yield in tidal submergence ecosystem.

The estimated determinants of technical inefficiency of the rice growers in tidal submergence ecosystem are given in Table 10.35. The coefficient of experience was negative and significant at 1 percent for *T. Aus* rice growers; indicating that if the farmers had higher experience in the seasons that would decrease inefficiency of rice cultivation. The coefficients of age of *T. Aus* growers was positive and significant at 1 percent level indicated that inefficiency effect increased with the increase of age level of the *T. Aus* farmers. On the other hand, the coefficient of extension service was negative and significant of *T. Aman, T. Aus* and *Boro* rice cultivars; indicating that these inputs have vital influence on intervention in inefficiency in tidal submergence ecosystem.

10.35 Maximum likelihood estimates of Translog TE model for tidal submergence ecosystem

Variables	Parameters	Translog TE model		
		T. Aus	*T. Aman*	*Boro*
		n=120	n=302	n=278
Intercept	β_0	-21.053***	-59.962***	-17.750*
Log RA	β_1	1.743**	3.950***	-1.824**
Log labour	β_2	4.756**	2.825***	6.744***
Log seed	β_3	33.354***	11.678***	-3.245
Log NPK	β_4	-5.934***	4.092***	-1.269
Log LP	β_5	-7.982***	2.898***	2.409**
Log irrigation	β_6	1.162	1.505*	2.580**
Log RA^2	β_{11}	-0.184**	-0.07	-0.080*
Log labour^2	β_{22}	-0.011	0.276	-0.157
Log seed^2	β_{33}	-1.503	-1.897**	-0.686
Log NPK^2	β_{44}	-1.043*	-0.292	-0.011
Log LP^2	β_{55}	3.735***	-0.078	-0.157*
Log irrigation^2	β_{66}	0.013	0.088	-0.193
Log RA x Log labour	β_{12}	-0.02	-0.244	0.115
Log RA x Log seed	β_{13}	-0.211	-0.857*	-0.084
Log RA x Log NPK	β_{14}	0.331	-0.164	0.12
Log RA x Log LP	β_{15}	-0.456*	-0.135	0.289**
Log RA x Log irri	β_{16}	0.190*	-0.094	0.092
Log labour x Log seed	β_{23}	5.863***	-1.122	1.375**
Log labour x Log NPK	β_{24}	1.408*	1.002	-0.32
Log labour x Log LP	β_{25}	-4.42	-0.64	-0.984***
Log labour x Log irri	β_{26}	0.168	-0.368	-0.712***
Log seed x Log NPK	β_{34}	1.961	-0.875	0.239
Log seed x Log LP	β_{35}	-10.712***	0.083	0.593
Log seed x Log irri	β_{36}	0.547	0.423	-0.144
Log NPK x Log LP	β_{45}	1.958***	-0.088	-0.062
Log NPK x Log irri	β_{56}	-1.166***	-0.627	0.359*
Inefficiency model				
Intercept	δ_0	0.269	0.967***	0.736
Farm size	δ_1	-0.0004	-0.0002	-0.001
Education	δ_2	-0.015	-0.016*	-0.039
Age	δ_3	-0.015***	-0.001	-0.006
Experience	δ_4	-0.016***	-0.002	-0.001
Extension	δ_5	-1.238***	-0.332***	-1.070*
Training	δ_6	-0.06	-0.016	0.319
Credit received	δ_7	0.012	0.023	0.027
Access to media	δ_8	-0.699*	0.02	0.348
Sigma Square	σ^2	0.087	0.044	0.38
Gamma	γ	1.000***	1.000***	0.954***
log likelihood		59.312***	32.0312	-30.412

Source: Authors' estimation based on field survey, 2019-2021.
* '10% level', ** '5% level', ***'1% level' significant.

10.10.9 Technical efficiency of rice farmers in different seasons in low lying ecosystem

The results show that the variance ratio parameter (γ) is greater than zero (0.993***,0.966*** and 0.998***) for models 1,2 and 3, respectively allows us to reject the hypothesis (H0: γ=0) of no significant technical inefficiency among seasonal rice growers. The results showed that the variance ratio parameter (γ) is greater than zero with statistically significant at 1 percent level, implying that the variation in *T. Aman, T. Aus* and *Boro* yield of low lying ecosystem from frontier yield was obtained among the farmers mainly arose by the differences in technological and management practices of seasonal rice yield rather than random variability. The significance of sigma square of the model models of seasonal rice yield indicated the existence of output variation among the farmers across the seasons in this ecosystem.

The aforesaid factors are under the control of the farmers and the influence of which can be altered to enhance their technical efficiency. The result shows that the coefficient of labor (man-days) was positive and significant at 5 percent level for *T. Aman* yield indicating that the yield of *T. Aman* is increased if the supply of labor is increased in low lying ecosystem. On the other hand, the coefficient of seed under *T. Aus* rice was positive and statistically significant at 5 percent level implying that if the supply of optimum amount seed is increased the yield would be increased. The result also shows that the coefficient of fertilizers (NPK) of *Boro* yield was positive and significant at 1 percent level implying that increased application of fertilizers could increase *Boro* yield. The coefficient of labor (Kg/ha), was negative and statistically not significant for *T. Aus* as well as *Boro* rice. The coefficient of NPK under *T. Aman* as well as *T. Aus* rice was positive and statistically not significant meaning that there is slim influence of NPK to increase yield in low lying ecosystem. The interaction between rice area and labor was negative and statistically not significant for *T. Aman*, *T. Aus* and *Boro* yield indicating that land area and labor jointly impacted on reducing the yield of rice in low lying ecosystem. On the other hand, the coefficient interaction between rice area and land preparation for *T. Aman* as well as *T. Aus* was positive and significant at 10 percent level; implying that optimum rice area and land preparation can increase yield considerably. The coefficient interaction between seed and land preparation was positive but statistically not significant under *T. Aman* and *T. Aus* yield indicating that these inputs have still some positive an effect on yield. Coefficient interaction between seed and NPK of *T. Aman* and *Boro* yield was positive and significant at 1 percent level; implying that seed and NPK could increase yield significantly.

The estimated determinants of technical efficiency of the *T. Aman, T. Aus* and *Boro* rice growers low lying ecosystem are presented in Table 10.36. The coefficients of education, extension contact and experience was negative and statistically significant as expected; indicating that these variables have robust influential effects on intervention to reduce the technical inefficiency of rice growers. The coefficients of training and access to media was negative but statistically not significant; indicating these factors also has some influence on intervention the inefficiency of the rice cultivars in low lying ecosystem.

10.36 Maximum likelihood estimates of Translog TE model for low lying ecosystem

Variables	Parameters	Translog TE model		
		T. Aus	*T. Aman*	*Boro*
		n=156	n=562	n=682
Intercept	β_0	7.167	3.449	11.784***
Log RA	β_1	-1.275	-0.115	0.141
Log labour	β_2	-2.719	0.630***	-0.153
Log seed	β_3	0.903**	-0.723	0.104
Log NPK	β_4	1.755	0.292	0.739**
Log LP	β_5	4.297*	0.947*	-0.301
Log RA^2	β_{11}	0.058	0.012	0.004
Log labour^2	β_{22}	0.316	0.085	-0.015
Log seed^2	β_{33}	0.518	-0.055	0.140**
Log NPK^2	β_{44}	0.855	-0.267***	0.188**
Log LP^2	β_{55}	-0.881***	-0.150**	-0.036
Log RA x Log labour	β_{12}	-0.163	-0.06	-0.027
Log RA x Log seed	β_{13}	0.102	-0.314**	0.05
Log RA x Log NPK	β_{14}	-0.078	0.02	-0.06
Log RA x Log LP	β_{15}	0.314*	0.148**	-0.009
Log labour x Log seed	β_{23}	0.802	-0.217	-0.2
Log labour x Log NPK	β_{24}	-1.746**	0.158	-0.224
Log labour x Log LP	β_{25}	1.149*	-0.192	0.307
Log seed x Log NPK	β_{34}	-0.035	0.441***	0.079
Log seed x Log LP	β_{35}	0.702	0.186	-0.099
Log NPK x Log LP	β_{45}	-0.5	0.038	0.043
Inefficiency model				
Intercept	δ_0	14.26	-15.324	-37.643
Farm size	δ_1	0.012	-0.001	-0.089
Education	δ_2	-0.897***	-0.530***	-0.405**
Age	δ_3	-1.446	0.151	0.744
Experience	δ_4	1.339	-0.080*	-0.157**
Extension	δ_5	4.494	-0.105*	-0.343**
Training	δ_6	-0.107	-0.678	0.29
Credit received	δ_7	-0.762	0.51	-0.886
Access to media	δ_8	-0.57	-0.946	-0.806
SigmaSq	$\sigma 2$	0.932	6.407	14.954
Gamma	γ	0.966***	0.993***	0.998***
log likelihood		38.685	-89.135	41.942

Source: Authors' estimation based on field survey, 2019-2021.
* '10% level', ** '5% level', ***'1% level' significant.

10.10.10 Technical efficiency of rice farmers in different seasons in drought ecosystem

The results show that the variance ratio parameter (γ) is greater than zero (0.959***,0.997*** and 0.984***) for models 1,2 and 3, respectively allows us to reject the hypothesis (H0: γ=0) of no significant technical inefficiency among seasonal rice growers. The results showed that the variance ratio parameter (γ) is greater than zero with statistically significant at 1 percent level, implying that the variation in *T. Aman, T. Aus* and *Boro* yield of drought ecosystem from frontier yield was obtained among the farmers mainly arose by the differences in technological and management practices of seasonal rice yield rather than random variability. The significance of sigma square of the model models of seasonal rice yield indicated the existence of output variation among the farmers across the seasons in this ecosystem.

The aforesaid factors are under the control of the farmers and the influence of which can be altered to enhance their technical efficiency. The result shows that the coefficients of labour (man-days) was positive and significant at 1 percent level for *T. Aman* as well as *T. Aus* yield, while the coefficient was negative and significant for *Boro* yield; indicating that increased labor supply increase *T. Aman* and *T. Aus* yield substantially but decrease *Boro* yield in drought ecosystem. The result also shows that the coefficients of fertilizers (NPK) under *T. Aus* as well as *Boro* yield was positive and significant at 1 level, indicating that good quality, timely application and optimum doses of different fertilizers could increase yield substantially. The coefficient of land preparation was positive and significant at 1 percent level under *T. Aus* yield, on the other hand although it was also positive but not statistically significant for both *T. Aman* and *Boro* yield implying that these inputs have at least influence on yield in drought ecosystem. The interaction coefficient between labor and seed for *T. Aus* and *Boro* yield was negative but statistically significant at 1 percent level implying that extra labor and use of more seeds decline the rice yield. The interaction between labor and irrigation for *T. Aman*, *T. Aus* and *Boro* yield was positive and significant at 10, 10 and 5 percent level respectively, indicating; jointly these two inputs influence to increase yield considerably.

The estimated determinants of technical inefficiency of the rice growers in drought ecosystem are given in Table 10.37. The coefficient of extension contacts and training was negative and significant at 1percent for *T. Aman* as well as *T. Aus and Boro* rice growers; indicating that if the farmers had received extension service and imparting more training that would decrease inefficiency of rice cultivation. On the other hand, credit had also negative and significant impact on inefficiency effect for *T. Aman* and *Boro* farmers. The negative sign in the inefficiency model indicates positive effect on the efficiency levels of the farmers. So, it can be apparent that provision of credit would reduce inefficiency of farmers in drought ecosystem.

10.37 Maximum likelihood estimates of Translog TE model for drought ecosystem

Variables	Parameters	Translog TE model		
		T. Aus	***T. Aman***	***Boro***
		n=208	**n=598**	**n=594**
Intercept	β_0	-37.753***	-9.528	3.446
Log RA	β_1	1.203**	0.078	0.003
Log labour	β_2	3.933***	2.759**	-2.830***
Log seed	β_3	1.073	0.721	2.525*
Log NPK	β_4	5.702***	1.347	1.597**

Variables	Parameters	Translog TE model		
		T. Aus	*T. Aman*	*Boro*
		n=208	n=598	n=594
Log LP	β_5	3.829***	1.32	0.39
Log irrigation	β_6	-17.083	0.023	0.166
Log RA^2	β_{11}	-0.024	0.023	0.059***
Log labour^2	β_{22}	-0.291	-0.709***	0.308***
Log seed^2	β_{33}	-0.645***	-0.123	0.004
Log NPK^2	β_{44}	-0.524***	-0.298***	-0.014
Log LP^2	β_{55}	-0.316**	-0.116*	-0.049
Log irrigation^2	β_{66}	0.042	-0.047	-0.096*
Log RA x Log labour	β_{12}	-0.282**	0.016	0.073
Log RA x Log seed	β_{13}	0.091	-0.027	-0.088
Log RA x Log NPK	β_{14}	-0.062	-0.0001	-0.074
Log RA x Log LP	β_{15}	-0.143	-0.055	0.02
Log RA x Log irri	β_{16}	0.048**	0.013	-0.048
Log labour x Log seed	β_{23}	-1.260***	0.194	-0.631***
Log labour x Log NPK	β_{24}	0.088	0.132	-0.096
Log labour x Log LP	β_{25}	-0.134	-0.142	0.326**
Log labour x Log irri	β_{26}	0.226*	0.157*	0.242**
Log seed x Log NPK	β_{34}	0.422	-0.116	-0.300**
Log seed x Log LP	β_{35}	0.723*	0.004	0.025
Log seed x Log irri	β_{36}	-0.126	-0.104	-0.025
Log NPK x Log LP	β_{45}	-0.608*	0.049	-0.254***
Log NPK x Log irri	β_{46}	-0.205	0.041	0.128
Inefficiency model				
Intercept	δ_0	0.810***	0.596***	-1.074
Farm size	δ_1	0.00002	0.00001	-0.001
Education	δ_2	-0.026***	0.003	-0.017
Age	δ_3	-0.004	-0.004*	-0.004
Experience	δ_4	0.006	-0.004*	0.013
Extension	δ_5	-0.380***	-0.297***	-0.266**
Training	δ_6	-0.150*	-0.175***	-0.151*
Credit received	δ_7	-0.132	-0.224***	-0.049***
Access to media	δ_8	-0.115	-0.039	1.119
SigmaSq	σ^2	0.077	0.055***	1.068
Gamma	γ	0.997***	0.959***	0.984
log likelihood		96.113	295.541	31.001

Source: Authors' estimation based on field survey, 2019-2021.
* '10% level', ** '5% level', ***'1% level' significant.

10.10.11 Technical efficiency of rice farmers in different seasons in hilly ecosystem

The results show that the variance ratio parameter (γ) is statistically greater than zero (0.998***,0.999*** and 0.477***) for models 1,2 and 3, respectively allows us to reject the hypothesis (H0: γ=0) of no significant technical inefficiency among seasonal rice growers. The results showed that the variance ratio parameter (γ) is greater than zero with statistically significant at 1 percent level, implying that the variation in *T. Aman, T. Aus* and *Boro* yield of hilly ecosystem from frontier yield was obtained among the farmers mainly arose by the differences in technological and management practices of seasonal rice yield rather than random variability. The significance of sigma square of the model models of seasonal rice yield indicated the existence of output variation among the farmers across the seasons in this ecosystem.

The aforesaid factors are under the control of the farmers and the influence of which can be altered to enhance their technical efficiency. The result shows that the coefficient of the land area under T. *Aman* yield *as* well as *T. Aus* and *Boro* yield was positive and significant at 10 and 1 percent level respectively; implying that increase of land area has positive effect on yield increase in hilly ecosystem. The coefficient of seed was positive and statistically significant for *T. Aman* and *Boro* season while the coefficient of seed under *T. Aus* rice cultivation (ha) was also found positive but statistically not significant, meaning that increase the optimum use of seed has positive effect on *T. Aman* and *Boro* yield increase and slight influence on *T. Aus* yield. The coefficient of land preparation under *T. Aus* rice cultivation (ha) was negative and statistically significant at 1% level, implying that there are no further opportunities to increase yield by increasing land area under *T. Aus* rice cultivation in this ecosystem. The result also shows that the coefficients of fertilizers (NPK) under *T. Aman* as well as *T. Aus* yield was positive and significant at 1 level, indicating that good quality, timely application and optimum doses of different fertilizers could increase yield substantially. The coefficient of interaction between land area and land preparation; labor and NPK; seed and NPK was positive and significant for *T. Aus* yield implying that combination of these inputs would increase the yield. The coefficient of interaction between labor and seed; NPK and land preparation was negative and significant under *T. Aus* yield implying that combination of these inputs would decrease the yield in hilly ecosystem.

The estimated determinants of technical inefficiency of the rice growers in hilly ecosystem are given in Table 10.38. The coefficient of farm size was negative and significant at 1percent level for *T. Aus* as well as *Boro* rice growers; indicating that farm size has positive effect on reducing the technical inefficiency *T. Aus* and *Boro* rice growers in hilly ecosystem. The coefficient of education was negative and significant at 10 percent level for *T. Aman* as well as *Boro* rice growers; indicating that if the farmers had received higher education that would decrease inefficiency of rice cultivation. The coefficient of extension service, training and access to media was negative and statistically significant for *T. Aman*, *T. Aus* and *Boro* farmers; implying that extension service, imparting more training and technological information in the seasons that would decrease inefficiency of rice cultivation in hilly ecosystem.

10.38 Maximum likelihood estimates of Translog TE model for hilly ecosystem

Variables	Parameters	Translog TE model		
		T. Aus	*T. Aman*	*Boro*
		n=79	n=335	n=286
Intercept	β_0	55.871***	6.788***	15.753
Log RA	β_1	3.686***	0.070*	1.392***
Log labour	β_2	5.447***	0.076	0.437
Log seed	β_3	0.613	0.081*	1.318***
Log NPK	β_4	5.895***	0.102***	0.758
Log LP	β_5	-9.619***	0.087*	-3.517
Log RA^2	β_{11}	-0.031	-	-0.094
Log labour^2	β_{22}	-0.431***	-	-0.093
Log seed^2	β_{33}	0.812***	-	-0.008
Log NPK^2	β_{44}	-0.464***	-	0.008
Log LP^2	β_{55}	0.868***	-	0.247
Log RA x Log labour	β_{12}	-0.680***	-	-0.122
Log RA x Log seed	β_{13}	0.164	-	-0.395***
Log RA x Log NPK	β_{14}	-0.003	-	-0.238
Log RA x Log LP	β_{15}	1.042***	-	0.114
Log labour x Log seed	β_{23}	-1.423***	-	-0.295
Log labour x Log NPK	β_{24}	0.964***	-	-1.94
Log labour x Log LP	β_{25}	1.850***	-	0.312
Log seed x Log NPK	β_{34}	0.561***	-	-0.016
Log seed x Log LP	β_{35}	-0.485**	-	0.1
Log NPK x Log LP	β_{45}	-1.382***	-	0.029
Inefficiency model				
Intercept	δ_0	1.398***	-189.69	0.385***
Farm size	δ_1	-0.014***	-0.885	-0.002**
Education	δ_2	0.027	-0.644**	-0.019*
Age	δ_3	-0.004	0.042	0.002
Experience	δ_4	-0.006*	-0.228*	-0.003*
Extension	δ_5	-0.081**	-0.316**	-0.091***
Training	δ_6	-0.193	-0.108	-0.381**
Credit received	δ_7	0.263	-0.253**	0.141
Access to media	δ_8	0	0	-0.184***
Sigma Square	σ^2	0.131***	52.379	0.086***
Gamma	γ	0.999***	0.998***	0.477***
log likelihood		25.393	-97.809	-17.449

Source: Authors' estimation based on field survey, 2019-2021.
* '10% level', ** '5% level', ***'1% level' significant.

10.10.12 Technical efficiency of rice farmers in *T. Aus* season in pooled data

The results show that the variance ratio parameter (γ) is statistically greater than zero (0.0918***) for models 1,2 and 3, respectively allows us to reject the hypothesis (H0: γ=0) of no significant technical inefficiency among seasonal rice growers. The results showed that the variance ratio parameter (γ) is greater than zero with statistically significant at 1 percent level, implying that the variation in *T. Aus* yield of pooled data from frontier yield was obtained among the farmers mainly arose by the differences in technological and management practices of seasonal rice yield rather than random variability. The significance of sigma square of the model models of seasonal rice yield indicated the existence of output variation among the farmers across the seasons in this ecosystem.

The result also showed that the coefficients of rice areas, labour and seed were positive and significant, indicating that one 1 percent increase in these inputs increased 2, 5 and 7 percent increase in yield, respectively.

The coefficient of interaction of seed and irrigation, labour and seed, NPK and LP was positive and highly significant, implying that 1 percent increase in these inputs increased 0.09, 4.5 and 3.5 percent yield, respectively. The interaction between labour and LP, seed and irrigation, NPK and irrigation was negative and significant, indicating increase in combination of these inputs declined the level of *T. Aus* yield.

The estimated determinants of technical inefficiency of the rice growers in *T. Aman* season are given in Table 10.39. The coefficient of farm size, training, credit received and access to media negative and significant; indicating that as farm size, training, credit received and access to media increases, their technical inefficiency decreases. The coefficient of education was also negative but insignificant (Table 10.39).

10.10.13 Technical efficiency of rice farmers in *T. Aman* season in pooled data

The results show that the variance ratio parameter (γ) is statistically greater than zero (0.0001 ***) for models 1,2 and 3, respectively allows us to reject the hypothesis (H0: γ=0) of no significant technical inefficiency among seasonal rice growers. The results showed that the variance ratio parameter (γ) is greater than zero with statistically significant at 1 percent level, implying that the variation in *T. Aman* yield of pooled data from frontier yield was obtained among the farmers mainly arose by the differences in technological and management practices of seasonal rice yield rather than random variability. The significance of sigma square of the model models of seasonal rice yield indicated the existence of output variation among the farmers across the seasons in this ecosystem.

The result also showed that the coefficients of rice areas, labour and LP were negative and statistically significant at 1 and 5 percent level, respectively implying that additional increase in the magnitude of these inputs decreased yield. The coefficient of seed. NPK and irrigation was positive, implying that increase in these inputs ineased the level of yield. The interaction between rice area (RA) and NPK was positive and significant, indicating application of these inputs has positive effect on *T. Aman* yield.

The estimated determinants of technical inefficiency of the rice growers in *T. Aman* season are given in Table 10.39. The coefficient of farm size and extension contacts were negative and significant;

indicating that as the farm size and extension services increases, their technical inefficiency decreases. The coefficient of education was also negative but insignificant (Table 10.39).

10.10.14 Technical efficiency of rice farmers in *Boro* season in pooled data

results show that the variance ratio parameter (γ) is statistically greater than zero (1.000***) for models 1,2 and 3, respectively allows us to reject the hypothesis (H0: γ=0) of no significant technical inefficiency among seasonal rice growers. The results showed that the variance ratio parameter (γ) is greater than zero with statistically significant at 1 percent level, implying that the variation in *T. Aus* yield of pooled data from frontier yield was obtained among the farmers mainly arose by the differences in technological and management practices of seasonal rice yield rather than random variability. The significance of sigma square of the model models of seasonal rice yield indicated the existence of output variation among the farmers across the seasons in this ecosystem.

The result also displayed that the coefficients of labour and LP were positive and significant, indicating that one 1 percent increase in these inputs increased 6.5 and 4.5 percent increase in *Boro* yield, respectively. The coefficient of interaction of rice area and irrigation, labour and seed, NPK and LP was positive and highly significant, implying that 1 percent increase in these inputs increased 0.09, 4.5 and 3.5 percent yield, respectively. The coefficients of seed and NPK were negative and significant, indicating that any increase in both seed and NPK decreased *Boro* yield, respectively.

The interaction between RA and LP and between seed and NPK was positive and significant, indicating one percent increase in combination of these inputs increased 0.40 and 1.14 percent yield in *Boro* season. The interaction between RA and irrigation was negative and significant, indicating one percent increase in combination of RA and irrigation reduced 0.50 percent yield.

Table 10.39 presents the determinants of technical inefficiency of farmer's specific rice cultivation. It denoted that in the stochastic frontier estimation, the parameter for inefficiency level usually enters the inefficiency effects component of the model (second stage) as the dependent variable. In addition, a negative sign on the coefficient variable is interpreted as a positive influence on efficiency (i.e., decrease in inefficiency). Conversely, a positive coefficient is treated as a negative influence on efficiency (an increase in inefficiency) (Brummer and Loy 2000; Coelli *et al.* 2005).

The coefficient of farm size, extension contacts and training negative and significant; indicating that as farm size, extension contacts and training increases, their technical inefficiency decreases (Table 10.39).

Table 10.39: Maximum likelihood estimates of Translog TE model in pooled data

Variables	Parameters	Translog TE model		
		T. Aus	***T. Aman***	***Boro***
Intercept	β_0	23.476 ***	46.072***	-21.866 ***
Log RA	β_1	2.716 ***	-2.283 **	0.882
Log labour	β_2	7.202 ***	-3.984 ***	6.5035***
Log seed	β_3	5.582 ***	0.349	-1.599 **
Log NPK	β_4	-11.102***	3.244 ***	-5.265***
Log LP	β_5	-4.922 ***	-7.152 ***	4.534 *
Log irrigation	β_6	0.0404	0.053	2.426

Variables	Parameters	Translog TE model		
		T. Aus	*T. Aman*	*Boro*
Log RA^2	β_{11}	-0.0041	0.046 *	0.045
Log labour^2	β_{22}	-0.98	1.188 ***	-0.999 ***
Log seed^2	β_{33}	-0.774	-0.643 *	-0.329
Log NPK^2	β_{44}	1.279 **	-0.702 *	1.404 ***
Log LP^2	β_{55}	0.539	0.703 ***	-0.437 ***
Log irrigation^2	β_{66}	0.007***	0.005	0.082
Log RA x Log labour	β_{12}	-0.539	0.067	-0.163
Log RA x Log seed	β_{13}	0.704	0.183	0.179
Log RA x Log NPK	β_{14}	-1.427 ***	0.393 **	-0.162
Log RA x Log LP	β_{15}	0.284	0.086	0.408 **
Log RA x Log irri	β_{16}	0.090 ***	-0.0043	-0.508 ***
Log labour x Log seed	β_{23}	4.560 ***	-0.505	-0.5007
Log labour x Log NPK	β_{24}	-0.611	-0.238	0.062
Log labour x Log LP	β_{25}	-1.688 **	-0.044	-0.196
Log labour x Log irri	β_{26}	-0.028	-0.0089	-0.0012
Log seed x Log NPK	β_{34}	-1.08	0.174	1.141 ***
Log seed x Log LP	β_{35}	-3.600 ***	0.412	0.124
Log seed x Log irri	β_{36}	0.959 *	0.0012	-0.178
Log NPK x Log LP	β_{45}	3.457 ***	0.0132	-0.639
Log NPK x Log irri	β_{46}	-0.864 **	-0.011	-0.36
Inefficiency model				
Intercept	δ_0	0.203	-0.413 *	0.648 ***
Farm size	δ_1	-0.0001**	-0.001***	-0.001***
Education	δ_2	0.0079	-0.012	0.01
experience	δ_3	0.0001	-0.011 ***	-0.004**
Extension	δ_4	0.136	-1.06***	-0.437 ***
Training	δ_5	-0.079*	0.06	-0.052*
Credit received	δ_6	-0.241	-0.517 ***	0.133
Access to media	δ_7	-0.017**	-1.150 ***	0.059
sigmaSq	σ^2	0.014	0.013 ***	0.037 ***
Gamma	γ	0.0918*	0.0001 **	1.00 ***
log likelihood		51.45	62.06	49.48

Source: Authors' estimation based on field survey, 2019-2021.
* '10% level', ** '5% level', ***'1% level' significant.

10.10.15 Farm specific technical efficiency index of rice farmers in different ecosystems

Ecosystem wise technical efficiency index of rice farmers by different farm size and season were given table 10.40. **In Favorable ecosystem,** the estimated farm-specific technical efficiency score of large farmers was 0.95, 0.78 and 0.93 for *T. Aman*, *T. Aus* and *Boro* rice, respectively. In case of medium farmers, the anticipated efficiency scores were 0.83, 0.78 and 0.90 for *T. Aman*, *T. Aus* and *Boro* rice, respectively whereas the efficiency scores of small farmers for *T. Aman*, *T. Aus* and *Boro* rice were 0.73, 0.75 and 0.88 respectively. Technical efficiency of large farmers in case of *T. Aman* rice was highest among the medium and small farmers in irrespective seasons. The average estimated technical efficiency was 0.89, 0.84 and 0.79 for large, medium and small farmers, respectively which means rice production could be increased by 11%, 16% and 21%, respectively with the same level of inputs without incurring any further cost.

In *Haor* ecosystem, the estimated farm-specific technical efficiency score of large farmers was 0.79, 0.88 and 0.74 for *T. Aman*, *T. Aus* and *Boro* rice, respectively. In case of medium farmers, the anticipated efficiency scores were 0.78, 0.80 and 0.77 for *T. Aman*, *T. Aus* and *Boro* rice, respectively whereas the efficiency scores of small farmers for *T. Aman*, *T. Aus* and *Boro* rice were 0.80, 0.80 and 0.76 respectively. Technical efficiency of large farmers in case of *T. Aus* rice was highest among the medium and small farmers in irrespective seasons. The average estimated technical efficiency was 0.80, 0.78 and 0.79 for large, medium and small farmers, respectively which means rice production could be increased by 20%, 22% and 21%, respectively with the same level of inputs without incurring any further cost.

In Salinity ecosystem, the estimated farm-specific technical efficiency score of large farmers was 0.73, 0.93 and 0.96 for *T. Aman*, *T. Aus* and *Boro* rice, respectively. In case of medium farmers, the anticipated efficiency scores were 0.79, 0.87 and 0.90 for *T. Aman*, *T. Aus* and *Boro* rice, respectively whereas the efficiency scores of small farmers for *T. Aman*, *T. Aus* and *Boro* rice were 0.80, 0.77 and 0.90 respectively. Technical efficiency of large farmers in case of T. *Boro* rice was highest among the medium and small farmers in irrespective seasons. The average estimated technical efficiency was 0.88, 0.85 and 0.82 for large, medium and small farmers, respectively which means rice production could be increased by 12%, 15% and 18%, respectively with the same level of inputs without incurring any further cost.

In drought ecosystem, the estimated farm-specific technical efficiency score of large farmers was 0.83, 0.87 and 0.82 for *T. Aman*, *T. Aus* and *Boro* rice, respectively. In case of medium farmers, the anticipated efficiency scores were 0.80, 0.79 and 0.91 for *T. Aman*, *T. Aus* and *Boro* rice, respectively whereas the efficiency scores of small farmers for *T. Aman*, *T. Aus* and *Boro* rice were 0.81, 0.78 and 0.81 respectively. Technical efficiency of large farmers in case of *T. Aus* rice was highest among the medium and small farmers in irrespective seasons. The average estimated technical efficiency was 0.84, 0.80 and 0.80 for large, medium and small farmers, respectively which means rice production could be increased by 16%, 20% and 20%, respectively with the same level of inputs without incurring any further cost.

In tidal submergence ecosystem, the estimated farm-specific technical efficiency score of large farmers was 0.57 and 0.87 for *T. Aman* and *Boro* rice, respectively. In case of medium farmers, the anticipated efficiency scores were 0.65, 0.89 and 0.78 for *T. Aman*, *T. Aus* and *Boro* rice, respectively whereas the efficiency scores of small farmers for *T. Aman*, *T. Aus* and *Boro* rice were 0.66, 0.84 and 0.75 respectively. Technical efficiency of medium farmers in case of *T. Aus* rice was highest among the medium and small farmers in irrespective seasons. The average estimated technical efficiency was 0.72, 0.77 and 0.75 for large, medium and small farmers, respectively which means rice production could be increased by 28%, 23% and 25%, respectively with the same level of inputs without incurring any further cost.

In submergence ecosystem, the estimated farm-specific technical efficiency score of large farmers was 0.82, 0.84 and 0.89 for *T. Aman*, *T. Aus* and *Boro* rice, respectively. In case of medium farmers, the anticipated efficiency scores were 0.85, 0.81 and 0.86 for *T. Aman*, *T. Aus* and *Boro* rice, respectively whereas the efficiency scores of small farmers for *T. Aman*, *T. Aus* and *Boro* rice were 0.85, 0.74 and 0.84 respectively. Technical efficiency of large farmers in case of *Boro* rice was highest among the medium and small farmers in irrespective seasons. The average estimated technical efficiency was 0.85, 0.84 and 0.81 for large, medium and small farmers, respectively which means rice production could be increased by 15%, 16% and 19%, respectively with the same level of inputs without incurring any further cost.

In low lying ecosystem, the estimated farm-specific technical efficiency score of large farmers was 0.79 and 0.87 for *T. Aman* and *Boro* rice, respectively. In case of medium farmers, the anticipated efficiency scores were 0.79, 0.80 and 0.89 for *T. Aman*, *T. Aus* and *Boro* rice, respectively whereas the efficiency scores of small farmers for *T. Aman*, *T. Aus* and *Boro* rice were 0.81, 0.86 and 0.89 respectively. Technical efficiency of medium farmers in case of *T. Aus* rice was highest among the medium and small farmers in irrespective seasons. The average estimated technical efficiency was 0.83, 0.83 and 0.85 for large, medium and small farmers, respectively which means rice production could be increased by 17%, 17% and 15%, respectively with the same level of inputs without incurring any further cost.

In hilly **ecosystem,** the estimated farm-specific technical efficiency score of large farmers was 0.82 and 0.74 for *T. Aus* and *Boro* rice, respectively. In case of medium farmers, the anticipated efficiency scores were 0.88, 0.80 and 0.90 for *T. Aman*, *T. Aus* and *Boro* rice, respectively whereas the efficiency scores of small farmers for *T. Aman*, *T. Aus* and *Boro* rice were 0.83, 0.76 and 0.78 respectively. Technical efficiency of medium farmers in case of *T. Aus* rice was highest among the medium and small farmers in irrespective seasons. The average estimated technical efficiency was 0.78, 0.88 and 0.79 for large, medium and small farmers, respectively which means rice production could be increased by 22%, 12% and 21%, respectively even with the existing technologies, if the management practices of the identified parameters are improved.

Table 10.40: Farm specific technical efficiency index of rice farmers in different ecosystems

Ecosystems	Efficiency	Large farmers				Medium farmers				Small farmers			
	parameter	*T. Aus*	*T. Aman*	*Boro*	Average	*T. Aus*	*T. Aman*	*Boro*	Average	*T. Aus*	*T. Aman*	*Boro*	Average
Favorable ecosystem	Mean	0.78	0.95	0.93	0.89	0.78	0.83	0.9	0.84	0.75	0.73	0.88	0.79
	Max	0.89	0.97	0.96	0.94	1	0.98	0.96	0.98	1	0.98	0.97	0.98
	Min	0.73	0.91	0.87	0.84	0.54	0.27	0.42	0.41	0.33	0.08	0.38	0.26
	SD	0.09	0.02	0.03	0.05	0.16	0.18	0.09	0.14	0.18	0.21	0.08	0.16
***Haor* ecosystem**	Mean	0.88	0.79	0.74	0.8	0.8	0.78	0.77	0.78	0.8	0.8	0.76	0.79
	Max	0.96	0.99	0.94	0.97	0.99	1	0.96	0.98	0.99	1	0.97	0.99
	Min	0.77	0.51	0.41	0.57	0.49	0.53	0.33	0.45	0.43	0.53	0.31	0.42
	SD	0.06	0.2	0.16	0.14	0.14	0.15	0.15	0.15	0.15	0.14	0.17	0.15
Salinity ecosystem	Mean	0.94	0.73	0.96	0.88	0.87	0.79	0.9	0.85	0.77	0.8	0.9	0.82
	Max	0.94	0.74	0.97	0.88	0.99	1	0.98	0.99	1	1	0.97	0.99
	Min	0.94	0.71	0.96	0.87	0.62	0.27	0.29	0.39	0.2	0.27	0.29	0.25
	SD	0.18	0.01	0.01	0.06	0.12	0.17	0.1	0.13	0.18	0.15	0.08	0.14
Drought ecosystem	Mean	0.87	0.83	0.82	0.84	0.79	0.8	0.81	0.8	0.78	0.81	0.81	0.8
	Max	0.98	0.98	0.96	0.97	0.99	0.98	0.97	0.98	0.99	0.98	0.96	0.98
	Min	0.65	0.57	0.38	0.53	0.47	0.45	0.22	0.38	0.23	0.25	0.22	0.23
	SD	0.1	0.12	0.17	0.13	0.13	0.13	0.17	0.14	0.15	0.13	0.15	0.14

Ecosystems	Efficiency parameter	Large farmers				Medium farmers				Small farmers			
		T. Aus	*T. Aman*	*Boro*	Average	*T. Aus*	*T. Aman*	*Boro*	Average	*T. Aus*	*T. Aman*	*Boro*	Average
Tidal submergence ecosystem	Mean	-	0.57	0.87	0.72	0.89	0.65	0.78	0.77	0.84	0.66	0.75	0.75
	Max	-	0.57	0.94	0.76	1	1	0.97	0.99	1	1	0.95	0.98
	Min	-	0.56	0.73	0.65	0.22	0.33	0.26	0.27	0.58	0.37	0.28	0.41
	SD	-	0.01	0.09	0.05	0.17	0.17	0.17	0.17	0.12	0.15	0.16	0.15
Submergence ecosystem	Mean	0.84	0.82	0.89	0.85	0.81	0.85	0.86	0.84	0.74	0.85	0.84	0.81
	Max	0.97	0.96	0.95	0.96	0.99	0.97	0.97	0.98	0.99	0.97	0.97	0.98
	Min	0.6	0.29	0.68	0.52	0.53	0.39	0.38	0.44	0.31	0.23	0.1	0.21
	SD	0.14	0.19	0.06	0.13	0.14	0.12	0.13	0.13	0.17	0.13	0.13	0.14
Low lying ecosystem	Mean	-	0.79	0.87	0.83	0.8	0.79	0.89	0.83	0.86	0.81	0.89	0.85
	Max	-	0.91	0.97	0.94	0.93	0.96	0.98	0.96	0.97	0.96	0.97	0.97
	Min	-	0.46	0.31	0.38	0.5	0.09	0.48	0.36	0.48	0.11	0.06	0.21
	SD	-	0.19	0.2	0.2	0.14	0.17	0.09	0.13	0.09	0.17	0.12	0.13
Hilly **ecosystem**	Mean	0.82	-	0.74	0.78	0.8	0.88	0.9	0.86	0.76	0.83	0.78	0.79
	Max	1	-	0.74	0.87	0.98	0.93	0.95	0.95	1	0.95	1	0.98
	Min	0.65	-	0.74	0.7	0.42	0.68	0.75	0.62	0.28	0.21	0.43	0.31
	SD	0.25	-	0.11	0.18	0.23	0.06	0.07	0.12	0.2	0.11	0.11	0.14

Source: Authors' estimation based on field survey, 2019-2021.

10.10.16 Level of technical efficiency of rice farmers in different ecosystems

Level of technical efficiency of rice farmers are presented in table 10.41.

In favorable ecosystem, Results showed that 1.51%, 7.54%, 15.52%, 21.55% and 53.88% of the *T. Aman* farmers had technical efficiency indices ranging between 0-20%, 21-40%, 41-60%, 61-80% and above 80%, respectively. In case of *T. Aus* farmers, 2.94%, 15.44%, 38.97% and 42.65% of the farmers had technical efficiency indices ranging between 21-40%, 41-60%, 61-80% and above 80%, respectively. Results also showed that 0.23%, 1.83%, 8.45% and 89.5% of the *Boro* farmers had technical efficiency indices ranging between 21-40%, 41-60%, 61-80% and above 80%, respectively. The much variation in TE from the frontier appeared that many of the *T. Aus* farmers have still good opportunity to become technically efficient in resource use in favorable ecosystem.

In *Haor* ecosystem, Results showed that 11.11%, 33.33% and 55.56% of the *T. Aman* farmers had technical efficiency indices ranging between 41-60%, 61-80% and above 80%, respectively. In case of *T. Aus* farmers, 13.13%, 29.29% and 57.58% of the farmers had technical efficiency indices ranging between 41-60%, 61-80% and above 80%, respectively. Results also showed that 3.45%, 14.48%, 29.66% and 52.41% of the *Boro* farmers had technical efficiency indices ranging between 21-40%, 41-60%, 61-80% and above 80%, respectively. The much variation in TE from the frontier appeared that many of the *Boro* farmers have still good opportunity to become technically efficient in resource use in *haor* ecosystem.

In salinity ecosystem, Results showed that 1.48%, 9.63%, 37.04% and 51.85% of the *T. Aman* farmers had technical efficiency indices ranging between 21-40%, 41-60%, 61-80% and above 80%, respectively. In case of *T. Aus* farmers, 0.83%, 2.5%, 10.83%, 30.83% and 55.0% of the farmers had technical efficiency indices ranging between below 20%, 21-40%, 41-60%, 61-80% and above 80%, respectively. Results also showed that 0.5%, 0.99%, 6.7% and 91.81% of the *Boro* farmers had technical efficiency indices ranging between 21-40%, 41-60%, 61-80% and above 80%, respectively. The much variation in TE from the frontier appeared that many of the *T. Aman* farmers have still good opportunity to become technically efficient in resource use in salinity ecosystem.

In drought ecosystem, Results showed that 0.52%, 8.19%, 34.49% and 56.79% of the *T. Aman* farmers had technical efficiency indices ranging between 21-40%, 41-60%, 61-80% and above 80%, respectively. In case of *T. Aus* farmers, 1.52%, 9.14%, 39.59% and 49.75% of the farmers had technical efficiency indices ranging between 21-40%, 41-60%, 61-80% and above 80%, respectively. Results also showed that 4.01%, 5.93%, 20.42% and 69.63% of the *Boro* farmers had technical efficiency indices ranging between 21-40%, 41-60%, 61-80% and above 80%, respectively. The much variation in TE from the frontier appeared that many of the *T. Aus* farmers have still good opportunity to become technically efficient in resource use in drought ecosystem.

In tidal submergence ecosystem, Results showed that 4.19%, 34.13%, 42.51% and 19.16% of the *T. Aman* farmers had technical efficiency indices ranging between 21-40%, 41-60%, 61-80% and above 80%, respectively. In case of *T. Aus* farmers, 1.47%, 2.94%, 19.12% and 76.47% of the farmers had technical efficiency indices ranging between 21-40%, 41-60%, 61-80% and above 80%, respectively. Results also showed that 4.32%, 14.03%, 26.98% and 54.68% of the *Boro* farmers had technical efficiency indices ranging between 21-40%, 41-60%, 61-80% and above 80%, respectively. The much variation in TE from the frontier appeared that many of the *T. Aman* farmers have still good opportunity to become technically efficient in resource use in tidal submergence ecosystem.

In submergence ecosystem, Results showed that 1.89%, 4.86%, 14.05% and 79.19% of the *T. Aman* farmers had technical efficiency indices ranging between 21-40%, 41-60%, 61-80% and above 80%, respectively. In case of *T. Aus* farmers, 1.14%, 15.91%, 34.09% and 48.86% of the farmers had technical efficiency indices ranging between 21-40%, 41-60%, 61-80% and above 80%, respectively. Results also showed that 0.23%, 1.58%, 3.84%, 15.8% and 78.56% of the *Boro* farmers had technical efficiency indices ranging between below 20%, 21-40%, 41-60%, 61-80% and above 80%, respectively. The much variation in TE from the frontier appeared that many of the *T. Aus* farmers have still good opportunity to become technically efficient in resource use in submergence ecosystem.

In low lying ecosystem, Results showed that 1.43%, 2.38%, 8.57%, 15.95% and 71.67% of the *T. Aman* farmers had technical efficiency indices ranging between below 20%, 21-40%, 41-60%, 61-80% and above 80%, respectively. In case of *T. Aus* farmers, 2.29%, 22.14% and 75.57% of the farmers had technical efficiency indices ranging between 41-60%, 61-80% and above 80%, respectively. Results also showed that 0.48%, 1.2%, 0.72%, 9.4% and 88.19% of the *Boro* farmers had technical efficiency indices ranging between below 20%, 21-40%, 41-60%, 61-80% and above 80%, respectively. The much variation in TE from the frontier appeared that many of the *T. Aman* farmers have still good opportunity to become technically efficient in resource use in low lying ecosystem.

In hilly **ecosystem**, Results showed that 1.21%, 2.02%, 18.62% and 78.14% of the *T. Aman* farmers had technical efficiency indices ranging between 21-40%, 41-60%, 61-80% and above 80%, respectively. In case of *T. Aus* farmers, 5.26%, 21.05%, 21.05% and 52.63% of the farmers had technical efficiency indices ranging between 21-40%, 41-60%, 61-80% and above 80%, respectively. Results also showed that 0.44%, 7.02%, 42.54% and 50.0% of the *Boro* farmers had technical efficiency indices ranging between 21-40%, 41-60%, 61-80% and above 80%. The much variation in TE from the frontier appeared that many of the *Boro* farmers have still good opportunity to become technically efficient in resource use in hilly ecosystem.

Table 10.41: Level of technical efficiency of rice farmers in different ecosystems

Ecosystems	TE (%)	*T. Aus*		*T. Aman*		*Boro*	
		No. of farmers	% of farmers	No. of farmers	% of farmers	No. of farmers	% of farmers
Favorable ecosystem	>20	0	0	7	1.51	0	0
	21-40	4	2.94	35	7.54	1	0.23
	41-60	21	15.44	72	15.52	8	1.83
	61-80	53	38.97	100	21.55	37	8.45
	<80	58	42.65	250	53.88	392	89.5
***Haor* ecosystem**	>20	0	0	0	0	0	0
	21-40	0	0	0	0	15	3.45
	41-60	13	13.13	6	11.11	63	14.48
	61-80	29	29.29	18	33.33	129	29.66
	<80	57	57.58	30	55.56	228	52.41
Salinity ecosystem	>20	1	0.83	0	0	0	0
	21-40	3	2.5	2	1.48	2	0.5
	41-60	13	10.83	13	9.63	4	0.99
	61-80	37	30.83	50	37.04	27	6.7
	<80	66	55	70	51.85	370	91.81
Drought ecosystem	>20	0	0	0	0	0	0
	21-40	3	1.52	3	0.52	23	4.01
	41-60	18	9.14	47	8.19	34	5.93
	61-80	78	39.59	198	34.49	117	20.42
	<80	98	49.75	326	56.79	399	69.63
Tidal submergence ecosystem	>20	0	0	0	0	0	0
	21-40	1	1.47	7	4.19	12	4.32
	41-60	2	2.94	57	34.13	39	14.03
	61-80	13	19.12	71	42.51	75	26.98
	<80	52	76.47	32	19.16	152	54.68
Submergence ecosystem	>20	0	0	0	0	1	0.23
	21-40	1	1.14	7	1.89	7	1.58
	41-60	14	15.91	18	4.86	17	3.84
	61-80	30	34.09	52	14.05	70	15.8
	<80	43	48.86	293	79.19	348	78.56
Low lying ecosystem	>20	0	0	6	1.43	2	0.48
	21-40	0	0	10	2.38	5	1.2
	41-60	3	2.29	36	8.57	3	0.72
	61-80	29	22.14	67	15.95	39	9.4
	<80	99	75.57	301	71.67	366	88.19
Hilly **ecosystem**	>20	0	0	0	0	0	0
	21-40	3	5.26	3	1.21	1	0.44
	41-60	12	21.05	5	2.02	16	7.02
	61-80	12	21.05	46	18.62	97	42.54
	<80	30	52.63	193	78.14	114	50

Source: Authors' estimation based on field survey, 2019-2021.

10.10.17 Impact evaluation of risk on rice production in different ecosystems

This chapter outlines the severity of damage of rice production due to risk in different ecosystems and represented using severity ranking model (SRM). The major consequence of the model was identified as risk. The sub-component of risk was biotic risk, abiotic risk and natural calamities. Biotic risk of rice farming connected with: i) insects; ii) diseases and iii) rats; abiotic risk included: i) drought, ii) water logged and iii) submergence; natural calamities included: i) flash flood, ii) rainfall and iii) hailstorm (Table 10.42). It was observed that the level of damage was the highest considering for insects infestation which was ranked as 1st (with CSS 6699) in favorable ecosystem. It was followed by disease (with CSS 6132), water logged (with CSS 5994), drought (with CSS 5616), hailstorm (with CSS 5055), rainfall (with CSS 4989), flash flood (with CSS 4791) and animal attack (with CSS 4326) and ranking as 2nd,3rd, 4th, 5th, 6th and 7th, respectively. In tidal submergence ecosystem, the level of damage was the highest considering for water logged condition which was ranked as 1st (with CSS 2264). It was found that rat (with CSS 4147), submergence (with CSS 3714), disease (with CSS 3522), drought (with CSS 3824), salinity (with CSS 3828) and insect (with CSS 2134) also ranked as 1st in tidal submergence, low lying, submergence, *haor*, drought, salinity and hilly ecosystem, respectively (Table 10.42). Therefore, it can be summarized that biotic risk was the main reason for the declination of rice production compare to aboitic risk and natural calamities in different ecosystems.

Table 10.42: Severity ranking of risk of rice production in different ecosystems

Particulars	Extreme	High	Medium	Low	Severity score	Severity rank
Favorable ecosystem						
Insects	1050	630	189	231	6699	I
Disease	861	567	315	357	6132	II
Animal attack	231	546	441	882	4326	VIII
Water logged	696	735	336	333	5994	III
Drought	738	498	306	558	5616	IV
Hailstorm	315	807	396	582	5055	V
Rainfall	480	489	471	660	4989	VI
Flash flood	327	564	582	627	4791	VII
***Haor* ecosystem**						
Disease	672	162	132	84	3522	I
Insect	480	318	138	114	3264	II
Rat	60	78	258	654	1644	V
Hailstorm	84	48	306	612	1704	IV
Flash flood	90	180	252	528	1932	III
Salinity ecosystem						
Insects	215	526	272	387	3369	III
Disease	162	460	286	492	3092	V
Animal attack	92	384	436	488	2880	VII
Water logged	102	612	354	332	3284	II
Salinity	208	792	220	180	3828	I
Hail storm	133	387	405	475	2978	VI
Rainfall	200	341	456	403	3138	IV

Particulars	Extreme	High	Medium	Low	Severity score	Severity rank
Drought ecosystem						
Insects	232	552	272	344	3472	II
Disease	176	464	304	456	3160	IV
Animal attack	80	392	456	472	2880	VII
Water logged	104	608	368	320	3296	III
Drought	200	800	224	176	3824	I
Hail storm	144	400	416	440	3048	VI
Rainfall	200	352	440	408	3144	V
Tidal submergence ecosystem						
Insect	205	193	116	185	1819	IV
Disease	205	173	151	172	1815	V
Rat	339	152	140	71	2161	II
Water logged	367	213	37	83	2264	I
Submergence	221	179	147	155	1869	III
Hailstorm	71	148	165	316	1373	VII
Rainfall	84	187	184	245	1509	VI
Submergence ecosystem						
Insect	546	252	120	132	3312	III
Disease	504	234	85	227	3115	IV
Rat	120	276	468	186	2430	VII
Water logged	600	210	96	144	3366	II
Submergence	756	168	60	66	3714	I
Hailstorm	234	402	222	192	2778	VI
Rainfall	366	252	240	192	2892	V
Low lying ecosystem						
Insect	448	435	253	264	3867	III
Disease	365	288	312	434	3383	V
Rat	608	357	208	227	4147	I
Water logged	603	280	293	224	4061	II
Submergence	400	384	379	237	3747	IV
Hailstorm	125	237	528	509	2779	VII
Rainfall	147	301	627	325	3069	VI
Hilly **ecosystem**						
Insects	317	191	102	90	2134	I
Disease	219	201	135	145	1894	III
Rat	303	187	106	104	2089	II
Submergence	109	133	212	246	1504	VII
Water logged	95	135	246	224	1499	VIII
Hail storm	121	190	89	300	1533	VI
Rainfall	165	172	195	170	1731	IV
Flash flood	95	165	237	203	1551	V

Source: Authors' estimation based on field survey, 2019-2021.

Note: Severity points: Extreme = 4, High = 3, Medium = 2, and Low = 1.

Calculation of severity score for insect = (350× 4) + (210 × 3) + (63 × 2) + (77 × 1) =2233.

Calculation for other risk was done accordingly.

10.11 Constraints faced by the respondent in different ecosystems

This section outlines the constraints faced by the famers during rice production in different ecosystems and presented using garrett's ranking technique (GRT). There are so many constraints faced by the farmers. The major constraints are: i) scarcity of labor, ii) high price of inputs, iii) lack of short-duration and high-yielding variety, iv) low price of rice, v) lengthy water logging condition, vi) flash flood inundation, vii) lack of storage and transportation facilities and viii) lack of training and extension support (Table 10.43). It was identified that low price of rice was the major constraint which was ranked as 1st (with Mean score 58.45) in favorable ecosystem. It was followed by low price of rice (with mean score 55.70), lengthy water logging condition (with mean score 57.92), flash flood inundation (with mean score 63.29), low price of rice (with mean score 69.56), low price of rice (with mean score 63.53), Lack of short-duration and salt tolerant variety (with mean score 63.72) and high price of inputs (with mean score 56.41) in tidal submergence, low lying, submergence, *haor*, drought, salinity and hilly ecosystems, respectively (Table 10.43).

Table 10.43: Ranking constraints associated with rice production in different ecosystems

Particulars	Rank						Total score	Mean score	Rank
	1	2	3	4	5	6			
Favorable ecosystem									
Scarcity of labor	411	336	378	270	306	399	106146	50.55	III
High price, low quality and non-availability of inputs	354	378	372	345	381	270	107337	51.11	II
Lack of short-duration and high-yielding variety	276	384	306	516	318	300	104370	49.70	IV
Low price of rice	645	468	330	354	180	123	122742	58.45	I
Lack of storage and transportation facilities	294	306	288	276	450	486	97992	46.66	VI
Lack of training and extension support	315	345	276	360	429	375	101952	48.55	V
***Haor* ecosystem**									
Early flash flood inundation	582	216	84	54	72	42	69072	65.78	II
High price, low quality and non-availability of inputs	516	210	120	66	90	48	66912	63.73	III
Lack of short-duration and high-yielding variety	510	240	156	60	72	12	68514	65.25	IV
Low price of rice	732	144	60	54	36	24	73044	69.57	I
Lack of storage and transportation facilities	180	108	288	342	72	60	55992	53.33	VI
Lack of proper training and extension support	252	168	360	120	96	54	59742	56.90	V

Particulars	Rank						Total score	Mean score	Rank
	1	2	3	4	5	6			
Salinity ecosystem									
Scarcity of labor	196	149	217	328	230	280	66235	47.31	VI
High price, low quality and non-availability of inputs	314	374	226	175	82	229	76295	54.50	III
Lack of short-duration and salt tolerant variety	652	309	183	108	92	56	89213	63.72	I
Low price of rice	364	299	252	148	255	82	78602	56.14	II
Lack of storage and transportation facilities	316	255	227	180	257	165	74239	53.03	IV
Lack of training and extension support	285	211	245	176	238	245	71005	50.72	V
Drought ecosystem									
Scarcity of labor	184	160	200	344	240	272	66008	47.15	VI
High price, low quality and non-availability of inputs	320	368	240	168	80	224	76624	54.73	III
Lack of short-duration and high-yielding variety	288	216	240	176	240	240	71240	50.89	V
Low price of rice	648	312	176	112	88	64	88936	63.53	I
Lack of storage and transportation facilities	360	304	256	160	264	56	79112	56.51	II
Lack of training and extension support	328	256	232	184	264	136	75272	53.77	IV
Tidal submergence ecosystem									
Scarcity of labor	140	131	113	153	107	56	37420	53.46	III
High price, low quality and non-availability of inputs	136	143	119	101	88	113	36392	51.99	V
Lack of short-duration and high-yielding variety	129	125	137	133	107	68	36915	52.74	IV
Lengthy water logging condition	179	140	128	109	67	77	38764	55.38	II
Low price of rice	160	156	136	104	100	44	38988	55.70	I
Lack of training and extension support	101	107	140	157	120	75	35477	50.68	VI

Particulars	Rank						Total score	Mean score	Rank
	1	2	3	4	5	6			
Submergence ecosystem									
Scarcity of labor	270	252	216	132	72	108	59550	56.71	III
High price, low quality and non-availability of inputs	144	120	210	318	60	198	51390	48.94	V
Lack of short-duration and high-yielding variety	120	186	162	240	108	234	50124	47.74	VI
Flash flood inundation	456	300	90	78	78	48	66450	63.29	I
Low price of rice	420	258	60	90	102	120	62508	59.53	II
Lack of training and extension support	138	150	192	234	216	120	51960	49.49	IV
Low lying ecosystem									
Scarcity of labor	348	292	348	140	168	104	79032	56.45	III
High price, low quality and non-availability of inputs	260	232	268	368	152	120	74420	53.16	IV
Lack of short-duration and high-yielding variety	160	220	288	356	164	212	69052	49.32	V
Lengthy water logging condition	368	280	320	280	104	48	81088	57.92	I
Low price of rice	308	340	356	172	140	84	79384	56.70	II
Lack of training and extension support	128	148	268	280	376	200	65044	46.46	VI
Hilly ecosystem									
Flash flood inundation	124	109	137	98	78	154	34749	49.64	III
High price, low quality and non-availability of inputs	205	125	130	87	92	61	39489	56.41	I
Lack of short-duration and high-yielding variety	104	92	95	98	115	196	32205	46.01	VI
Low price of rice	112	90	99	110	105	184	32817	46.88	V
Lack of storage and transportation facilities	195	132	108	92	105	68	38844	55.49	II
Lack of proper training and extension support	112	87	98	106	149	148	33190	47.41	IV

Source: Authors' estimation based on field survey, 2019-2021.

11. Research highlight

Title of the sub-project : Economic Viability and Production Efficiency of Rice at Farm Level: A Macro Level Study in Bangladesh

Background: Rice is the foremost cereal and staple food in Bangladesh, grows in three distinct seasons round the year which occupies about 76.85% (11.42 Mha) of the total cropped area (AYS, 2020). Rice alone constitutes 85% of the total food grains produced annually (BER, 2021). It is the principal source of agricultural GDP and livelihoods to majority of the rural population which provides about 62% of the calorie and 46% of protein of average daily intake of the consumers (HIES, 2010). It is an important parameter for determining social and political stability (Nath, 2015) and provides a sense of food security to the people. In spite of various constraints, since independence, there has been more than three-fold increase in rice production in Bangladesh, which jumped from around 10 MT in 1971-72 to about 36.06 MT in 2015-16 (BBS, 2020). This has been transformed the country from so called "Bottomless Basket" to a "Full of Food Basket". In recent years, the country has not only earned self-sufficiency status in rice production, but also gradually entering into the export regime (BER, 2015). Due to the proliferation of shallow and deep tube wells and the development of high-yielding seeds for different seasons, rice yields have increased dramatically and the share of dry-season rice has increased substantially (Hossain, 2009).

The major achievement of rice research in Bangladesh, as in other Asian countries might be recognized as to development of high yielding modern varieties. The key drivers of adoption popular varieties in the different seasons were included higher yield potential, environmental suitability, market demand and price as well as preferred grain quality.

Objectives:

i) assess input use pattern and economic viability (profitability and risks) of *T. Aus*, *T. Aman* and *Boro* rice production for different farm types (e.g small, medium & large) in different ecosystems;

ii) evaluate technical efficiency and identify factors responsible for variation in the level of efficiency among different farm types; and

iii) identify the constraints of rice farming in different seasons, ecosystems and drivers of adoption of rice varieties at the farm level.

Methodology: Department of Agricultural Extension (DAE) divided the whole country into fourteen Agriculture Regions. These fourteen agricultural regions are; namely, Dhaka, Mymensingh, Faridpur, Cumilla, Chattogram, Rangamati, Sylhet, Khulna, Jashore, Barishal, Rajshahi, Bogura, Rangpur and Dinajpur, respectively. Out of 14 agricultural regions, 28 districts were chosen taking 2 from each of the region. Following the terms and condition of the sub-project, BRRI component surveyed 10 regions e.g., Cumilla, Sylhet, Barishal, Dinajpur, Chattogram, Khulna, Jashore, Mymensingh, Rangpur and Rajshahi and data of the rest of four regions (Bogura, Dhaka, Faridpur and Rangamati) were collected by other component (Bangladesh Agricultural University, Mymensingh) of the sub-project. Considering the presentiveness of the ecosystems, all component of this sub-project surveyed districts were grouped into 8 ecosystems such as favorable, *haor*, coastal saline, drought prone, tidal submergence, submergence, low-lying and hilly ecosystems. Purposive sampling technique was used in selecting the locations; namely, region, districts and

upazilas with due consideration of different rice ecosystems (e.g., favorable, *haor*, saline coastal, drought prone, tidal submergence, submergence, and low-lying and hilly). Data editing, entry, analysis and report writing was done combined by BRRI and BAU component.

In order to ensure that the study is nationally Representative, a multi-stage (two stage sampling frame-work) random sampling technique was followed for selection of the villages and purposive sampling was used to choose the households for the survey (large, medium and small farmers). A full list of farm households with operating area of the selected villages was collected from the Upazila Agricultural Office of DAE which have been used as a sampling frame for selecting the respondents. Then purposive stratified sampling technique was adopted to select the respondents of different farm household types (e.g., small, medium and large). Based on the farm household distribution reported in Agricultural Census 2019 in Bangladesh, sample framing was structured but number of surveyed households were not exactly matched with pre-structed sampling frame during survey. In many cases, *Aus* rice growers and large farmers were not much available. Then, based on the field experience, the sampling frame were restructured to apply stratified random sampling method across the seasons and types of famers. Table 8.2 presents the chosen distribution of sample for all agricultural regions. Finally, almost twelve farmers from *T. Aus* rice growers, thirty-eight from both *T. Aman* and thirty-seven from *Boro* rice growers were interviewed from each village. Thus, in total 9,800 farm households were interviewed from 14 agricultural regions, 700 from each of the region with well-structured questionnaire. Data on constraint to rice production was collected using 5-point Likert scales. The severity of damage of rice production due to risk in different ecosystems was estimated by using severity ranking model (SRM). Moreover, BRRI have collected data from 7000 farm households whereas BAU collected from 2800 farm households.

The developed questionnaire was pretested through collecting data from Mymensingh and Dinajpur areas and then the actual and practical experiences assembled from pre-testing. Besides, FGD and KIS was a conducted by using the prepared checklist. Both survey and reporting were carried out in three phases. The first phase was 14 February, 2018 to 13 February 2019, the second phase was 14 February, 2019 to 13 February, 2020 and the third phase was 14 February, 2021 to 31 January, 2022. The collected data were carefully checked and cleaned by each enumerator before submitting to data entry operator for developing a master sheet. Data were then scrutinized, classified, cleaned and coded after entering into MS Excel sheet for developing a reliable and realistic database which consists of a wealth of updated region-specific rice production information. The accounting calculation and econometric model were employed, as needed. Mostly, descriptive statistics were used for analyzing the collected data. The data was analyzed using Rstudio STATA16 and @RISK software programme version 8.2.

Analytical Techniques such as descriptive statistics, profit equation and technical efficiency using econometric model as well as risk analysis were used in order to derive the result for the objectives which is presented in the following section in brief.

Key findings

Economic viability: In assessing economic viability of rice cultivation at the reported market price, the result revealed that variability of yield of rice and straw value in all ecosystems on farm profit was synthesized based on the households' survey and key informants survey.

In favorable ecosystem: Per ha inputs use in Boro season by small farmer was relatively higher compared to large and medium farmer in favorable ecosystem. Almost farmers used high yielding varieties (HYV) rice seed from market and most of them did not treat the rice seed to control diseases before sowing.

The actual total paid out cost (TPC) usually includes seed, land preparation, hired labor, fertilizers, herbicides, insecticides, and power thresher whereas the total imputed cost (TIC) includes land rent and family labor. The TPC was estimated to be 80%, 71% and 67% of total cost for large, medium and small farmer, respectively in *T. Aman* season whereas TIC was 32%, 28% and 19% of total cost for small, large and medium farmer, respectively T. *Aman* growing season. TPC of large farmer was 78% of total cost, and decreased to 67-73% of total cost for medium and small farmer whereas TIC of small farmer was 35% of total cost and declined to 26% of total cost for large farmer and 21% for medium farmer in *T. Aus* season. The TPC was 82% of total cost for large farmer and decreased 76% for medium farmer and 66% for small farmer, respectively but TIC was 33%, 23% and 17% of total cost for small, large and medium farmer, respectively in *Boro* season.

Per ha total cost of medium farmer was higher by Tk. 7658 and Tk. 3180 compared to large and small farmer in Boro growing season. Per ha total cost of T. *Aman* season was relatively higher for small farmer than large farmer by Tk. 5105 and medium farmer by Tk.5772. In addition, per ha total cost of *T. Aus* season was relatively higher for medium farmer than large farmer by Tk. 15497 and for small farmer by Tk.4934. The BCR was found more than one (ranging from 1.41 to 1.72) on cash cost and (ranging from 1.04 to 1.25) full cost basis in all rice season with the positive net return denoting that return outyielded total investment in rice production

Seasonal rice production by large, medium and small farmers was found to be more profitable in the farmers' perceived typical and best case than average and worse case. However, farmers always suffer from negative net-income in the worst case caused by weather stress. Risk in *T. Aus* (nearly 46-60%) appeared due to both yield and straw value, higher than that in Boro for all farm types. Medium farmer experienced extreme effect of price variation (45-50%) on NI in both *T. Aus* and *Boro* followed by *T. Aman*. However, the fluctuation in the price of rice was found relatively lower than the combined effect of yield and straw value.

In *haor* ecosystem: Large farmer of *T. Aman, T. Aus* and *Boro* rice used more than 80% hired labor, for all kind of production activities. On the contrary, Small farmer used nearly 43%, 50% and 39% of family labor in *T. Aman*, *T. Aus* and *Boro* in rice cultivation, respectively. Medium farmer used 75%, 45% and 57% of hired labor in the respective season to accomplish intercultural and postharvest activities. Contractual costs of rice production in all growing seasons was higher for large farmer compared to medium and small farmer in *haor* ecosystem. Most of the farmers purchased HYV rice seed from market. All farm types used seed rate of 41 kg/ha and 35 kg/ha in *T. Aman* and *Boro* season respectively, whereas large and medium farmer used about 22 kg/ha and 33 kg/ha in *T. Aus* season.

Only large farmer applied about 11% and 19% lower amount of urea than the recommended dose (185kg/ha) in case of *T. Aman* and *T. Aus* season. On the other hand, they also used 45% higher dose of urea in *Boro* season (BRRI Adhunik Dhaner Chas 2020). Medium and small farmer applied much lower dose of urea in all rice growing seasons. In addition, small and medium farmer applied more TSP as well as MOP than large farmer even more than recommended rate. Per ha total cost of

large farmer was higher by Tk. 807 and Tk. 6499 compared to medium and small farmer in Boro growing season. Per ha total cost of T. *Aman* rice was relatively higher for large farmer than that for medium farmer by Tk. 20310 and for small farmer by Tk. 12200. Per ha total cost *T. Aus* rice was also higher for large farmer than that for medium farmer by Tk. 7384 and for small farmer by nearly Tk. 1766. The BCR was found more than one on cash cost (ranging from 1.48 to 2.07) and full cost basis (ranging from 1.06 to 1.38) in all rice seasons with the positive net return denoting that return outyielded total investment in rice production in *haor* ecosystem. However, the chance of achieving net-income (NI) per ha above the benchmark total imputed cost per ha become highly negative whereas the likelihood of achieving GR (gross return) above the benchmark appeared to be highly positive in all rice growing season. The rice production was economically viable at current price and average seasonal yields, but yield and price have outmost effect on the profitability of the rice cultivation which was aroused by erratic climate (temperature, heat wave and rainfall), occurrence of casual flood and market distortion in *haor* ecosystem.

In salinity ecosystem: Contractual costs of large farmer were comparatively higher compared to medium and small farmer due to dependency on hired labor in all rice growing seasons. Only large farmer applied 63 kg/ha more amount of urea in Boro season, whereas in case of T. *Aman* season medium farmer applied 68 kg/ha more amount of urea than the recommended dose (185 kg/ha). In addition, large, medium and small farmer applied more TSP and MOP for producing rice than the recommended rate. Large farmer usually avoids to apply DAP, Gypsum, Zinc and theovit in producing *T. Aus* and Boro rice.

Per ha total cost of small farmer was higher by Tk.19380 and Tk. 8637 compared to large and medium farmer in producing Boro rice. Per ha total cost was relatively higher for large farmer than that for medium farmer by Tk. 11369 and small farmer by Tk.6757 in T. *Aman*. In addition, per ha total cost of *T. Aus* season was relatively higher for medium farmer compared to large farmer by Tk. 16007 and small farmer by Tk.799, because of differences in family labor and fertilizer application. The BCR was found more than one on cash cost (ranging from 1.58 to 1.97) and full cost basis (ranging from 1.11 to 1.41) in all rice season and the positive net return denoting that return outyielded total investment in rice production.

The BCR was found more than one on cash cost (ranging from 1.58 to 1.97) and full cost basis (ranging from 1.11 to 1.41) in all rice season and the positive net return denoting that return outyielded total investment in rice production. The risk of getting NI per ha above the benchmark cost per ha of rice growing appeared to be higher compared to that of getting gross income in all cases. Both rice yield and straw value contributed together by more than 60% to the risk occurrence in getting NI per ha above benchmark cost of rice production in all season. Large farmer experienced higher risk of price variation (40%) on NI in both by T. *Aman* followed by medium farmer in Boro rice production. However, the risk of marker price volatility of rice was found relatively lower than the combined effect of yield and straw value.

In drought ecosystem: Large, medium and small farmer used same amount of urea (175 kg/ha) in T. *Aman* rice growing season which was quite same as recommended dose. In case of Boro season, large farmer applied about 77 kg/ha more urea, while medium farmer and small farmer applied 63 kg/ha and 40 kg/ha urea, respectively than the moderate recommended dose (185 kg/ha). In addition, large, medium and small farmer applied more TSP and MOP than the recommended rate.

Average yield of large farmer (7.38 t/ha) in Boro season is considerably higher than medium farmer (6.78 t/ha) and small farmer (5.99 t/ha). In T. *Aman*, yield performance of small farmer was (5.69 t/ha) higher compared to medium (5.39 t/ha) and small (4.94 t/ha). Average yield of small farmer (4.84 t/ha) was higher than medium farmer (4.07t/ha) and large farmer (4.342 t/ha) in *T. Aus* rice growing season in drought ecosystem. Per ha total cost of T. *Aman* season was relatively higher for medium farmer than that for large farmer by Tk. 1473 and for small farmer by Tk.9184. In addition, per ha total cost of *T. Aus* season was relatively higher for medium farmer than that for large farmer by Tk. 18131 and for small farmer by Tk.12743. It is important to mention that wages and market price of input did not vary across the season among farmer's categories.

Rice production in all seasons for large, medium and small farmers was found to be more profitable in the farmers' perceived typical and best case than worse case whereas farmers always suffer from negative net-income in the worst case. The risk of obtaining net-income (NI) per ha in *T. Aus* above the lower benchmark total imputed cost per ha in *T. Aus* appeared to be higher for all categories of farmers. However, chance of probability of NI indicated the higher probability to become negative in T. *Aman*. It appeared that the likelihood of getting NI per ha above the threshold level tend to remain highly negative while the likelihood of getting GR per ha above the threshold level always remained positive regardless of season and farm categories. The risk occurred in getting the NI per ha above benchmark cost of owned resources from yield and straw value was higher for large farmer than that for both medium farmer and small farmer in drought ecosystem. The rice production was economically viable at current price and average seasonal yields, but yield and price have outmost effect on the profitability of the rice cultivation.

In tidal submergence: Most of the large farmer depended on hired labor such as 77% in T. *Aman* and 66% in Boro and 100 in *T. Aus*, respectively for intercultural and harvest operations, whereas small farmer used 35-45% family labor to carry out intercultural and post-harvest activities operation. All farm types used hired labor to carry out planting and harvesting which are usually labor-intensive operations. Contractual costs of large farmer were found higher than medium farmer and small farmer in T. *Aman* as well as *T. Aus* rice growing season. Large farmer and small farmer applied about 47% and 33% more dose of urea in Boro season than the recommended dose (185kg/ha) respectively, while medium farmer applied 33% less urea than recommendation (BRRI Adhunik Dhaner Chas 2020). Urea application for T. *Aman* and *T. Aus* season was also lower than recommended dose. In addition, all farmers applied TSP, MOP, Gypsum and other fertilizer (DAP, zinc and theovit) lower than the recommended dose in all rice growing seasons. Yield for small farmers (7.88t/ha) in *Boro* season is slightly higher than large farmers (7.42t/ha) and medium farmers (7.59t/ha). On the contrary, large farmer (4.99t/ha) also slightly outyielded than medium farmers and small farmers (4.94 t/ha), In *T. Aus* season, yield of medium farmers (4.74t/ha) is substantially higher than that for large farmers (3.63 t/ha) and small farmer (4.39 t/ha). The BCR on cash cost basis (ranging from (1.44 to 2.11) and full cost basis (ranging from 1.10 to 1.35) in *Boro* season showed higher than one due to high yield potential and fair market price. Moreover, the net return also showed positive meaning that net return outyield total investment in rice production.

However, the chance of probability of NI above the benchmark becomes negative while the chance of receiving GR per ha above this threshold always remain highly positive. Both rice yield and straw value contributed to the risk occurrence ranging from 55 to 67% in getting NI per ha above benchmark cost of rice production in all season. Large farmers experienced higher risk of price variation on the achievement of NI per above the lower benchmark total imputed cost per ha in both T. *Aman* and *T. Aus* (43%) while small farmers experienced higher risk of price variation (42%) in Boro followed by and medium farmers (35%) in T. *Aman* rice production. The risk occurred in getting the NI per ha above benchmark cost of owned resources from yield and straw value was higher for large farmers than that for both medium farmers and small farmers in drought ecosystem.

In submergence ecosystem: Large farmers used almost 62%, 56% and 86% of hired labor among T. *Aman*, *T. Aus* and Boro, respectively for all kind of production activities. On the contrary, Small farmers used nearly 54%, 72% and 49% of family labor in T. *Aman*, *T. Aus* and Boro, respectively and medium farmers used 53%, 76% and 62% of hired labor in the respective three seasons to accomplish intercultural and postharvest activities. Contractual costs for large farmers were also higher than that for medium farmers and small farmers in all rice growing seasons. Average yield for large farmers (6.99 t/ha) in *Boro* season is considerably higher than medium farmers (5.99 t/ha) and small farmers (6.59 t/ha). In T. *Aman*, yield of small farmers (4.94 t/ha) was higher than large farmers (4.89 t/ha) and medium farmers (4.86 t/ha). In *T. Aus* season, yield of small farmers (3.99 t/ha) was lower than that of large farmers and medium farmers (4.49 t/ha).

Per ha total cost of producing *T. Aus* rice for medium farmers was relatively higher than that for large farmers by Tk. 25400 and small farmers by Tk. 786, due mainly to differences in hired labor, contractual cost and fertilizer application. In addition, per ha total cost of Boro rice for large farmers was also higher than that for medium farmers and small farmers by nearly Tk. 28760 and 17097, respectively. The BCR on cash cost (ranging from 1.35 to 2.32) and full cost basis (ranging from 1.04 to 1.51) in all seasons in having much higher than one and the positive net return indicated that profit outyielded total cost of rice production.

Rice production in all seasons for large, medium and small farmers was found to be more profitable in the farmers' perceived typical and best case than that in the worst case. However, farmers always suffer from negative net-income in the worst case caused by weather stress (unpredictive climatic factor such as erratic temperature and rainfall, and flash flood). However, the small farmers were found riskier in *T. Aus* rice production in submergence ecosystem since higher probability of NI per ha in *T. Aus* become negative. However, the fluctuation in the price of rice was found to be relatively lower than the combined effect of yield and straw value. The variability in the NI per ha from yield and straw value was higher for medium farmers and small farmers than for large farmers.

In low lying ecosystem: Large farmers used 86%, 92% and 85% hired labor for *T. Aman*, *T. Aus* and in *Boro* rice production respectively, for all kind of operation. On the contrary, small farmers used nearly 42% family labour in rice cultivation and decreased to 21% in *T. Aman*, 27% in *T. Aus* and 26% in *Boro* for medium farmers. Contractual costs for large farmers were found to be higher than medium farmers and small farmers in all rice growing seasons because large farmers used to hire more contractual labour. All farmers used to buy HYV rice seed from market because they

did not like to do maintenance operation of seed storage. Even though farmers' practice was higher than recommended seed rate, seed rate did not vary much among different farmers' categories.

Only large farmers applied about 2% and 12% more urea in T. *Aman* and Boro season, respectively than the recommended dose (185kg/ha), while medium farmers applied 2% and 25% higher urea in T. *Aman* and Boro season. In addition, small farmers used to apply more TSP and MOP than that of large and small farmers. Rate of other fertilizer such DAP, Gypsum, Zinc and theovit was found almost same among the farmers' types. Average yield of medium farmers and small farmers (6.59 t/ha) in Boro season is considerably higher than large farmers (5.27 t/ha); In case of T. *Aman*, yield performance was found to be same (4.94t/ha) for large farmers, medium farmers and small farmers; in *T. Aus* season, average yield for small farmers (4.29 t/ha) was higher than that for medium farmers (3.99 t/ha) and small farmers (3.95 t/ha) in low lying ecosystem.

Per ha total cost of Boro season for medium farmers was higher by Tk. 11260 and Tk. 13819 than that for large farmers and small farmers, respectively due to differences in the man-days of hired labor and irrigation costs. Per ha total cost of T. *Aman* seasons was relatively higher for medium farmers than that for large farmers by Tk. 10720 and small farmers by Tk.15109, because of differences in the man days of hired labor, contractual cost and fertilizers application. In addition, per ha total cost of medium farmers and small farmers in *T. Aus* season was almost same which was slightly higher than that for large farmers by Tk. 7700, because of differences in family labor and fertilizer application. It is important to mention that wages and market price of input did not vary across the season among farmers's categories. The BCR on cash cost (ranging from 1.43 to 2.01) and full cost basis (ranging from 1.09 to 1.33) in all seasons in had more than one and the positive net return, denoting that return outyielded total investment in rice production.

However, the cumulative probability of gaining NI indicated the higher probability to become negative while the chance of receiving GR per ha above the threshold remained positive. Both rice yield and straw value contributed together to the risk occurrence ranging from 55 to 65% in getting NI per ha above benchmark total imputed cost cost in *T. Aman* while more than 70% risk was induced by both yield and straw value in both *T. Aus* and *Boro* seasons. Small farmers experienced higher risk of price variation on the achievement of NI per above the lower benchmark cost per ha in both *T. Aman* (46%) followed by medium and small farmers, respectively in the same season. However, the risk of marker price volatility of rice was found relatively lower in *T. Aus* and Boro under low-lying ecosystem.

In hilly ecosystem: Large farmers used 52 kg/ha seed for producing *T. Aus* rice which is 28 kg higher than medium farmers and more than double small farmers. Large farmers used considerably seed rate of 25 kg/ha in T. *Aman* 45 kg/ha in Boro whereas small farmers used seed rate of 46 kg/ha in T. *Aman* and 24 kg/ha in *T. Aus* and 42 kg/ha in Boro. Contractual costs for large, medium and small farmers didn't vary much extent, it was quite same in all the seasons. Seed rate was not quite higher than recommended rate among different farmers' categories.

All categories of the farmers used lower amount of urea than the recommended dose and that was the reason for lower yield. In addition, large, medium and small farmers applied moderate amount of TSP in both *T. Aus* and Boro season, but the situation was different in case of T. *Aman* season

where they used more than the recommended dose (56 kg/ha). Average yield of large farmers (5.6 t/ha) in Boro season was considerably higher than medium farmers (5.3 t/ha) and small farmers (5.2 t/ha). In T. *Aman*, yield performance of large farmers was also (4.9 t/ha) higher compared to medium farmers (4.4 t/ha) and small farmers (4.7 t/ha). On the contrary, average yield of medium farmers (4.76 t/ha) in *T. Aus* found higher than small farmers (4.7t/ha) and large farmers (4.36 t/ha).

Per ha total cost of *T. Aman* season was relatively higher for large farmers than that for medium farmers by Tk. 6933 and small farmers by Tk.2610 because of differences in the man days of hired labor, contractual cost and fertilizers application. In addition, per ha total cost of *T. Aus* season was relatively higher for small farmers than that for large farmers by Tk. 3591 and medium farmers by Tk.7443 because of differences in family labor and fertilizer application. It is important to mention that wages and market price of input did not vary across the season among farmers's categories. The BCR found more than one on cash cost (ranging from 1.91 to 2.430 and full cost basis (ranging from 1.30 to 1.48) in all rice season and the positive net return denoting that return outyielded total investment in rice production.

Rice production in all seasons for large, medium and small farmers was found to be more profitable in the farmers' perceived typical and best case than that in the worst case. However, farmers always suffer from negative net-income in the worst case caused by weather stress (unpredictive climatic factor such as erratic temperature and rainfall, and drought). However, chance of probability of obtaining NI per ha indicated the higher probability to become negative in all seasons while the chance of receiving GR per ha above the threshold substantially remained positive.

The estimated value of γ for all the estimated model in in T. *Aman*, *T. Aus* and Boro under all ecosystems allows us to reject the hypothesis (H0: $\gamma=0$) of no significant technical inefficiency among seasonal rice growers. The variance ratio parameter (γ) is greater than zero with statistically significant at 1 and 5 percent level, implying that the yield variation in *T. Aman, T. Aus* and *Boro* from frontier yield was obtained among the farmers mainly arose by the differences in technological and management practices of seasonal rice yield rather than random variability. The significance of sigma square of the model models of seasonal rice yield indicated the existence of technical efficiency variation among the farmers across the seasons in this ecosystem. The strong statistical significance of Sigma-squared ($\sigma 2$) indicated that technical efficiency analysis can explain the differences between farms 'technical efficiency and the technical efficiency locus (points on the frontier). Moreover, the significance of $\sigma 2$ confirms that the frontier model is stochastic rather than deterministic. The coefficient of education, training, extension service, access to media and credit was found negative and significant at different significant level indicating that if the farmers had received higher education, training, extension service, access to media and credit that would decrease inefficiency of rice cultivation. The average estimated technical efficiency of farm categories was 0.85, 0.84 and 0.81 for large, medium and small farmers, respectively which means rice production could be increased by 15%, 16% and 19%, respectively with the same level of inputs without incurring any further cost.

B. Implementation Status

1. Procurement (component wise):

A. BRRI component

Description of equipment and capital items	PP Target		Achievement		Remarks
	Physical (No.)	Financial (Tk.)	Physical (No.)	Financial (Tk.)	
(a) Office equipment		**278000**			
Furniture	04	80000		**278000**	
Executive table	04	40000	04	80000	
Executive chair	02	40000	04	40000	
File cabinet	02	48000	02	40000	
Steel almira	09	36000	02	48000	
Visitor chair	04	20000	09	36000	
Computer table	04	14000	04	20000	
Computer chair			04	14000	
		350000		**350000**	
Computer and accessories	04	240000	04	240000	
Desktop computer	04	40000	04	40000	
UPS	03	60000	03	60000	
Laser printer	01	10000	01	10000	
Scanner					
(b) Lab &field equipment					
(c) Other capital items					
Equipment		**285000**		**285000**	
Camera (SLR)	01	25000	01	25000	
Photocopier	01	130000	01	130000	
Projector	01	70000	01	70000	
GPS	02	60000	02	60000	

B. BAU component

Description of equipment and capital items	PP Target		Achievement		Remarks
	Physical (No.)	Financial (Tk.)	Physical (No.)	Financial (Tk.)	
(a) Office equipment					
Computer and accessories	01	55,800	01	55,800	
Laptop					
(b) Lab &field equipment					
(c) Other capital items					

2. Establishment/renovation facilities: (Not applicable)

Description of facilities	Newly established		Upgraded/refurbished		Remarks
	PP Target	Achievement	PP Target	Achievement	

3. Training/study tour/ seminar/workshop/conference organized:

Description	Number of participant			Duration (Days/weeks/ months)	Remarks
	Male	Female	Total		
(a) Training	10	5	15	1 time (1 day)	
(b) Workshop	140	20	160	2 time (1 day)	
(c) Others (if any)					



Picture 7: Workshop and progress meeting of this Sub-project

C. Financial and Physical Progress (combined & component wise)

A. Combined

Fig in Tk

Items of expenditure/ activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
a. Contractual staff salary	3154160	3129245	3415556	-261396	108	Salary needed for extended time
b. Field research/lab expenses and supplies	9615600	8396825	9226568	389032	96	
c. Operating expenses	2245000	1035615	1101203	1143797	49	
d. Vehicle hire and fuel, oil & maintenance	3627500	2911300	2986601	640899	82	
e.Training/workshop/ seminar etc.	250000	125000	340495	-90495	136	Revised budget for PCR workshop
f. Publications and printing	390000	28000	408000	-18000	105	Revised budget for PCR printing
g. Miscellaneous	330000	70525	66795	263205	20	
h. Capital expenses	1581000	1552800	1552465	28535	98	
Total	**21193260**	**17249310**	**19097683**	**2095577**	**90**	

B. BRRI component

Fig in Tk

Items of expenditure/ activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
a. Contractual staff salary	1615220	1552000	1696312	81092	100	
b. Field research/lab expenses and supplies	7083000	6640000	6939568	-143432	98	
c. Operating expenses	1600000	855575	856163	-743837	50	
d. Vehicle hire and fuel, oil & maintenance	2477500	2597000	2647301	169801	100	
e. Training/workshop/ seminar etc.	250000	125000	340495	90495	26	
f. Publications and printing	350000	28000	408000	58000	100	
g. Miscellaneous	250000	70525	66795	-183205	100	
h. Capital expenses	1483000	1497000	1496665	13665	100	
Total	**15108720**	13365100	**14451299**	**657421**	**96**	

B. BAU component

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance	Physical progress (%)	Reasons for deviation
a. Honorarium and Contractual staff salary	1538940	1577245	1567244	-28304	102	
b. Field Research/Lab Expenses	2532600	1756825	1637000	895600	65	
c. Operating Expenses	645000	180040	180040	464960	28	
d. Vehicle Hire and Fuel, Oil & Maintenance	1150000	314300	314300	835700	27	
e. Training/Workshops/Seminars etc.	0	0	0	0	0	
f. Publications and Printing	40000	0	0	40000	0	
g. Miscellaneous	80000	0	0	80000	0	
h. Capital Expenses	98000	55800	55800	42200	57	
Total Budget	**6084540**	**3884210**	**3754384**	**2330156**	**62**	

D. Achievement of Sub-project by Objectives (Tangible form): Technology generated/ developed

Description of facilities	Newly established		Upgrade/refurnished		Remarks
	PP Target	Achievement	PP Target	Achievement	

E: Information/Knowledge generated/Policy generated

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output	Outcome (short term effect of the research)
To assess input use pattern and economic viability (profitability and risks) of *T. Aus, T. Aman* and *Boro* rice production for different farm types (e.g small, medium & large) in different regions;	Profitability analysis and Monte Carlo simulations by triangular for distribution, cumulative probability distribution	• Benefit cost ratio both on cash and full cost basis was more than one. Especially, BCR on cash cost basis in *Boro* season showed almost two times of investment due to high yield potential and better market price. • Yield was the major contributor in variation of net return in different seasons followed by market prices of rice.	The generated information regarding profitability of seasonal rice cultivation under different ecosystems by this project has effective reference in the determination of procurement policy of rice and rice.

General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output	Outcome (short term effect of the research)
General/specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output	Outcome (short term effect of the research)
To evaluate technical efficiency and identify factors responsible for variation in the level of efficiency among different farm types.	The stochastic frontier production function approach was employed to estimate farm-specific technical efficiency.	• The study revealed that experience, education, extension service, training, access to credit facilities and media had strong influence to reduce technical inefficiency of rice cultivation under different ecosystems.	The farmers will get smooth policy and technical support through intensive extension service during seasons, proper training on rice technologies and cultivation, access to agriculture credit and media.
To identify the constrains of rice farming in different seasons, ecosystems and drivers of adoption of rice varieties at the farm level.	Constraint to rice production was collected using 5 point-Likert) scale.	The unavailability of labour, higher wage, higher price of fertilizer and insecticides and low price of rice were major constraints.	Quick policy support on mechanization of rice cultivation to mitigate the about crises and ensure the fair price of rice

F. Materials Development/Publication made under the Sub-project (not applicable

Publication	Number of publication		Remarks (e.g. paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/ booklet/leaflet/flyer etc.			
Journal publication	1	1	Kamruzzaman M. and Uddin M.T. 2020. Economic viability of *Boro* rice production in *haor* ecosystem of Kishoreganj District. *Bangladesh Journal of Agricultural Economics*, 41(2):45-62.
Video clip/TV program			
News Paper/Popular Article			
Other publications, if any			

G. Description of generated Technology/Knowledge/Policy

i. **Technology Factsheet (title of the technology, introduction, description, suitable location/ecosystem, benefits, name and contact address of author) (not applicable)**

ii. **Effectiveness in policy support (if applicable)**

Since, Ministry of Agriculture and Ministry of Food, the People's Republic of Bangladesh declared procurement price of rice and rice with a joint effort every year, the generated information regarding profitability of seasonal rice cultivation under different ecosystems by this project has effective reference in the determination of procurement policy of rice and rice.

H. Technology/Knowledge generation/Policy Support (as applied)

iii. **Immediate impact on generated technology (commodity & non-commodity) (not applicable)**

iv. **Generation of new knowledge that help in developing more technology in future**

Rice cultivation in *T. Aman, T. Aus* and *Boro* and was found riskier under submergence, drought as well as *haor* ecosystem due to climatic factors such as erratic rainfall, temperature and flash flood. The probability of obtaining net-income of seasonal rice cultivation was found to become negative. Especially small farmers experienced more risk from yield variation by environment and market distortion. This study recommended the development of more climate resilient rice varieties with technologies as well as fine-tuned policy for stable market price for the rice growers.

v. **Technology transferred that help increased agricultural productivity and farmers' income (not applicable)**

vi. **Policy support**

Since most of the farmers under all ecosystems preferred to grow *T. Aman* and *Boro* rice but a smaller group of farmers used to grow *T. Aus* rice, the study recommended to give more emphasis on providing intensive extension service during seasons, proper training on rice technologies and cultivation, increasing an access to agriculture credit and media to reduce inefficiency in rice cultivation. The most of respondents claimed to get support on mechanization of rice cultivation to mitigate the about crises and ensure the fair price of rice.

The study also implied that rice cultivation in T. *Aman*, *T. Aus* and Boro and was found riskier under submergence, drought as well as *haor* ecosystem due to climatic factors such as erratic rainfall, temperature and flash flood, broadcasting of agriculture weather as well as disasters will be on time to protect the crops from damages.

I. Information regarding Desk and Field Monitoring

i. **Desk Monitoring [description & output of consultation meeting, monitoring workshops/seminars etc.)**

During the project period from beginning to end, fourteen desk monitoring was carried out and 2 consultation meeting was held among two components with coordinator. Three

seminar/workshop was held during the project period including inception workshop. Suggestions and feedback was included for further improvement of the research methodology and analysis.

ii. **Field Monitoring (date & no. of visit, name and addresses of team visit and output)**

During the project period from beginning to end, in order to implement the project activities according to the schedule within the time frame of the project proposal, twenty-eight field monitoring was done. The needful measures had been undertaken to identify the problems and make right progress for further improvement of the project activities.

iii. **Weather data, flood/salinity/drought level (if applicable) and natural calamities**

Farmer's perception on risk/uncertainty during rice cultivation due to biotic stresses (insect and diseases, Rat and Birds), abiotic stress (Submergence, Drought, Salinity, Cold, Acidic soil and Water logged) as well as natural calamities (Flash flood, Cyclone, Hail storm, Heavy and irregular rainfall) were documented using both the response score [1=Yes and 2=No] and rank score regarding damages [1=Most important, 2= Important, 3= Less important]

J. Sub-project Auditing (covers all types of audit performed)

Types of audit	Major observation/ issues/ objections raised; if any	Amount of Audit (Tk.)	Status at the sub-project end	Remarks
Govt. (by FAPAD)	No objection raised	3 three	Year-1 (2018-2019) Year-2 (2019-2020) Year-3(2020-2021)	
Internal (by MI & Co.)	No objection raised	1 (one)	Year (2018-2019)	




Picture 8: Audit and monitoring team of PIU-BARC, NATP-2, BARC

K. Lessons Learned

i) Rice varieties, technologies use, input use pattern and agronomic management of rice cultivation.
ii) Profitability of rice cultivation under different ecosystems.
iii) Risk occurance toward rice cultivation due to weather consdition and market disruption especially market price.

iv) Farmer's technical efficiency for small medium and large farmers under different ecosystems.

v) Uncertainty and constraints toward rice cultivation due to biotic, abiotic and unavailability of labour during the seasons.

vi) Scope for sustainable rice cultivation under different ecosystems.

L. Challenges

Execution of project activities i.e. data collection at the household level, focus group discussion and other field activities had been hampered and even postponed due to COVID-19 pandemic and longtime lockdown. In addition, during the period of 2018-2020, farmers got bothered to provide necessary information due to lower market price of rice in local market.

M. Suggestions for Future Planning

The study generated comprehensive data about rice cultivation under all rice growing ecosystems over the Bangladesh. Input-output as well as maket price data of rice cultivation after two or three year's interval will be upgrade the previously collected information. To declare the procurement price of rice and monitor the rice market during every season, data upgradation is prime requisite.

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Appendices

Table 1: Percent area coverage under different rice varieties in *T. Aus* season in different regions

Varieties	Regions			
	Mymensingh	Sylhet	Khulna	Chattogram
BAU63	0	0	0	0
Bina dhan11	0	0.16	0	0
Bina dhan17	0	0.525	0	0
Bina dhan19	0	0.16	0	0
Bina dhan7	0.35	3.62	0	0
BR1	2.71	2.56	0	1.45
BR11	0	0.315	1.555	0
BR14	0	1.475	0	0
BR19	0	0.63	0	0
BR2	0.36	0.63	0	11.195
BR21	0	0	0	0
BR22	0	1.855	0	0
BR25	0	0.82	0	0
BR26	0	1.105	0	0
BR3	0	1.185	0	0
BR8	0	0	0	0
BRRI dhan27	0	0.555	0	0.215
BRRI dhan28	2.44	4.04	4.235	15.095
BRRI dhan32	0	1.28	0	0
BRRI dhan34	0.35	0	0	0
BRRI dhan40	0	0	0	0
BRRI dhan42	0	0	0	0.175
BRRI dhan44	0	0	0	0.255
BRRI dhan46	0.785	3.005	0	0
BRRI dhan47	0	1.475	0	1.665
BRRI dhan48	17.07	33.72	25.91	10.285
BRRI dhan49	1.315	4.27	0	0
BRRI dhan50	0	1.845	0	0
BRRI dhan51	0	0	0	0
BRRI dhan52	0.35	0	6.245	1.45
BRRI dhan55	0	0	0	2.35

Table 1: Continued.

Varieties	Regions			
	Mymensingh	Sylhet	Khulna	Chattogram
BRRI dhan56	0	0	0	0
BRRI dhan58	0	0	0	0
BRRI dhan62	0	0	0	0
BRRI dhan63	0	0	0	0
BRRI dhan64	0	0	0	6.41
BRRI dhan74	0	0	0	5.13
BRRI dhan75	0	0	9.41	0
BRRI dhan76	0	0	0	0
BRRI dhan77	0	0	0	0
BRRI dhan78	0	0	0	12.82
BRRI dhan82	0	0	0	0
BRRI dhan83	0	0	0	0
BRRI dhan85	0	0.365	0	0
BRRIdhan46	0	4.255	0	0
Chinigura	0.36	0.255	1.41	0
Hybrid	2.265	0.315	1.365	3.435
Pajam	1.045	0.95	0	6.41
Horidhan	1.83	0	0	0
Local	0	2.31	0	0
Jamaibabu	0	0	4.38	0
Nerika	0.695	0.765	0	3.69
Minikit	0	0	0	0
Swarna	0	0	0	0
Zira	0	0	0	0
Wheat	0	0	0	0
Vegetables	0	1.565	0	1.16
Jute	0	0	0	0
Mustard	0	0	0	0
Pea nut	0	0	0	0
Sugarcane	0	0	0	0
Fruit orchard	0	0	0	0
Fish	0	0	20.425	0
Fallow	36.15	23.98	25.065	16.815
Total	**100**	**100**	**100**	**100**

Table 1: continue

Varieties	Regions					
	Rajshahi	Jashore	Barisal	Rangpur	Cumilla	Average
BAU63	0	0	2.71	0	0	0.3
Bina dhan11	0	0	0	0	0	0.03
Bina dhan17	0	0	0	0	0	0.12
Bina dhan19	0	0	0	0	0	0.03
Bina dhan7	0	0.555	0	0	1.26	1.03
BR1	0	0	0	0	0	1.03
BR11	0	0	0.545	0	0.675	0.24
BR14	0	0	0	0	0	0.32
BR19	0	0	0	0	0.175	0.16
BR2	0	0.49	0.325	0	32.625	6.32
BR21	0.2	0	0	0	0	0.05
BR22	0	0	0	0	0.77	0.51
BR25	0	0	0	0	0	0.18
BR26	1.97	0	0	0	4.025	1.25
BR3	0	0	0	0.635	0	0.29
BR8	0	0	0.81	0	0	0.02
BRRI dhan27	0	0	5.73	0	1.55	0.83
BRRI dhan28	5.06	3.99	0.34	0	3.265	3.72
BRRI dhan32	0	0	0	0	0	0.29
BRRI dhan34	0	0	0	0	0	0.03
BRRI dhan40	0	0	0	0	0.25	0.03
BRRI dhan42	0	0	0	0	0	0.03
BRRI dhan44	0	0	0	0	0	0.04
BRRI dhan46	0	0	0	0	0	0.74
BRRI dhan47	0	0	1.3	0	0	0.67
BRRI dhan48	10.755	20.6	13.74	67.515	36.855	26.6
BRRI dhan49	0	1.46	0	0	0.61	1.27
BRRI dhan50	0	0	0	0	0.265	0.45
BRRI dhan51	0.865	0	0	0	0	0.19
BRRI dhan52	0	0	0	0	0	0.67
BRRI dhan55	0.52	0	0	0	0	0.49
BRRI dhan56	18.03	0	0	1.785	0	4.26
BRRI dhan58	2.26	0	0	0	0	0.5
BRRI dhan62	0	0	0	1.56	0	0.03

Table 1: continue

Varieties	Regions					
	Rajshahi	Jashore	Barisal	Rangpur	Cumilla	Average
BRRI dhan63	0.345	0	0	0	0	0.08
BRRI dhan64	0	0	0	0	0	0.12
BRRI dhan74	0.715	0	0	0	0	0.25
BRRI dhan75	0	0	0	0	0	0.23
BRRI dhan76	16.7	0	0	0	0	3.66
BRRI dhan77	0	0.395	0	0	0	0.06
BRRI dhan78	0	0	0	0	0	0.23
BRRI dhan82	0	1.775	0	7.885	0	0.63
BRRI dhan83	0.345	0	0	0	0	0.08
BRRI dhan85	0	0	0	0	0	0.08
BRRIdhan46	0	0	0	0	0	0.95
Chinigura	0	0	0	0	0	0.12
Hybrid	0	0.24	0	0	0.75	0.62
Pajam	2.68	0	0.475	0	0.505	1.15
Horidhan	0	0	0	0	0	0.16
Local	1.71	3.005	39.96	0	0.09	5
Jamaibabu	0	0	0	0	0	0.29
Nerika	0	0	0	0	0	0.82
Minikit	3.905	10.355	0	0	0	1.68
Swarna	3.28	0.23	0	0	0	0.75
Zira	0.69	3.195	0	0	0.125	0.37
Wheat	0.26	0	0	0	0	0.06
Vegetables	4.395	9.4	4.535	3.015	3.195	3.25
Jute	0.68	6.48	0.465	0	0	0.59
Mustard	1.905	0	0	0	0	0.42
Pea nut	0	0	0	0	0.505	0.07
Sugarcane	1.175	1.435	0	0	0	0.33
Fruit orchard	0.165	3.32	0	0	0	0.26
Fish	0	0.66	0	0	0	0.53
Fallow	21.39	32.41	29.06	17.61	12.52	24.36
Grand Total	100	100	100	100	100	100

Source: Field survey, 2019-20

Table 2: Percent area coverage under different rice varieties in *T. Aman* season in the study district

Varieties	Regions				
	Dinajpur	Mymensingh	Sylhet	Khulna	Chattogram
BR2	0	0	0.625	0	0
BR3	0	0.055	0	0	0
BR4	0	0	0	0	0
BR5	0	0	0	0	0
BR7	0	0	0	0	0
BR10	0	0.46	0	15.75	0.035
BR11	0	1.99	2.81	2.415	3.395
BR12	0	0	0	0	0
BR17	0	0	0.12	0	0
BR22	0	0.05	29.44	0	3.905
BR23	0	0.79	0	8.715	1.91
BR25	0	0	1.83	0	0
BR26	0	0	0	0	0.175
BRRI dhan30	0	0.085	0	12.195	0.52
BRRI dhan31	0	0	0	0	0
BRRI dhan32	0	5.875	2.91	0	0
BRRI dhan34	0	2.4	0.105	0	0
BRRI dhan36	0	0.34	0	0	0
BRRI dhan39	0	1.655	0	0.68	2.94
BRRI dhan40	0	0.52	0	0.075	0.94
BRRI dhan41	0	0	0	0	1.155
BRRI dhan42	0	0	0.12	0	0.15
BRRI dhan43	0	0	0	0	0.2
BRRI dhan44	0	0	0.245	0	0.975
BRRI dhan46	0	0.38	26.73	0	7.49
BRRI dhan47	0	0	0	0.225	0
BRRI dhan49	9.25	10.05	5.26	8.975	18.82
BRRI dhan51	0	1.175	0	0.51	0.15
BRRI dhan52	0	2.725	0	0	6.635
BRRI dhan53	0	0	0	0	0.21
BRRI dhan54	0	0	0	0	0
BRRI dhan56	0	0	0	0	0
BRRI dhan57	0	0	0	0	0
BRRI dhan58	1.61	0.32	0	0.315	0.175
BRRI dhan62	0	0.32	0	0	0
BRRI dhan64	0	0.055	0	0	0
BRRI dhan68	0	0	0.375	0	0
BRRI dhan70	0	0	0	0.15	0

Table 2: Continued.

Varieties	Regions				
	Dinajpur	Mymensingh	Sylhet	Khulna	Chattogram
BRRI dhan71	0	1.1	0	0	0
BRRI dhan72	0	0.14	0	0	0
BRRI dhan73	0	0	0	0	0
BRRI dhan74	0	0	0	0	0.125
BRRI dhan75	0	0	0	3.055	0
BRRI dhan76	0	0	0	0	0
BRRI dhan80	0	0.125	0	0.15	0
BRRI dhan81	0	0	0	0	0
BRRI dhan84	0	0	0	0.43	2.355
BRRI dhan86	0	0	0	0	0
BRRI dhan87	0	0.38	0	3.47	0
BRRI dhan90	0	0	0	0	0
Bina dhan7	0	1.755	0.77	0	0
Bina dhan11	0	0	0	0	0.105
Bina dhan17	0	0	0.485	0	0.06
Hybrid	4.27	13.81	2.235	3.96	0.49
Horidhan	0.24	8.695	0	0	3.53
Pajam	0	1.345	0.65	0	3.915
Swarna	62.215	0.9	0	10.03	2.875
Ranjit	0	2.57	0	0	0
Zira	0.32	0	0	0	0
Minikit	0	0	0	0	0
Jamaibabu	0	0	0	1.435	0
Local	10.33	16.83	7.855	0.185	2.885
Kalijira	0	0.245	0.52	0	0
Kataribhog	0	0	0	0	0
Chinigura	0	0	0.685	1.02	9
Najirshail	0	0.165	0.73	0	0
Maize	0.9	0.43	0	0	0
Pulse	0	0	0	0	0
Pea nut	3.12	0	0	0	0
Vegetables	4.98	5.035	2.025	3.3	4.845
Sugarcane	0	0	0	0	0
Pan	0	0	0	0	0
Fruit orchard	0.84	0.17	0	0	2.11
Fish	0	0.1	0	12.5	0
Fallow	1.92	16.955	13.465	10.46	17.92
Grand Total	100	100	100	100	100

Source: Field survey, 2019-20

Table 2: Continued.

Varieties	Regions					
	Rajshahi	Jashore	Barisal	Rangpur	Cumilla	Average
BR2	0	0	0	0	0	0.06
BR3	0	0	0	0	0	0.01
BR4	0	0	0	0.27	0	0.03
BR5	0.22	0	0	0	0	0.02
BR7	0	0	0	0	0.09	0.01
BR10	0	0.73	0	0	0	1.7
BR11	0	0.1	2.435	6.71	0	1.99
BR12	0	0	0	0.02	0	0
BR17	0.065	0	0	0	0	0.02
BR22	0	0	24.73	0	29.885	8.8
BR23	0	0	4.1	0	0.78	1.63
BR25	0	0	0	0	0	0.18
BR26	0	0	0	0	0	0.02
BRRI dhan30	0	0.425	0	0	0	1.32
BRRI dhan31	0	0	0.54	0	0	0.05
BRRI dhan32	0	0	0	0.35	0.445	0.96
BRRI dhan34	0.49	0	0	1.44	0	0.44
BRRI dhan36	0.06	0	0	0	0	0.04
BRRI dhan39	0.335	1.9	0	0	0	0.75
BRRI dhan40	0	0	0	0	0.425	0.2
BRRI dhan41	0	0	0.365	0	0	0.15
BRRI dhan42	0	0	0	0	0	0.03
BRRI dhan43	0	0	0	0	0	0.02
BRRI dhan44	0	0	0	0.09	0	0.13
BRRI dhan46	0	0	0	0	10.675	4.53
BRRI dhan47	0	0	0	0	0	0.02
BRRI dhan49	1.75	41.34	5.615	5.31	13.555	11.99
BRRI dhan51	2.12	0.765	1.985	0	0.18	0.69
BRRI dhan52	0	0	3.07	0.91	0	1.33
BRRI dhan53	0	0	0	0	0	0.02
BRRI dhan54	0	0	0	0.45	0	0.05
BRRI dhan56	0.215	0	0	0	0	0.02
BRRI dhan57	0.12	0	0	0	0	0.01
BRRI dhan58	0	0	0	0.36	0.355	0.31
BRRI dhan62	0	0.22	0.16	0	0	0.07
BRRI dhan64	0	0	0	0	0	0.01
BRRI dhan68	0	0	0	0	0	0.04
BRRI dhan70	0	0	0	0	0	0.02

Table 2: Continued.

Varieties	Regions					
	Rajshahi	Jashore	Barisal	Rangpur	Cumilla	Average
BRRI dhan71	0	0	0	0.78	0.09	0.2
BRRI dhan72	0	0	0.55	0	0	0.07
BRRI dhan73	0	0	0	0	0.845	0.08
BRRI dhan74	0	0	0	0	0.09	0.02
BRRI dhan75	0	0.55	0	0	0.445	0.41
BRRI dhan76	1.635	0	1.48	0	0	0.31
BRRI dhan80	0	0	0	0	0	0.03
BRRI dhan81	0.06	0	0	0	0	0.01
BRRI dhan84	0	0	0	0	0	0.28
BRRI dhan86	0	0	0.21	0	0	0.02
BRRI dhan87	0.06	2.39	0.43	0	0	0.67
BRRI dhan90	0	0.13	0	0	0	0.01
Bina dhan7	0.265	0.71	0	0.42	14.275	1.82
Bina dhan11	0	0.11	0.18	0	0	0.04
Bina dhan17	0	0	0	0	0	0.05
Hybrid	6.12	0.31	1.15	0.08	0.465	3.29
Horidhan	0	0	0	0	0	1.25
Pajam	0	0	0	0.58	0	0.65
Swarna	52.605	35.415	0	63.91	0	22.8
Ranjit	0	0	0	6.99	0.09	0.97
Zira	2.21	1.44	0	0.81	0	0.48
Minikit	0	0.745	0	0	0	0.07
Jamaibabu	0	0	0	0	0	0.14
Local	3.2	3.335	37.65	3.99	6.18	9.24
Kalijira	0.06	0.075	0.66	0.24	1.755	0.36
Kataribhog	0.46	0	0	0.32	0	0.08
Chinigura	0	0	2.455	1.07	1.625	1.59
Najirshail	0	0	0	0.09	2.22	0.32
Maize	0.6	0	0	0	0	0.19
Pulse	0.18	0	0	0	0.17	0.04
Pea nut	0	0	0	0	0.76	0.39
Vegetables	5.08	3.215	5.325	1.78	3.45	3.9
Sugarcane	0.12	0.44	0	0	0	0.06
Pan	0	0	1.2	0	0	0.12
Fruit orchard	3.515	0	0	0	0	0.66
Fish	0.605	0	0	0	0.09	1.33
Fallow	17.84	5.65	5.705	3.04	11.06	10.4
Grand Total	100	100	100	100	100	100

Source: Field survey, 2019-20

Table 3: Percent area coverage under different rice varieties in *Boro* season in the study district

Varieties	Regions				
	Dinajpur	Mymensingh	Sylhet	Khulna	Chattogram
BR1	0	0	0	0	0.205
BR2	0	0.025	0	0	0.12
BR3	0	0	0	0	0
BR4	0	0.48	0	0	0
BR5	0	0	0	0	0.165
BR6	0	0	0	0	0.07
BR8	0	0	0	0	0.58
BR9	0	0	0	0	0
BR10	0	0	0	0	0
BR12	0	0.1	0	0	0
BR14	0	0.82	0.61	0	0
BR16	0	0.075	0	0	0.515
BR17	0	0	0.09	0	0
BR18	0	0	0	0	0
BR19	0	1.405	0.13	0.605	0
BR22	0	0	0	0	0
BR23	0	0	0	0	0.355
BR25	0	0	0	0	0.21
BR26	0	0	0	0	0.285
BRRI dhan27	0	0	0	0	0.6
BRRI dhan28	8.92	28.535	20.715	48.575	16.495
BRRI dhan29	33.3	45.12	65.94	0	11.405
BRRI dhan32	0	0	0	0	0
BRRI dhan33	0	0	0	0	11.58
BRRI dhan34	0	0	0	0	0.445
BRRI dhan37	0	0	0	0	0
BRRI dhan39	0	0	0	0	2.485
BRRI dhan40	0	0	0	0	0
BRRI dhan41	0	0	0	0	0
BRRI dhan46	0	0	0.315	0	0.915
BRRI dhan47	0	0	0	0	0
BRRI dhan48	0	0	0	0	3.05
BRRI dhan49	0	0	0.155	0	0.62
BRRI dhan50	0	0	0.045	0	0.145
BRRI dhan58	1.53	2.255	0	5.7	2.015
BRRI dhan59	0	0	0	0.32	0
BRRI dhan61	0	0	0	0.35	0
BRRI dhan63	0	0.23	0	6.965	0
BRRI dhan64	0	0	0	0	0
BRRI dhan67	0	0	0	3.45	2.15

Table 3: Continued.

Varieties	Regions				
	Dinajpur	Mymensingh	Sylhet	Khulna	Chattogram
BRRI dhan68	0	0.25	0	0	0.08
BRRI dhan81	0.21	0.035	0	5.27	0
BRRI dhan82	0	0	0	0	0
BRRI dhan84	0	0	0	0.83	0
BRRI dhan88	0	0	0	0	0
BRRI dhan89	0	0	0	0.35	0
Bina dhan10	0	0	0	0	0.795
Bina dhan18	0	0	0.09	0	0
Bina dhan5	0	0	0.22	0	0
Bina dhan7	0	0	0.22	0	0.17
Bina dhan8	0	0	0	0	0.825
Hybrid	17.405	7.54	0.22	21.105	11.585
Horidhan	0	0.05	0	0	1.895
Pajam	0	0	0	0	0
Nerika	0	0	0.44	0	0.715
Najirshail	0	0	0	0	0
Kalijira	0	0	0	0	0
Binni	0	0	0	0	0.555
Kataribhog	0	0	0	0.52	0.12
Miniket	0	0	0	0	0
Minikit	0	0	0	0.67	0
Swarna	0	0	0	0	0
Jamaibabu	0	0	0	1.05	0
Zira	1.075	0.115	0	0	0
Local	1.72	1.2	0.065	0.335	1.27
Fruit orchard	0	0.4	0	0	0
Banana	0	0	0	0	0
Maize	0.71	0.6	0	0	0
Mustard	1.39	0	0	0	0
Pea nut	7.82	0	0	0	0.115
Potato	2.07	0.135	0	0	0
Pulse	0	0	0	0	0.205
Vegetables	3.56	9.27	1.115	2.045	14.95
Wheat	0.73	0	0	0	0
Jute	0	0.23	0	0	0
Fish	0	0	0	1.06	0
Fallow	19.555	1.115	9.645	0	12.31
Grand total	100	100	100	100	100

Source: Field survey, 2019-20

Table 3: Continued.

Varieties	Regions					
	Rajshahi	Jashore	Barisal	Rangpur	Cumilla	Average
BR1	0.08	0	0	0	0.22	0.05
BR2	0.16	0	0	0	0	0.03
BR3	0.085	0	0	0	0	0.01
BR4	0	0	0	0.09	0	0.06
BR5	0	0	0	0	0	0.02
BR6	0	0	0	0	0	0.01
BR8	0	0	0.52	0	0	0.11
BR9	0	0	1.055	0	0	0.11
BR10	0	0	0.865	0.32	0	0.12
BR12	0	0	0	0	0	0.01
BR14	0	0	0	0.45	0.87	0.28
BR16	0	0	0	0	0.2	0.08
BR17	0	0	0	0	0	0.01
BR18	0	0	0.56	0	0	0.06
BR19	0	0	0	0	0	0.21
BR22	0	0	0.38	0	0.125	0.05
BR23	0	0	0.325	0	0	0.07
BR25	0	0	0	0	0	0.02
BR26	0	0	0	0	0	0.03
BRRI dhan27	0	0	0.135	0	0	0.07
BRRI dhan28	34.315	23.07	32.87	25.62	31.635	27.08
BRRI dhan29	1.05	0	13.1	41.38	41.44	25.27
BRRI dhan32	0	0	0.09	0	0	0.01
BRRI dhan33	0	0	0	0	0	1.16
BRRI dhan34	0	0	0	0	0	0.04
BRRI dhan37	0	0	0.28	0	0	0.03
BRRI dhan39	0	0	0.28	0	0	0.28
BRRI dhan40	0	0	0	0	0.15	0.02
BRRI dhan41	0	0	0.23	0	0	0.02
BRRI dhan46	0	0	0.09	0	0	0.13
BRRI dhan47	0	0	5.455	0	0	0.55
BRRI dhan48	0.115	0	0.31	0	5.325	0.88
BRRI dhan49	0	0	0	0.05	0	0.08
BRRI dhan50	0.235	8.12	0.33	0.25	0.28	0.94
BRRI dhan58	0.695	0	1.12	1.77	4.485	1.96
BRRI dhan59	0	0	0	0	0	0.03
BRRI dhan61	0	0	0.15	0	0	0.05
BRRI dhan63	1.6	0	0	0.34	0.57	0.97
BRRI dhan64	0	0	0.16	0	0	0.02
BRRI dhan67	0	0	1.44	0	0	0.7

Table 3: Continued.

Varieties	Regions					
	Rajshahi	Jashore	Barisal	Rangpur	Cumilla	Average
BRRI dhan68	0	0	0	0	0	0.03
BRRI dhan81	2.145	0	0.07	0.355	0.155	0.82
BRRI dhan82	0	0	0.065	0	0	0.01
BRRI dhan84	0	0	0	0	0.125	0.1
BRRI dhan88	0	0	0	0	0.13	0.01
BRRI dhan89	0	0	0	0.22	0.12	0.07
Bina dhan10	0	0	0.89	0	0	0.17
Bina dhan18	0	0	0	0	0	0.01
Bina dhan5	0	0	0	0	0	0.02
Bina dhan7	0	0	0	0	0	0.04
Bina dhan8	0	0	0	0	0	0.08
Hybrid	0.86	0	0.42	21.84	4.735	8.57
Horidhan	0	0	0	0	0	0.19
Pajam	0.04	0	0	0	0	0
Nerika	0	0	0	0	0	0.12
Najirshail	0.54	0	0	0	0.095	0.06
Kalijira	0.175	0	0	0	0	0.02
Binni	0	0	0	0	0	0.06
Kataribhog	7.935	0	0	0	0.06	0.86
Miniket	0	0.49	0	0	0	0.05
Minikit	0.46	26.55	0	0	0	2.77
Swarna	0	0	0.23	0	0	0.02
Jamaibabu	0	0	0	0	0	0.11
Zira	28.38	26.225	0	0.525	0.185	5.65
Local	0.79	0	1.76	0.09	0.22	0.75
Fruit orchard	0.415	0	0	0.08	0	0.09
Banana	0.06	0	0	0	0	0.01
Maize	0	0	0.49	0.78	0.33	0.29
Mustard	2.035	0	0.465	0	0	0.39
Pea nut	0	0	0.19	0.62	0.135	0.89
Potato	0.59	0	0.14	0	0.185	0.31
Pulse	1	2.285	10.13	0	0	1.36
Vegetables	8.88	1.19	8.845	3.325	1.125	5.43
Wheat	0.655	0	0	0	0	0.14
Jute	0	0	0.43	0	0	0.07
Fish	0	0	0	0	0	0.16
Fallow	6.715	12.07	16.1	1.885	7.105	8.68
Grand Total	**100**	**100**	**100**	**100**	**100**	**100**

Source: Field survey, 2019-20

Table 4: Good traits of rice varieties

Varieties	% of Farmers	Varieties	% of Farmers
BR2		BRRI dhan75	
Fine grain	10	Fine grain	10
Good eating quality	20	Good eating quality	10
High market demand and price	10	Good straw yield	20
Higher yield performance	20	High Market demand and price	20
less requirement of fertilizer	10	Higher yield performance	10
Low requirement of fertilizer	10	Less attack of insect and pest	20
No lodging and shattering	20	Less attack of stem borer	10
BR3		less requirement of fertilizer	10
Higher yield performance	10	Low irrigation cost	10
BR4		Low weed infestation	10
Good eating quality	10	No lodging and shattering	10
Higher yield performance	20	BRRI dhan76	
BR5		Early harvest	10
Fine grain	10	Good straw yield	10
Good eating quality	10	High Market demand and price	10
High Market demand and price	10	Higher yield performance	20
BR7		Less attack of insect and pest	20
Early harvest	10	Less attack of rat	10
Fine grain	10	Less attack of stem borer	10
Good eating quality	30	less requirement of fertilizer	10
High Market demand and price	10	No lodging and shattering	20
Higher yield performance	30	No problem	10
Less attack of stem borer	10	Tall plant height	10
Low irrigation cost	10	BRRI dhan80	
BR10		Early harvest	20
Fine grain	30	Fine grain	10
Good eating quality	20	Good eating quality	10
Good straw yield	10	High market demand and price	10
High Market demand and price	20	Higher yield performance	20
Higher yield performance	20	BRRI dhan81	
Less attack of insect and pest	10	Good eating quality	10
Less attack of stem borer	10	Higher yield performance	10
less requirement of fertilizer	10	Less attack of insect and pest	10

Table 4: Continued.

Varieties	% of Farmers	Varieties	% of Farmers
Suitable for low land	20	No lodging and shattering	20
BR11		BRRI dhan82	
Early harvest	30	Good straw yield	10
Fine grain	40	Higher yield performance	30
Good eating quality	30	less requirement of fertilizer	10
Good straw yield	30	More tillering	10
High Market demand and price	30	BRRI dhan84	
Higher yield performance	30	Fine grain	20
Less attack of insect and pest	10	Good eating quality	20
Less attack of stem borer	10	Higher yield performance	10
less requirement of fertilizer	20	BRRI dhan86	
Low irrigation cost	10	Early harvest	10
Low production cost	20	Higher yield performance	10
No lodging and shattering	40	BRRI dhan87	
Suitable for high land	10	Early harvest	10
BR14		Fine grain	30
Less attack of insect and pest	10	Good eating quality	30
Low irrigation cost	10	Good straw yield	20
BR21		High Market demand and price	20
Higher yield performance	10	Higher yield performance	20
Low irrigation cost	10	Less attack of insect and pest	20
Suitable for low land	10	Less attack of stem borer	10
BR22		Low production cost	10
Drought tolerant	10	No lodging and shattering	10
Early harvest	30	Tall plant height	20
Fine grain	40	BRRI dhan90	
Good eating quality	30	Early harvest	10
Good straw yield	30	High Market demand and price	10
High Market demand and price	40	BINA dhan7	
Higher yield performance	30	Early harvest	30
Less attack of insect and pest	40	Fine grain	30
Less attack of stem borer	30	Good eating quality	30
less irrigation cost	10	Good straw yield	20
less requirement of fertilizer	80	High Market demand and price	40

Table 4: Continued.

Varieties	% of Farmers	Varieties	% of Farmers
Less unfilled grain	10	Higher yield performance	40
Low production cost	20	Less attack of insect and pest	30
Low weed infestation	10	Less requirement of inputs and rofitable	10
More tillering	20	No lodging and shattering	20
No lodging and shattering	40	Short duration	10
Suitable for late planting	30	BINA dhan8	
Suitable for low land	30	Good eating quality	30
Tall plant height	30	High Market demand and price	20
BR23		Higher yield performance	20
Blast infestation	10	Less attack of insect and pest	20
Early harvest	10	Less requirement of inputs and profitable	10
Fine grain	30	Lower blast infestation	10
Good eating quality	30	No lodging and shattering	20
Good straw yield	20	BINA dhan11	
High Market demand and price	30	Higher yield performance	10
Higher yield performance	30	BINA dhan17	
Less attack of insect and pest	10	Fine grain	10
Less attack of stem borer	10	Good eating quality	10
Low irrigation cost	20	Higher yield performance	20
Low production cost	20	Less attack of insect and pest	10
No lodging and shattering	20	Less attack of stem borer	10
Submergence tolerant	10	Less requirement of inputs and profitable	10
Suitable for late planting	10	ACI	
Suitable for low land	30	Good eating quality	10
Tall plant height	30	High Market demand and price	10
BR25		Higher yield performance	20
Fine grain	20	Aloron	
Good eating quality	20	Good eating quality	10
High market demand and price	20	Good straw yield	10
Higher yield performance	10	Higher yield performance	10
BR26		AZ	
Fine grain	10	Fine grain	10

Table 4: Continued.

Varieties	% of Farmers	Varieties	% of Farmers
Higher yield performance	10	Good eating quality	30
Less requirement of fertilizer	10	Good straw yield	20
BRRI dhan27	40	Higher yield performance	20
Fine grain	10	less requirement of fertilizer	10
Good eating quality	10	Less requirement of inputs and profitable	10
Higher yield performance	10	No lodging and shattering	10
BRRI dhan28		Short duration	10
Drought tolerant	10	Dhanigold	
Early harvest	30	Fine grain	10
Fine grain	30	Good eating quality	30
Good eating quality	30	Good straw yield	10
Good straw yield	40	High market demand and price	10
High Market demand and price	40	Higher yield performance	30
Higher yield performance	30	Less rquirement of inputs and profitable	10
Less attack of insect and pest	30	Medium duration	10
less requirement of fertilizer	30	Short duration	10
Low irrigation cost	20	Hira	
Low production cost	30	Good eating quality	30
More tillering	10	Good straw yield	10
No lodging and shattering	20	High Market demand and price	20
No problem	10	Higher yield performance	30
Panicle cutter	10	Less attack of insect and pest	30
Suitable for low land	10	less requirement of fertilizer	10
BRRI dhan29		No lodging and shattering	10
Early harvest	10	Ispahani	
Fine grain	20	Good straw yield	10
Good eating quality	30	Higher yield performance	10
Good straw yield	30	No lodging and shattering	10
High Market demand and price	30	SL8	
Higher yield performance	30	Good eating quality	10
Less attack of insect and pest	20	High market demand and price	10
Less attack of stem borer	10	Higher yield performance	10
Low fertilizer cost	10	Less attack of insect and pest	10

Table 4: Continued.

Varieties	% of Farmers	Varieties	% of Farmers
Low irrigation cost	10	More straw yield	10
More tillering	10	No lodging and shattering	20
No lodging and shattering	20	Sonar Bangla	
BRRI dhan30		Good straw yield	10
Fine grain	20	Higher yield performance	20
Good straw yield	20	less requirement of fertilizer	10
High Market demand and price	30	Tej	
High milling outturn	10	Bold grain	10
Higher yield performance	20	Good eating quality	10
Less attack of insect and pest	10	High Market demand and price	10
Less attack of stem borer	10	High market demand and price	10
No lodging and shattering	20	Higher yield performance	20
BRRI dhan32		Low production cost	10
Early harvest	10	Kainchan	
Fine grain	30	Fine grain	10
Good eating quality	30	Good eating quality	30
Good straw yield	20	High Market demand and price	10
High Market demand and price	10	High market demand and price	10
Higher yield performance	30	Higher yield performance	10
Less attack of insect and pest	10	Madhobi	
Less attack of stem borer	10	Fine grain	40
Low irrigation cost	10	Good eating quality	30
No lodging and shattering	30	Good quality straw	10
BRRI dhan33		Good quality straw	10
Good eating quality	10	High Market demand and price	10
Higher yield performance	10	High market demand and price	40
BRRI dhan34		Higher yield performance	40
Early harvest	20	Less attack of insect and pest	20
Fine grain	30	less requirement of fertilizer	10
Good eating quality	30	Low production cost	10
Good straw yield	20	Low requirement of fertilizer	10
High Market demand and price	30	Low unfilled grain	10
Higher yield performance	30	Mollah	
BRRI dhan36		Good eating quality	10

Table 4: Continued.

Varieties	% of Farmers	Varieties	% of Farmers
Good eating quality	10	Higher yield performance	10
High market demand and price	10	Poroshmoni	
Higher yield performance	10	Fine grain	10
No lodging and shattering	10	Good eating quality	20
BRRI dhan39		High Market demand and price	10
Early harvest	10	High market demand and price	10
Fine grain	20	Higher yield performance	10
Good eating quality	20	Poroshmoni	40
Good straw yield	20	Horidhan	
High Market demand and price	20	(blank)	30
Higher straw yield	10	Draugt tolerant	10
Higher yield performance	30	Easy threshing	10
Less attack of insect and pest	30	Fine grain	20
Less attack of stem borer	10	Free seed	10
Low irrigation cost	10	God quality straw	20
Low production cost	10	Good eating quality	30
No lodging and shattering	20	Good straw yield	20
Tall plant height	20	High Market demand and price	30
BRRI dhan40		Higher yield performance	30
Early harvest	20	Less attack of insect and pest	10
Good eating quality	20	Less care and monitoring	10
Good straw yield	20	less requirement of fertilizer	10
High Market demand and price	10	Low irrigation	10
Higher yield performance	30	Low price of seed	10
Less attack of insect and pest	10	Low production cost	10
Less attack of stem borer	10	No lodging	10
Low production cost	10	Minikit	
Low weed infestation	10	No lodging	20
No lodging and shattering	20	No lodging and shattering	10
BRRI dhan41		No shattering	10
Fine grain	10	Short duration	10
Good eating quality	10	Fine grain	30
Good straw yield	10	Good eating quality	30
High market demand and price	20	Good quality straw	20

Table 4: Continued.

Varieties	% of Farmers	Varieties	% of Farmers
Higher yield performance	20	Good straw yield	10
Less attack of insect and pest	10	High Market demand and price	30
Low fertilizer cost	10	Higher yield performance	30
Low irrigation cost	10	Less attack of insect and pest	10
Suitable for low land	10	less requirement of fertilizer	10
BRRI dhan42		Low production cost	20
Early harvest	10	Low weed infestation	10
Fine grain	10	More tillering	10
Good eating quality	10	Short duration	20
Higher yield performance	10	Nerika	
Less attack of stem borer	10	Fine grain	10
BRRI dhan43		Free seed	10
Fine grain	10	Good eating quality	10
Good eating quality	20	Higher yield performance	10
Higher yield performance	10	Less attack of insect and pest	20
Less attack of stem borer	10	No lodging	30
No lodging and shattering	10	Pajam	
BRRI dhan44		Fine grain	30
Good eating quality	10	Free seed	10
High market demand and price	10	Good eating quality	30
Higher yield performance	20	Good quality straw	10
Less attack of insect and pest	20	Good straw yield	10
less requirement of fertilizer	10	High Market demand and price	30
Less unfilled grain	10	Higher yield performance	30
No lodging and shattering	20	Less attack of insect and pest	30
Tall plant height	10	Low production cost	20
BRRI dhan46		Low requirement of fertilizer	20
Early harvest	10	No lodging	30
Fine grain	40	Ranjit	
Good eating quality	30	Fine grain	20
Good straw yield	30	Good eating quality	30
High Market demand and price	20	Good quality straw	10
High milling outturn	10	Good straw yield	10
Higher yield performance	30	High Market demand and price	10

Table 4: Continued.

Varieties	% of Farmers	Varieties	% of Farmers
Less attack of insect and pest	30	High market demand and price	20
Less attack of stem borer	20	Higher yield performance	30
less requirement of fertilizer	30	Low production cost	10
Low irrigation cost	20	Low requirement of fertilizer	10
Low production cost	30	Swarna	
No lodging and shattering	40	Aromatic rice	10
Submergence tolerant	10	Bold grain	30
Suitable for low land	10	Drought tolerant	20
Tall plant height	20	Early harvest	10
BRRI dhan47		Fine grain	30
High Market demand and price	10	Good eating quality	40
Higher yield performance	10	Good quality straw	20
Suitable for low land	10	Good quality straw	10
BRRI dhan48		Good straw yield	10
Drought tolerant	10	High Market demand and price	10
Early harvest	30	High market demand and price	30
Fine grain	30	Higher yield performance	30
Good eating quality	40	Less attack of BPH	10
Good leftover quality	10	Less attack of insect and pest	40
Good straw yield	10	Less production cost	10
High Market demand and price	30	less requirement of fertilizer	10
Higher yield performance	30	Less requirement of fertilizer	10
Less attack of insect and pest	50	Less unfilled grain	20
Less attack of stem borer	20	Low fertilizer	10
less requirement of fertilizer	30	Low irrigation cost	30
Low irrigation cost	10	Low price of seed	10
Low production cost	10	Low production cost	30
More tillering	10	Low requirement of fertilizer	10
No lodging and shattering	30	More tillering	10
No problem	10	No lodging	40
Suitable for late planting	10	No lodging	10
Tall plant height	10	No lodging and shattering	20
BRRI dhan49		No problem	10
Early harvest	30	No shattering	10

Table 4: Continued.

Varieties	% of Farmers	Varieties	% of Farmers
Fine grain	40	Sheath rot	10
Good eating quality	40	Short duration	30
Good straw yield	30	Short plant height	10
High Market demand and price	30	Suitable for low land	10
Higher yield performance	40	Suitable for high land	10
Less attack of insect and pest	40	Suitable for low land	30
Less attack of stem borer	30	Suitable for puffed rice	10
less requirement of fertilizer	30	Zira	
Less unfilled grain	20	Aromatic rice	20
Low production cost	30	Bold grain	10
More tillering	10	Fine grain	30
No lodging and shattering	30	Good eating quality	30
Suitable for low land	10	Good quality straw	30
Tall plant height	10	Good quality straw	10
BRRI dhan50		Good straw yield	10
Aromatic rice	30	Good straw yield	10
Fine grain	30	High Market demand and price	20
Good eating quality	40	High market demand and price	30
Good straw yield	20	Higher yield performance	60
High Market demand and price	40	Less attack of insect and pest	10
Higher straw yield	10	Less care and monitoring	10
Higher yield performance	40	less requirement of fertilizer	10
Less attack of insect and pest	20	Low production cost	10
Less attack of stem borer	10	Short duration	10
Low production cost	10	Bold grain	10
Low requirement of fertilizer	10	Fine grain	10
No lodging and shattering	40	Good eating quality	10
Suitable for low land	10	Good quality straw	10
Tall plant height	10	Good straw yield	10
BRRI dhan51		High market demand and price	20
Fine grain	20	Higher yield performance	10
Good eating quality	30	Less attack of BPH	10
Good straw yield	10	Less attack of insect and pest	20
High Market demand and price	30	Long duration	10

Table 4: Continued.

Varieties	% of Farmers	Varieties	% of Farmers
Higher yield performance	30	Low production cost	10
Less attack of stem borer	10	No lodging	10
Low fertilizer cost	10	No problem	10
Low irrigation cost	10	Good eating quality	10
Low production cost	10	High market demand and price	10
No lodging and shattering	20	Higher yield performance	20
Submergence tolerant	30	Kalijira	
BRRI dhan52		(blank)	40
Early harvest	20	Aromatic rice	20
Fine grain	30	Fine grain	20
Good eating quality	30	Good eating quality	40
Good straw yield	30	Good leftover quality	10
High Market demand and price	30	Good quality straw	20
Higher yield performance	30	Good straw yield	10
Less attack of insect and pest	40	High Market demand and price	40
Less attack of stem borer	30	Higher yield performance	30
less requirement of fertilizer	20	Kataribhog	
Low irrigation cost	30	Low irrigation cost	10
Low production cost	10	Low requirement of fertilizer	10
No lodging and shattering	30	No lodging	10
Submergence tolerant	20	Fine grain	10
Suitable for late planting	10	Good eating quality	10
Tall plant height	10	Good quality straw	10
BRRI dhan53		High market demand and price	30
High market demand and price	10	Higher yield performance	10
BRRI dhan55		Low requirement of fertilizer	10
Early harvest	10	No lodging	10
Higher yield performance	10	Local	
BRRI dhan56		Aromatic rice	50
Early harvest	30	Drought tolerant	10
Fine grain	10	Early harvest	10
Good eating quality	20	Easy threshing	10
Good straw yield	10	Fine grain	30
High Market demand and price	30	Good eating quality	40

Table 4: Continued.

Varieties	% of Farmers	Varieties	% of Farmers
Higher yield performance	30	Good leftover quality	10
Less attack of insect and pest	10	Good quality straw	40
Less attack of stem borer	10	Good straw yield	10
less requirement of fertilizer	10	High Market demand and price	40
BRRI dhan57		More tillering	20
Fine grain	20	Higher yield performance	40
High Market demand and price	10	Less attack of insect and pest	40
Higher yield performance	10	Less bird attack	10
BRRI dhan58		Less care and monitoring	20
Fine grain	20	Less production cost	10
Good eating quality	30	less requirement of fertilizer	20
Good straw yield	10	Less unfilled grain	20
High market demand and price	20	Less weed infestation	10
Higher straw yield	10	Long duration	20
Higher yield performance	30	Low irrigation cost	40
Less attack of insect and pest	10	Low production cost	40
less requirement of fertilizer	20	Low requirement of fertilizer	20
Low irrigation cost	20	Low weed infestation	20
Low production cost	10	No lodging	60
No lodging and shattering	20	No problem	10
BRRI dhan62		Short duration	20
Fine grain	10	Short plant height	10
Higher yield performance	10	Submergence tolerant	20
No lodging and shattering	10	Suitable for high land	10
BRRI dhan63		Suitable for late planting	10
Fine grain	30	Suitable for low land	40
Good eating quality	30	Suitable for puffed rice	30
Good straw yield	10	Tall plant height	20
High Market demand and price	30	Najirshail	
Higher yield performance	30	(blank)	30
Less attack of insect and pest	30	Aromatic rice	10

Varieties	% of Farmers	Varieties	% of Farmers
Less attack of stem borer	20	Bold grain	10
Low fertilizer cost	10	Fine grain	30
No lodging and shattering	30	Good eating quality	30
BRRI dhan67		Good quality straw	20
Good eating quality	10	Good straw yield	10
Higher yield performance	10	High Market demand and price	20
BRRI dhan71		Higher yield performance	20
Early harvest	10	Low irrigation cost	10
Fine grain	10	Low production cost	10
Good eating quality	20	No lodging	10
Higher yield performance	20	Short duration	10
BRRI dhan72		Chinigura	
Good eating quality	10	Aromatic rice	10
High market demand and price	10	Fine grain	20
Higher yield performance	10	Good eating quality	30
Less attack of stem borer	10	Good quality straw	10
BRRI dhan73		Good straw yield	10
Fine grain	20	High Market demand and price	30
Good eating quality	20	Higher yield performance	20
High market demand and price	10	Less attack of insect and pest	10
Higher yield performance	10	Low irrigation cost	10
BRRI dhan74		More market demand and price	10
Good eating quality	10	More straw yield	10
Good straw yield	10	Suitable for puffed rice	10
Higher yield performance	20	Jamaibabu	
Less attack of insect and pest	10	Fine grain	10
less requirement of fertilizer	20	Good eating quality	10
No lodging and shattering	20	Less attack of insect and pest	10

Source: Field survey, 2019-20

Table 5: Input use pattern, productivity and price of seasonal rice cultivation in Dinajpur region

Inputs items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Seed	22	35	15	22	37	22	32	37	34
Human labour (man-days/ha)									
Hired	30	30	66	58	37	52	42	42	52
Family	0	0	0	30	37	22	33	26	47
Contractual	20209	20209	23209	14970	14970	25359	7230	10712	18982
Fertilizer (Kg/ha)									
Urea	143	160	261	161	160	187	288	160	299
TSP	82	75	91	49	75	112	82	75	150
MOP	93	75	82	124	112	149	82	75	150
DAP	0	75	0	124	112	112	82	112	75
Gypsum	0	75	0	25	75	37	82	37	75
Sulpher	0	7	0	0	7	7	16	7	7
Zinc	0	7	0	7	7	7	8	7	7
Mg	0	7	0	12	7	7	10	7	7
Theovit	0	0	0	12	7	7	8	7	7
Yield (ton/ha)									
Worse	2.47	2.89	4.79	2.31	2.99	3.39	2.47	2.99	4.19
Average	3.49	4.49	6.5	3.93	4.49	7.48	3.99	4.49	6.59
Best	4.99	5.09	9.1	5.27	7.41	9.28	4.94	6.18	8.98
Straw (Tk/ha)									
Worse	4491	3742	1871	3742	5239	4491	7485	2994	3742
Average	8982	11976	11976	11982	14970	11976	13227	5988	14970
Best	11227	11976	22455	14970	29939	14970	18712	7485	22455
Price (Tk/ton)									
Worse	16250	18000	16000	16250	13000	15000	16000	16250	18750
Average	20000	21250	22000	21250	20000	23000	23000	21250	25000
Best	27000	22500	26000	22500	26000	24500	23750	23750	30000

Source: Field survey, 2019-2020

Table 6: Production costs and return (Tk./ha) of seasonal rice in Dinajpur region

Cost and income (Tk/ha)	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Paid out cost (A)	51562	63193	87993	62662	60287	92283	66694	62920	90049
Seed	945	1607	644	945	1589	945	1374	1589	1460
Land preparation	7410	8982	7136	5703	8982	7485	7410	8982	7485
Hired labour	12328	12328	27122	23834	15205	21369	17259	17259	21369
Contractual	20209	20209	23209	9970	14970	25359	7230	10712	18982
Power thresher	4814	4814	6814	3446	3742	2994	3233	3742	2994
Fertilizer	5856	10013	7945	12424	12506	13923	14737	11381	16510
Irrigation	0	3742	13173	4611	1871	18712	4940	3742	14653
Herbicides	0	0	0	494	299	748	618	449	449
Insecticides	0	1497	1950	1235	1123	748	2470	1123	2245
Imputed cost (B)	16545	21041	25248	29589	33984	34324	30856	31723	44579
Seedbed	1846	2245	2245	2470	1800	2245	2470	2245	2245
Family labour	0	0	0	12328	15205	9041	13561	10684	19314
Land rent	14269	18269	22269	14269	18269	22269	14269	18269	22269
IOC at 4% for 5 months	430	527	733	522	502	769	556	524	750
Total cost (A+B)	68107	84234	113241	92252	94271	126607	97550	94643	124545
Gross return (Tk/ha)	78840	107408	154976	95593	104788	184127	105043	101420	179636
Net return (Tk/ha)	10734	23173	41735	3342	10516	57520	7493	6776	45441
BCR (Cash cost)	1.53	1.7	1.76	1.53	1.74	2	1.58	1.61	2
BCR (Full cost)	1.16	1.28	1.37	1.04	1.11	1.45	1.08	1.07	1.34

Source: Field survey, 2019-2020

Table 7: Input use pattern, productivity and price of seasonal rice cultivation in Mymensingh region

Input items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Seed	38	38	37	29	29	28	47	31	38
Human labour (man-days/ha)									
Hired	32	43	49	69	38	72	22	35	32
Family	17	11	14	22	14	25	45	45	46
Contractual	16467	25348	33188	10300	12260	14000	8500	9500	14200
Fertilizer (kg/ha)									
Urea	131	190	287	140	190	287	150	190	247
TSP	48	115	115	63	95	115	76	124	124
MOP	76	76	62	95	95	76	95	94	76
DAP	76	115	41	114	114	114	143	62	124
Gypsum		57	57	74	48	57	38	62	75

Input items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Sulpher	0	38	12	0	10	11	38	10	12
Zinc	0	11	6	0	10	11	0	6	6
Theovit	0	11	11	0	6	11	0	12	7
Yield (ton/ha)									
Worse	2.04	3.04	3.95	3.04	3.04	3.8	2.99	3.04	3.8
Average	3.8	4.56	6.89	4.56	4.56	6.18	3.98	4.94	6.08
Best	5.18	6.41	9.89	5.37	6.6	9.6	5.56	6.08	10.88
Straw (Tk/ha)									
Worse	12500	12500	12500	19000	12500	12500	15000	12500	12500
Average	17500	21875	17500	24000	17500	20000	24000	23000	20000
Best	30000	30000	30000	27500	27500	28750	30000	30000	25000
Price (Tk/ton)									
Worse	2994	3742	3742	8742	3742	2994	2245	2994	5988
Average	14970	28068	14970	9485	14970	7485	7485	14970	7485
Best	16467	37424	22455	12724	22455	11976	11227	22455	8982

Source: Field survey, 2019-2020

Table 8: Production costs (Tk./ha) and return of seasonal rice cultivation in Mymensingh region

Input items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Paid out cost (A)	61170	72020	90920	71601	60730	90694	50152	54071	68915
Seed	2100	2100	2044	1602	1602	1547	2597	1713	2100
Land preparation	6980	6460	6175	7980	7980	7600	5600	6175	6175
Hired labour	15133	20335	23173	32631	17971	34050	10404	16552	15133
Contractual	20126	20126	22789	10300	12260	14000	8500	9500	14200
Power thresher	7906	3800	7906	3800	3800	3800	3800	3800	2660
Fertilizer	6799	14441	14029	11157	13156	15802	12651	12686	15020
Irrigation	1425	3744	11820	1850	2375	11350	1850	1175	11200
Herbicides	4	380	686	760	1425	247	1900	618	574
Insecticides	698	633	2298	1520	713	2298	2850	1853	1853
Imputed cost (B)	29674	26927	31451	32126	28252	36865	42824	42857	46615
Seedbed	2375	2375	2161	2375	2375	2375	2375	2375	2375
Family labour	8040	5202	6621	10404	6621	11823	21281	21281	21754
Land rent	18750	18750	21911	18750	18750	21911	18750	18750	21911
IOC at 4% for 5 months	510	600	758	597	506	756	418	451	574
Total cost (A+B)	90845	98947	122371	103727	88981	127559	92977	96928	115530
Gross return (Tk/ha)	104745	127818	135598	110085	94770	130985	97035	107595	129085
Net return (Tk/ha)	13900	28871	13227	6358	5788	3426	4058	10667	13555

Input items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
BCR (Cash cost)	1.71	1.77	1.49	1.54	1.56	1.44	1.93	1.99	1.87
BCR (Full cost)	1.15	1.29	1.11	1.06	1.07	1.03	1.04	1.11	1.12

Source: Field survey, 2019-2020

Table 9: Input use pattern, productivity and price of seasonal rice cultivation in Sylhet region

Input items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Seed	22	41	41	33	41	41	41	41	41
Human labour (man-days/ha)									
Hired	67	72	63	22	33	33	33	33	41
Family	10	9	11	27	11	37	33	25	25
Contractual	15905	16230	18407	13000	16075	18112	8233	9880	16347
Fertilizer (Kg/ha)									
Urea	150	165	254	130	190	165	131	165	165
TSP	75	82	82	82	82	82	82	82	82
MOP	75	82	66	82	82	82	82	82	82
DAP	0	82	79	82	82	82	82	82	41
Gypsum	0	82	49	41	82	41	41	82	82
Sulpher	7	8	8	8	8	8	8	8	8
Zinc	7	8	8	8	8	8	8	8	8
Mg	0	16	16	16	16	16	16	16	16
Theovit	2	8	8	8	8	8	8	8	8
Yield (ton/ha)									
Worse	2.25	3.29	4.91	2.65	3.29	4.29	2.47	3.29	4.12
Average	3.9	5.47	6.93	3.94	4.95	6.59	3.89	4.94	7.59
Best	4.94	5.94	9.26	4.94	6.04	9.88	4.94	6.59	9.48
Straw (Tk/ha)									
Worse	6736	7485	3742	5988	7485	3742	4491	7485	3742
Average	12982	18712	9730	7485	14970	14970	10982	18712	8982
Best	14479	22455	11227	11227	18712	18712	11227	22455	11227
Price (Tk/ton)									
Worse	15000	15000	12500	18000	13750	15000	20000	12500	10000
Average	22000	21750	21000	21750	21500	18750	23000	20000	19500
Best	30000	30000	25000	25000	25000	25000	25000	25000	25000

Source: Field survey, 2019-20

Table 10: Production costs (Tk./ha) and return of seasonal rice cultivation in Sylhet region

Cost and income	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Paid out cost (A)	66730	80456	93877	51055	61773	77822	56227	61845	77025
Seed	946	1763	1763	1419	1763	1763	1763	1763	1763
Land preparation	7485	8233	8233	8233	8233	8233	5233	8233	8233
Hired labour	26800	28800	25200	8800	13200	13200	13200	13200	16400
Contractual	15905	16230	18407	13000	16075	18112	14653	14653	14653
Power thresher	3485	4775	4199	2799	4117	4199	3499	2799	3499
Fertilizer	8864	15267	15741	13534	15751	14201	13553	15269	14199
Irrigation	1235	3900	16467	1293	1976	16467	1647	4117	16467
Herbicides	600	499	873	823	329	823	1198	329	329
Insecticides	1411	988	2994	1153	329	823	1482	1482	1482
Imputed cost (B)	26854	28027	30584	35147	26400	43439	35590	34437	39044
Seedbed	1846	2305	2470	2470	2470	2058	2470	2470	2470
Family labour	4000	3600	4400	10800	4400	14800	13200	10000	10000
Land rent	20452	21452	22932	21452	19015	25932	19452	21452	25932
IOC at 4% for 5 months	556	670	782	425	515	649	469	515	642
Total cost (A+B)	93584	108484	124461	86202	88174	121261	91817	96282	116068
Gross return (Tk/ha)	98782	137670	155218	93228	121438	138470	100528	117512	156922
Net return (Tk/ha)	5198	29187	30757	7026	33264	17209	8711	21230	40854
BCR (Cash cost)	1.48	1.71	1.65	1.83	1.97	1.78	1.79	1.9	2.04
BCR (Full cost)	1.06	1.27	1.25	1.08	1.38	1.14	1.09	1.22	1.35

Source: Filed survey, 2019-20

Table 11: Input use pattern, productivity and price of seasonal rice cultivation in Khulna

Input items	Large farmer (Above 3 ha)			Medium farmer) (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Seed (kg/ha)	30	37	30	25	37	37	29	37	37
Human labour (man-days/ha)									
Hired	13	67	64	44	37	61	30	52	52
Family	22	34	30	10	34	22	45	37	22
Contractual	13978	10978	21758	14820	10978	22455	27424	22455	22455
Fertilizer (kg/ha)									
Urea	110	190	225	99	247	225	110	190	374
TSP	90	90	90	148	99	150	75	150	150

Input items	Large farmer (Above 3 ha)			Medium farmer) (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
MOP	46	112	127	99	99	112	112	75	150
DAP	0	75	1	1	75	41	135	75	112
Gypsum	31	75	75	74	49	75	75	75	75
Sulpher	0	37	0	0	37	0	0	7	25
Zinc	0	15	0	0	7	7	7	15	15
Theovit	6	7	7	5	7	7	7	7	7
Yield (ton/ha)									
Worse	2.09	2.99	3.49	2.93	2.59	4.49	2.54	2.99	3.49
Average	4.49	4.49	7.48	4.82	5.39	7.51	4.49	5.99	6
Best	6.18	6.59	8.38	6.9	5.99	8.65	4.79	7.48	8.98
Straw (Tk/ha)									
Worse	11227	5239	18712	20958	14970	3742	11227	7485	7485
Average	22455	26197	22455	22455	30089	14970	14970	29939	18712
Best	37424	29939	26197	31436	44909	18712	22455	44909	22455
Price (Tk/ton)									
Worse	12500	19000	18000	12000	16250	15000	16250	12500	15000
Average	22500	25000	27500	25000	22500	22000	20000	20000	25000
Best	30000	30000	30000	27500	30000	30000	30000	25000	30000

Source: Field survey, 2019-20

Table 12: Production costs (Tk./ha) and return of seasonal rice in Khulna region

Cost and income (Tk/ha)	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Paid out cost (A)	38146	65565	81467	53918	53157	80897	49400	62269	79968
Seed	1289	1607	1289	1074	1589	1589	1246	1589	1589
Land preparation	6736	5988	6736	4940	5988	8982	5988	5239	6736
Hired labour	4713	24292	23204	15953	13415	22117	10877	18853	18853
Contractual	13978	10978	21758	14820	10978	22455	14653	14653	14653
Power thresher	2245	4491	2245	2470	4117	3458	1871	4491	2245
Fertilizer	6188	13719	10142	8624	13579	13143	11398	13739	19424
Irrigation	1871	2994	11976	4803	2196	7485	1871	2245	14970
Herbicides	3	374	1123	247	173	187	374	337	374
Insecticides	1123	1123	2994	988	1123	1482	1123	1123	1123

Cost and income (Tk/ha)	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Imputed cost (B)	24409	33388	36070	20814	33285	32791	33242	34448	33157
Seedbed	1846	2245	2245	2470	2245	1871	2245	2245	2245
Family labour	7976	12327	10877	3626	12327	7976	16316	13415	7976
Land rent	14269	18269	22269	14269	18269	22269	14269	18269	22269
IOC at 4% for 5 months	318	546	679	449	443	674	412	519	666
Total cost (A+B)	62556	98954	117537	74732	86442	113688	82642	96717	113126
Gross return (Tk/ha)	123500	138470	228288	142885	151344	180163	104788	149697	168676
Net return (Tk/ha)	60944	39516	110751	68152	64902	66475	22146	52980	55551
BCR (Cash cost)	3.24	2.11	2.8	2.65	2.85	2.23	2.12	2.4	2.11
BCR (Full cost)	1.97	1.4	1.94	1.91	1.75	1.58	1.27	1.55	1.49

Source : Field survey, 2019-20

Table 13: Input use pattern, productivity and price of seasonal rice cultivation in Chattogram region

Input items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Seed (kg/ha)	22	35	15	35	41	41	41	37	41
Human labour (man-days/ha)									
Hired	50	56	56	48	64	60	44	46	62
Family	0	0	0	17	12	25	13	19	19
Contractual (Tk/ha)	14718	14718	13221	18105	10712	9712	8712	5712	8712
Fertilizer use (kg/ha)									
Urea	150	190	272	100	190	124	100	190	124
TSP	71	124	86	90	62	82	62	124	93
MOP	75	62	82	93	82	82	93	62	62
DAP	39	124	82	41	62	82	124	124	124
Gypsum	48	26	33	45	41	31	41	62	31
Sulpher		25	8	0	14	8	26	8	31
Zinc	8	99	8	8	11	8	16	8	6
Theovit	7	7	12	7	8	12	6	12	12
Yield (ton/ha)									
Worse case	2.99	3.18	4.12	2.29	3.95	5.28	2.47	2.47	4.71
Average	3.8	4.53	6.42	3.46	4.94	6.59	3.95	4.94	6.93
Best case	4.99	6.65	8.4	6.05	6.06	9.88	5.94	6.89	8.41
Straw (Tk/ha)									
Worse case	2245	7485	3742	5988	4491	5239	5239	5239	6736
Average	11227	18712	11227	18712	14970	14970	7485	11227	14970
Best case	18712	52394	22455	22455	18712	14970	18712	14970	18712

Input items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Price (Tk/ton)									
Worse case	10000	13000	12000	12500	11250	12500	15000	15000	16250
Average	23750	25000	23000	23750	21250	20000	23750	21250	20000
Best case	27000	30000	24500	23750	25000	21429	25000	25000	25000

Source: Field survey, 2019-20

Table 14: Production costs (Tk./ha) and return of seasonal rice cultivation in Chattogram region

Cost items (Tk/ha)	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Paid out cost (A)	61620	89940	85375	56777	71883	82065	69022	72655	94500
Seed	836	1340	570	1330	1557	1557	1557	1406	1557
Land preparation	6587	9880	7136	6469	8645	9880	9880	8233	9115
Hired labour	27384	30670	30670	26289	35052	32861	24098	25193	33956
Contractual	14718	14718	13221	7151	10712	9712	14653	14653	14653
Fertilizer	9320	25754	13987	9175	11560	11119	11883	14710	13683
Irrigation	0	3529	14820	1544	1235	12350	2470	2744	15438
Herbicides	425	375	510	618	278	494	278	278	278
Insecticides	0	1323	1112	1853	494	741	1853	3088	2470
Power thresher	2350	2350	3350	2350	2350	3350	2350	2350	3350
Imputed cost (B)	16628	21224	25060	37476	27910	39115	24434	31750	35315
Seedbed	1846	2205	2080	2470	2470	2470	2470	2470	1853
Family labour	0	0	0	20264	6572	13692	7120	10406	10406
Land rent	14269	18269	22269	14269	18269	22269	14269	18269	22269
IOC at 4% for 5 months	513	749	711	473	599	684	575	605	788
Total cost (A+B)	78248	111163	110435	94253	99794	121180	93456	104405	129815
Gross return (Tk/ha)	101477	131926	158933	100865	119945	146703	101345	116202	153530
Net return (Tk/ha)	23229	20763	48498	6611	20151	25523	7889	11797	23715
BCR (Cash cost)	1.65	1.47	1.86	1.78	1.67	1.79	1.47	1.6	1.62
BCR (Full cost)	1.3	1.19	1.44	1.07	1.2	1.21	1.08	1.11	1.18

Source: Field survey, 2019-20

Table 15: Input use pattern, productivity and price of seasonal rice cultivation in Rajshahi region

Input items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Seed	41	37	37	37	37	37	37	37	37
Human labour (man-days/ha)									
Hired	60	94	43	75	82	76	22	20	22
Family	22	18	12	30	30	30	52	30	45
Contractual	14579	10579	18712	18568	13832	15448	18712	14510	16000

Input items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Fertilizer (kg/ha)									
Urea	143	190	247	150	190	198	124	190	225
TSP	54	105	111	75	75	150	75	75	75
MOP	76	112	111	112	75	112	75	75	75
DAP	34	112	49	112	75	112	112	75	150
Gypsum	0	75	62	37	75	75	37	75	75
Sulpher	0	7	35	15	22	7	7	7	7
Zinc	2	7	7	7	7	7	7	7	7
Mg	2	0	6	7	7	10	10	7	7
Theovit	2	0	6	7	7	10	10	7	7
Yield (ton/ha)									
Worse	2.99	2.97	4.03	2.1	2.99	5.04	2.99	2.99	4.03
Average	4.49	5.09	7.41	4.56	5.39	7.51	4.74	5.39	5.99
Best	5.43	6.74	8.89	5.99	8.07	12.35	5.39	5.99	10.08
Straw (Tk/ha)									
Worse	2994	11227	5239	7485	11227	3742	7485	7485	5988
Average	7485	14970	8982	18712	18712	7485	13473	22455	11227
Best	8982	26197	11976	22455	22455	18712	14970	29939	22455
Price (Tk/ton)									
Worse	13750	20000	20000	16250	15000	15000	17500	12500	15000
Average	23750	22500	21250	23750	24500	25000	22500	20000	20000
Best	28750	30000	25000	25000	27500	30000	25000	25000	25000

Table 16: Production costs (Tk./ha) and return of seasonal rice cultivation in Rajshahi region

Input items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Paid out cost (A)	61389	82707	81806	87724	85166	93010	51065	52770	67014
Seed	1640	1480	1480	1480	1480	1480	1480	1480	1480
Land preparation	7485	7485	7561	7485	8982	6736	6736	6736	6736
Hired labour	27000	42300	19350	33750	36900	34200	9900	9000	9900
Contractual	14579	10579	18712	18568	13832	15448	14653	14653	14653
Power thresher	3000	3000	3249	2994	7111	3742	2994	3742	3742
Fertilizer	6118	12155	13669	12427	12446	15303	11261	11844	14036
Irrigation	748	3024	14820	9523	2994	14970	2245	3742	14970

Input items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Herbicides	4	163	988	374	299	374	299	449	374
Insecticides	814	2520	1976	1123	1123	756	1497	1123	1123
Imputed cost (B)	31008	29808	30463	35226	35205	38657	44821	34935	44965
Seedbed	1846	2268	2470	2245	2245	2470	2245	2245	2245
Family labour	9900	8100	5400	13500	13500	13500	23400	13500	20250
Land rent	18750	18750	21911	18750	18750	21911	18750	18750	21911
IOC at 4% for 5 months	512	689	682	731	710	775	426	440	558
Total cost (A+B)	92396	112514	112269	122951	120372	131667	95886	87705	111979
Gross return (Tk/ha)	114144	129488	166444	127012	150745	195205	120177	130236	130985
Net return (Tk/ha)	21748	16974	54175	4062	30373	63538	24178	41594	18919
BCR (Cash cost)	1.86	1.57	2.03	1.45	1.77	2.1	1.86	2.27	1.69
BCR (Full cost)	1.24	1.15	1.48	1.03	1.25	1.48	1.25	1.47	1.17

Source: Field survey, 2019-20

Table 17: Input use pattern, productivity and price of seasonal rice cultivation in Jashore region

Inputs items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Seed (kg/ha)	37	26	25	37	37	29	37	37	37
Human labour (man days/ha)									
Hired	67	52	76	67	58	97	60	75	60
Family	12	10	15	7	7	22	17	22	22
Contractual (Tk/ha)	17964	22314	17964	15054	15951	10964	4933	4943	11964
Fertilizer (kg/ha)									
Urea	120	160	277	100	160	299	120	160	225
TSP	93	90	150	75	150	150	150	150	150
MOP	93	85	112	112	112	75	112	150	75
DAP	0	150	0	75	75	75	75	75	75
Gypsum	0	75	88	75	37	75	37	75	75
Sulpher	0	15	37	37	59	7	37	7	75
Zinc	0	15	7	7	7	7	7	7	7
Mg	0	0	0	0	0	7	7	15	9
Theovit	0	11	0	7	7	7	7	7	7
Yield (ton/ha)									
Worse	2.99	3.89	4.03	2.99	2.96	4.49	2.99	4.49	4.39
Average	4.19	4.79	7.35	3.59	5.39	6.05	4.94	5.99	5.99
Best	5.65	6.59	11.43	5.99	6.59	7.48	5.99	7.48	9.88
Straw (Tk/ha)									
Worse	800	2000	1000	1000	1000	600	1000	1000	1000
Average	1200	4000	2250	2000	2500	1500	2000	3000	2500
Best	1500	7000	3000	2500	3000	2000	3000	4000	3000

Inputs items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
	Price (Tk/ton)								
Worse	12500	16250	17000	15000	15000	15000	15000	15000	15000
Average	22000	21250	23000	25000	20000	25000	21500	20000	25000
Best	25000	26250	27500	27500	25000	27500	26000	25000	30000

Source: Field survey, 2019-20

Table 18: Production costs (Tk./ha) and return of seasonal rice in Jashore region

Cost and income (Tk/ha)	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Paid out cost (A)	60572	76739	92313	67633	68593	92066	65602	77381	82166
Seed	1722	1219	1164	1722	1722	1350	1722	1722	1722
Land preparation	6175	7485	7485	5988	5988	5988	5988	5988	5988
Hired labour	24292	18853	27555	24292	21029	35169	21754	27193	21754
Contractual	17964	17964	17964	15054	15951	10964	14653	14653	14653
Power thresher	0	6814	12098	5614	5988	5988	3742	4485	4491
Fertilizer	5927	14364	13227	10982	14136	15771	13881	15725	16721
Irrigation	2245	2994	10082	2245	2245	14970	2245	2227	14970
Herbicides	0	748	494	988	412	371	494	1647	371
Insecticides	2245	1946	2245	748	1123	1497	1123	3742	1497
Imputed cost (B)	21047	27803	31108	19692	26647	33831	23301	32159	33748
Seedbed	1846	2245	2058	2245	2245	2245	2245	2245	2245
Family labour	4351	3626	5439	2538	2538	7976	6164	7976	7976
Land rent	14345	21292	22841	14345	21292	22841	14345	21292	22841
IOC at 4% for 5 months	505	639	769	564	572	767	547	645	685
Total cost (A+B)	81619	104505	123421	87325	95241	125897	88903	109541	115914
Gross return (Tk/ha)	93413	105794	171327	91818	110282	152724	108210	122758	152197
Net return (Tk/ha)	11794	1288	47906	4493	15041	26828	19307	13217	36283
BCR (Cash cost)	1.54	1.46	1.86	1.36	1.61	1.66	1.65	1.59	1.85
BCR (Full cost)	1.14	1.01	1.39	1.05	1.16	1.21	1.22	1.12	1.31

Source: Field survey, 2019-20

Table 19: Input use pattern, productivity and price of seasonal rice cultivation in Barishal region

Items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Seed (kg/ha)	22	30	37	40	37	37	41	37	37
Human labour (man-days/ha)									
Hired	50	52	49	54	20	49	54	49	49
Family	0	15	25	32	37	23	29	37	37
Contractual (Tk/ ha)	24700	25605	12350	13525	23712	24700	12350	12525	17964
Fertilizer use (kg)									
Urea	150	160	272	120	160	124	100	160	247
TSP	50	150	86	62	99	137	165	62	124
MOP	75	112	124	99	99	99	82	99	124
DAP	0	62	49	64	25	49	62	82	62
Gypsum	0	112	25	82	88	49	82	82	49
Sulpher	0	37	0	0	0	0	0	8	1
Zinc	0	0	12	8	0	12	0	26	0
Theovit	0	7	0	0	7	1	1	8	2
Yield (ton/ha)									
Worse case	2.43	2.99	3.95	2.2	2.96	3.95	2.74	2.47	4.94
Average	3.63	4.99	7.42	4.74	4.94	7.59	4.39	4.94	7.88
Best case	5.85	6.48	9.4	5.49	6.06	9.56	5.92	6.25	10.87
Straw (Tk/ha)									
Worse case	7485	8982	3742	7485	8982	3742	7485	8982	3742
Average	11227	18712	7485	11227	18712	7485	11227	18712	7485
Best case	14970	22455	13473	14970	22455	13473	14970	22455	13473
Price (Tk/ton)									
Worse case	16000	17000	14000	16000	17000	14000	16000	17000	14000
Average	24000	21000	20000	24000	21000	20000	24000	21000	20000
Best case	28000	30000	27000	28000	30000	27000	28000	30000	27000

Source: Field survey, 2019-20

Table 20: Production costs (Tk./ha) and return of seasonal rice cultivation in Barishal region

Cost items (Tk/ha)	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	***T. Aman***	***Boro***	***T. Aus***	***T. Aman***	***Boro***	***T. Aus***	***T. Aman***	***Boro***
Paid out cost (A)	68453	87881	80432	69746	58029	84783	67471	74415	86978
Seed	945	1286	1590	1718	1590	1590	1761	1590	1590
Land preparation	6587	8982	7410	9880	6175	9880	8350	8645	8645
Hired labour	23576	24519	23104	25462	9430	23104	25462	23104	23104
Contractual	24700	25605	12350	13525	23712	24700	12350	12525	17964
Fertilizer	3088	4410	4631	4310	3705	4631	3175	3470	4631
Irrigation	5853	19748	13934	10454	11035	12505	11786	16683	14149
Herbicides	3705	2994	14820	2470	1235	7410	1705	6175	14820
Insecticides	0	0	741	445	882	741	412	371	222
Power thresher	0	337	1853	1482	265	222	2470	1853	1853
Imputed cost (B)	17298	24932	41273	33022	35212	39749	31588	36036	46986
Seedbed	1846	2245	3088	2470	2400	2470	2470	3088	3088
Family labour	0	7073	11788	15088	17446	10845	13674	17446	17446
Land rent	14882	14882	25728	14882	14882	25728	14882	14882	25728
IOC at 4% for 5 months	570	732	670	581	484	707	562	620	725
Total cost (A+B)	85752	112813	121706	102767	93240	124532	99059	110451	133964
Gross return (Tk/ha)*	98347	123502	155925	125045	122452	159218	116614	122452	165085
Net return (Tk/ha) **	12595	10755	34219	22277	31587	34686	17554	12001	31121
BCR (Cash cost)	1.44	1.53	1.94	1.79	2.11	1.88	1.73	1.65	1.9
BCR (Full cost)	1.15	1.1	1.28	1.22	1.35	1.28	1.18	1.11	1.23

*Gross retrun(GR)=Yield*Price + straw value, **NI=GR-A-B
Source: Field survey, 2019-20

Table 21: Input use pattern, productivity and price of seasonal rice cultivation in Rangpur region

Input items	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Seed	37	22	22	37	22	22	37	22	22
Human labour (man-days/ha)									
Hired	20	67	83	82	45	25	25	35	35
Family	16	41	13	25	47	22	64	45	45
Contractual	21700	18700	20712	10068	18712	18098	14850	19970	14970
Fertilizer (Kg/ha)									
Urea	131	190	262	110	190	225	150	190	187
TSP	75	112	75	75	112	112	75	75	120
MOP	75	75	75	112	75	75	112	75	75
DAP	0	75	75	47	69	90	99	75	50
Gypsum	37	37	37	22	37	37	37	37	37
Sulpher	0	15	30	0	15	7	49	10	37
Zinc	0	11	7	0	7	7	15	7	7
Mg	0	0	6	0	0	0	0	1	1
Theovit	0	7	7	7	7	7	20	7	20
Yield (ton/ha)									
Worse	2.62	2.97	4.49	2.99	2.99	4.49	2.99	2.4	4.49
Average	4.49	4.89	6.99	4.49	4.86	5.99	3.99	4.94	6.59
Best	5.99	6.92	8.98	5.37	7.48	9.14	4.94	5.99	9.88
Straw (Tk/ha)									
Worse	6736	3742	4491	6736	11227	3742	1497	7485	3742
Average	14970	18712	8982	13473	14970	11227	12227	22455	11227
Best	18712	22455	14970	18712	22455	14970	14970	29939	14970
Price (Tk/ton)									
Worse	16250	15000	12500	16250	12500	15000	18750	15000	15000
Average	22000	21500	17500	24500	20000	20000	24750	25000	20000
Best	27000	26250	28000	28000	30000	30000	30000	30000	25000

Source: Field survey, 2019-20

Table 22: Production costs (Tk./ha) and return of seasonal rice cultivation in Rangpur region

Cost and income (Tk/ha)	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	***T. Aman***	***Boro***	***T. Aus***	***T. Aman***	***Boro***	***T. Aus***	***T. Aman***	***Boro***
Paid out cost (A)	49107	73550	97199	70472	62111	68547	59567	53809	73865
Seed	2469	1468	1468	2469	1468	1468	2469	1468	1468
Land preparation	5239	5988	5988	5239	5988	5988	6736	5988	5988
Hired labour	7685	25743	31891	31507	17290	9606	9606	13448	13448
Contractual	21700	18700	20712	10068	18712	18098	14653	14653	14653
Power thresher	2994	3742	3742	1871	2245	3742	4940	2245	3742
Fertilizer	6214	13411	14311	11833	12814	13364	17421	11554	18100
Irrigation	1871	3000	14970	5988	2245	14970	1871	2994	14970
Herbicides	374	374	374	374	225	187	748	337	374
Insecticides	561	1123	3742	1123	1123	1123	1123	1123	1123
Imputed cost (B)	30497	40706	29154	34533	42916	34999	44651	42078	44479
Seedbed	1846	2245	2245	2245	2245	1871	2470	2245	2470
Family labour	6148	15753	4995	9606	18059	8453	24591	17290	17290
Land rent	22094	22094	21104	22094	22094	24104	17094	22094	24104
IOC at 4% for 5 months	409	613	810	587	518	571	496	448	616
Total cost (A+B)	79604	114256	126353	105005	105027	103546	104219	95888	118345
Gross return (Tk/ha)	113770	123854	131270	123500	112226	130985	111029	140955	142961
Net return (Tk/ha)	34165	9598	4917	18495	7199	27439	6811	45067	24616
BCR (Cash cost)	2.32	1.68	1.35	1.75	1.81	1.91	1.86	2.62	1.94
BCR (Full cost)	1.43	1.08	1.04	1.18	1.07	1.26	1.07	1.47	1.21

Source: Field survey, 2019-20

Table 23: Input use pattern, productivity and price of seasonal rice cultivation in Cumilla region

Cost items (Tk/ha)	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Seed	41	33	25	33	41	41	26	41	28
Human labour (man-days/ha)									
Hired	61	64	66	61	82	90	44	44	62
Family	5	8	12	23	8	16	33	25	32
Contractual	14467	14171	16858	9173	16347	15583	9350	9880	14700
Fertilizer (Kg/ha)									
Urea	91	190	206	110	190	247	120	190	165
TSP	82	82	91	66	82	82	82	82	124
MOP	82	106	82	124	82	82	124	82	124
DAP	0	75	33	82	82	82	165	82	82
Gypsum	0	35	41	82	41	41	41	82	41
Sulpher	0	8	8	8	8	8	8	8	8
Zinc	0	0	8	8	8	8	8	8	8
Mg	0	0	0	8	8	8	8	8	8
Theovit	0	8	8	8	8	8	8	8	8
Yield (ton/ha)									
Worse	2.47	3.29	3.38	2.46	3.29	4.12	2.65	3.29	3.29
Average	4.29	4.94	5.27	3.99	4.94	6.59	3.95	4.94	6.59
Best	5.29	5.65	7.98	5.76	6.59	7.92	5.54	6.92	9.88
Straw (Tk/ha)									
Worse	4491	3742	5239	5239	7485	5239	2245	3742	5239
Average	8982	11227	13473	115988	11227	13473	11227	11227	7485
Best	11227	14970	14970	14970	14970	14970	14970	14970	14970
Price (Tk/ton)									
Worse	17500	15000	15000	17500	16250	14500	18750	12500	15000
Average	23750	20000	22500	23750	22500	23750	23750	20000	22500
Best	21250	22500	25000	27500	27500	25000	25000	25000	25000

Source: Field survey, 2019-20

Table 24: Production costs (Tk./ha) and return of seasonal rice cultivation in Cumilla region

Cost and income (Tk/ha)	Large farmer (Above 3 ha)			Medium farmer (1.1-3ha)			Small farmer (0.22-1.00 ha)		
	T. Aus	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*	*T. Aus*	*T. Aman*	*Boro*
Paid out cost (A)	64162	74627	84893	63621	85866	104488	60667	66005	83676
Seed	1557	1251	950	1254	1557	1557	988	1557	1064
Land preparation	7410	7410	8233	5880	9880	7940	5640	7410	7410
Hired labour	27450	28800	29700	27450	36900	40500	19800	19800	27900
Contractual	14467	14171	16858	9173	16347	15583	14653	14653	14653
Power thresher	5450	7057	8233	5233	6175	8233	3200	3200	1544
Fertilizer	4950	10484	10956	11173	11919	13013	12599	12386	13034
Irrigation	2587	3293	8233	1647	2058	16467	2470	4117	16467
Herbicides	474	748	494	988	412	371	494	1647	371
Insecticides	290	1411	1235	823	618	823	823	1235	1235
Imputed cost (B)	22750	24459	29819	31470	24905	32194	35945	32390	39221
Seedbed	1846	2117	2058	2470	2470	2470	2470	2470	2470
Family labour	2250	3600	5400	10350	3600	7200	14850	11250	14400
Land rent	18120	18120	21654	18120	18120	21654	18120	18120	21654
IOC at 4% for 5 months	535	622	707	530	716	871	506	550	697
Total cost (A+B)	86912	99086	114712	95091	110771	136682	96612	98395	122897
Gross return	110948	110027	132033	106409	122377	169906	105087	110027	155685
Net-income	23559	10941	17321	11318	11606	33224	8475	11632	32788
BCR (Cash cost)	1.72	1.47	1.56	1.67	1.43	1.63	1.73	1.67	1.86
BCR (Full cost)	1.27	1.11	1.15	1.12	1.1	1.24	1.09	1.12	1.27

Source: Field survey, 2019-20

Table 25: Input use pattern of rice production in Dhaka region

Input item	*T. Aus*		*T. Aman*		*Boro*		
	Small	Medium	Small	Medium	Small	Medium	Large
Family labor	35	3	31	20	33	24	9
Hired labor	50	22	53	49	45	51	44
Seed (Kg/ha)	40	31	45	50	47	37	23
Urea	175	241	176	176	255	254	189
TSP	67	74	41	38	84	95	87
MoP	73	124	40	47	84	65	65
DAP	40	0	67	45	55	39	37
Gypsum	12	62	27	15	20	28	10

Table 26: Input use pattern of rice production in Bogura region

Input item	*T. Aus*			*T. Aman*			*Boro*		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
Family labor	15	14	5	19	11	4	25	15	10
Hired labor	23	22	28	30	28	41	33	30	50
Seed (Kg/ha)	31	35	35	43	39	48	37	33	38
Urea	168	110	109	200	200	139	242	230	239
TSP	68	69	75	59	66	160	56	99	149
MoP	98	75	99	90	86	141	115	142	159
DAP	57	35	56	71	74	144	91	81	86
Gypsum	29	26	9	25	23	34	34	42	64

Table 27: Input use pattern of rice production in Faridpur region

Input item	*T. Aus*	*T. Aman*			*Boro*		
	Small	Small	Medium	Large	Small	Medium	Large
Family labor	25	30	24	8	38	28	8
Hired labor	48	57	59	32	69	61	51
Seed (Kg/ha)	74	64	58	42	68	59	46
Urea	110	151	161	178	201	210	163
TSP	96	67	74	23	79	94	94
MoP	29	85	114	0	121	134	176
DAP	0	73	86	119	93	99	92
Gypsum	0	28	34	25	40	41	60

Table 28: Input use pattern of rice production in Rangamati region

Input item	*T. Aus*			*T. Aman*			*Boro*	
	Small	Medium	Large	Small	Medium	Large	Small	Medium
Family labor	58	45	25	58	35	32	61	44
Hired labor	68	38	59	54	52	67	45	67
Seed (Kg/ha)	46	24	52	49	46	25	37	42
Urea	141	119	77	138	118	124	136	124
TSP	41	57	46	101	103	0	102	106
MoP	33	0	15	33	67	0	58	35
DAP	29	42	46	39	38	0	32	17

Table 29: Cost and return of rice production in Dhaka region

Particulars	*T. Aus*		*T. Aman*		*Boro*		
	Small	Medium	Small	Medium	Small	Medium	Large
Seed	1511	1389	2118	1785	2711	2083	1429
Seed bed	1891	2470	1836	1408	2300	2072	1591
Power tiller	5544	3705	5564	6246	5870	5909	3409
Labor	32123	23465	24702	25885	30183	37001	27192
Fertilizer	7367	9003	7092	6242	9872	9360	5853
Irrigation	737	1667	1819	1860	2467	2269	485
Insecticide	3096	325	4348	4661	12528	10854	3660
i. Total variable cost	52270	42025	47479	48087	65930	69548	43619
Land use cost	5868	5235	3800	3800	5581	5581	6167
Interest on operating capital	2613	2101	2374	2404	3297	3477	2181
ii. Total fixed cost	8481	7336	6174	6204	8878	9059	8347
iii. Total cost (i+ii)	60751	49361	53653	54291	74808	78607	51966
Productivity (maund/ha)	122	112	96	90	134	135	107
Price (Tk./maund)	668	625	680	680	631	631	655
Main product (Tk./ha)	81930	70000	64900	60198	84019	84779	70160
By- product (Tk./ha)	3802	18525	7329	9750	3896	4553	5097
iv. Gross return (Tk./ha)	85732	88525	72229	69948	87915	89331	75257
v. Gross margin (Tk./ha)	31627	46500	21876	21363	20881	19210	31638
vi. Net return (Tk./ha)	23146	39164	15702	15159	12003	10151	23290
vii. Benefit cost ratio	1.63	2.11	1.53	1.44	1.34	1.28	1.90

Table 30: Cost and return of rice production in Bogura region

Particulars	*T. Aus*			*T. Aman*			*Boro*		
	Small	**Medium**	**Large**	**Small**	**Medium**	**Large**	**Small**	**Medium**	**Large**
Seed	2161	2032	1738	2246	1840	2383	2270	2024	2378
Seed bed	1151	986	1001	1755	973	1434	1704	1268	993
Power tiller	6438	5844	6736	7454	5603	8252	6898	6310	8000
Labor	23428	17909	21918	18971	16906	25921	26174	25878	28624
Fertilizer	8422	6754	7539	9301	9200	13749	11367	12323	13357
Irrigation	4223	2918	2822	2808	2147	4492	3932	4937	5207
Insecticide	2165	2342	4678	3766	2656	3887	15695	12055	10437
i. Total variable cost	47989	38785	46431	46301	39325	60119	68041	64796	68995
Land use cost	3445	3445	3210	4060	4109	3570	4098	4098	4316
Interest on operating capital	2399	1939	2322	2315	1966	3006	3402	3240	3450
ii. Total fixed cost	5844	5384	5532	6375	6076	6576	7500	7338	7765
iii. Total cost (i+ii)	53833	44169	51962	52676	45401	66694	75541	72133	76761
Productivity (maund/ha)	108	102	91	125	127	137	153	153	156
Price (Tk./maund)	585	585	570	656	656	630	634	634	638
Main product (Tk./ha)	33203	30110	51870	41205	43798	86310	49305	51221	33607
By- product (Tk./ha)	31195	30951	449	44179	41567	2948	50168	49101	69016
iv. Gross return (Tk./ha)	64398	61061	52319	85384	85365	89258	99473	100323	102623
v. Gross margin (Tk./ha)	16409	22276	5888	39083	46040	29139	31432	35527	33627
vi. Net return (Tk./ha)	10565	16892	357	32709	39965	22563	23932	28189	25862
vii. Benefit cost ratio	1.34	1.59	1.12	1.85	2.31	1.44	1.51	1.59	1.59

Table 31: Cost and return of rice production in Faridpur region

Particulars	*T. Aus*			*T. Aman*			*Boro*		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
Seed	3680	-	-	3053	2936	3028	4640	3614	2122
Seed bed	950	-	-	1546	1587	1563	2920	2680	2901
Power tiller	9753	-	-	5354	5535	7500	7738	6777	6326
Labor	17966	-	-	35245	35099	26125	51120	56554	53986
Fertilizer	6405	-	-	8872	9734	10778	11798	12890	13171
Irrigation	247	-	-	1450	2170	2375	2046	2016	2849
Insecticide	1098	-	-	4137	5002	7125	12717	13634	23677
i. Total variable cost	40098	-	-	59656	62063	58493	92979	98164	105032
Land use cost	8353	-	-	11972	11972	13268	13268	13268	13368
Interest on operating capital	2005	-	-	2983	3103	2925	4649	4908	5252
ii. Total fixed cost	10358	-	-	14955	15076	16193	17917	18176	18619
iii. Total cost (i+ii)	50456	-	-	74612	77138	74686	110896	116341	123652
Productivity (maund/ha)	83	-	-	106	111	80	166	183	154
Price (Tk./maund)	850	-	-	900	900	900	914	914	940
Main product (Tk./ha)	70550	-	-	96538	100263	72000	151638	167160	147120
By- product (Tk./ha)	2474	-	-	4955	3378	5375	5897	6678	5153
iv. Gross return (Tk./ha)	73024	-	-	101493	103640	77375	157535	173838	152273
v. Gross margin (Tk./ha)	32926	-	-	41836	41578	18882	64556	75673	47241
vi. Net return (Tk./ha)	22569	-	-	26881	26502	2689	46639	57497	28622
vii. Benefit cost ratio	1.82	-	-	1.68	1.65	1.32	1.72	1.79	1.46

Table 32: Cost and return of rice production in Rangamati region

Particulars	*T. Aus*			*T. Aman*			*Boro*		
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
Seed	3547	2364	6329	2994	3772	1482	3208	3048	2122
Seed bed	1866	2182	1935	2908	4909	3088	2718	3267	2901
Power tiller	7382	11688	9263	11729	10453	3088	11814	11884	6326
Labor	35683	25018	25318	35586	30070	29640	38513	39198	53986
Fertilizer	5027	4553	3813	6793	7117	2470	7267	6297	13171
Irrigation	450	-	0	1169	553	-	3220	3706	2849
Insecticide	1622	1328	1204	2261	1807	3088	7039	3734	23677
i. Total variable cost	55577	47132	47861	62191	57705	42856	70182	69941	105032
Land use cost	6348	6250	6250	10890	10875	9375	9827	9639	13368
Interest on operating capital	2779	2357	2393	3110	2885	2143	3509	3497	5252
ii. Total fixed cost	9126	8607	8643	14000	13760	11518	13336	13136	18619
iii. Total cost (i+ii)	64703	55739	56504	76190	71465	54374	83518	83077	123652
Productivity (maund/ha)	129	118	84	115	110	124	132	135	154
Price (Tk./maund)	845	920	920	920	920	980	838	838	940
Main product (Tk./ha)	109970	108560	77280	104980	101278	121520	110460	113473	147120
By- product (Tk./ha)	1904	3063	3846	4426	4733	2845	4314	3288	5153
iv. Gross return (Tk./ha)	111874	111623	81126	109406	106010	124365	114974	116764	152273
v. Gross margin (Tk./ha)	56297	64491	33264	47215	48305	81509	44791	46823	47241
vi. Net return (Tk./ha)	47170	55884	24621	33216	34545	69991	31455	33687	28622
vii. Benefit cost ratio	1.99	2.37	1.7	1.78	1.84	2.9	1.645	1.67	1.46

Table 33: Descriptive statistics of SFs in rice growing and regions

Region	Stat	Yield	RL	Lab	NPK	Seed	Irri	PTC	Exp	Edu	FS	Extn	ATCR	Train
							T. Aus							
	Min	1482	12	26	29	14	0	2245	2	0	16	0	0	0
	Max	7904	300	583	1630	49	16467	10978	60	20	624	1	1	1
	Mean	3816	100	118	352	33	7657	5999	25	8	171	1	0	1
	STDV	1079	82	95	300	10	5426	2369	16	6	144	0	1	1
							T. Aman							
	Min	2994	25	57	237	15	0	1684	2	0	57	0	0	0
Dinajpur	Max	5646	900	1377	741	49	6227	9880	45	17	279	1	1	1
	Mean	4349	182	123	380	38	2700	7063	21	7	156	1	1	1
	STDV	648	122	161	83	8	1891	1747	11	5	55	0	0	0
							Boro							
	Min	2994	25	57	237	15	0	1684	2	0	57	0	0	0
	Max	5646	900	1377	741	49	6227	9880	45	17	279	1	1	1
	Mean	4349	182	123	380	38	2700	7063	21	7	156	1	1	1
	STDV	648	122	161	83	8	1891	1747	11	5	55	0	0	0
							T. Aus							
	Min	2040	20	68	188	13	0	2280	4	0	36	0	0	0
	Max	6080	1170	273	356	48	45620	9980	60	17	285	1	1	1
	Mean	4092	192	127	276	35	2829	6385	23	5	137	1	1	1
	STDV	947	221	43	40	10	6288	1837	14	5	58	0	1	1
							T. Aman							
	Min	1900	7	33	209	10	0	1826	0	0	22	0	0	0
Mymensingh	Max	6893	1400	226	515	49	8616	24700	61	20	944	1	1	1
	Mean	4405	150	110	353	30	1872	6960	28	5	148	1	0	0
	STDV	940	130	30	57	11	2356	2562	14	5	107	0	0	1
							Boro							
	Min	2390	12	76	190	11	7125	3144	3	0	12	0	0	0
	Max	10640	795	225	670	49	21613	17980	65	20	572	1	1	1
	Mean	5814	156	144	409	32	13211	6808	26	5	143	1	0	0
	STDV	1129	115	33	104	9	3604	2042	15	5	88	0	0	0
							T. Aus							
	Min	3293	30	58	164	16	0	3952	4	0	85	0	0	0
	Max	7026	1044	149	387	49	16467	26347	60	17	1215	1	1	1
	Mean	5004	339	93	292	38	2446	8220	27	4	205	1	0	0
	STDV	746	208	22	50	6	3168	3101	14	4	173	0	0	1
							T. Aman							
	Min	2305	50	52	193	19	0	1900	1	0	30	0	0	0
Sylhet	Max	6126	720	164	463	49	4574	9880	60	30	764	1	1	1
	Mean	4692	268	100	335	39	463	7739	28	4	163	1	0	0
	STDV	736	133	22	54	5	1127	1359	15	5	84	0	0	0
							Boro							
	Min	2964	36	58	206	8	4117	4117	2	0	30	0	0	0
	Max	8299	660	189	576	49	30875	23053	65	16	870	1	1	1
	Mean	6528	232	96	361	38	11976	7948	30	4	163	1	0	0
	STDV	1126	125	26	84	8	6489	2038	14	4	95	0	1	0

Region	Stat	Yield	RL	Lab	NPK	Seed	Irri	PTC	Exp	Edu	FS	Extn	ATCR	Train
							T. Aus							
	Min	1192	33	67	137	16	0	4491	3	5	40	0	0	0
	Max	7186	632	118	374	47	8970	7736	40	18	319	1	1	1
	Mean	4489	252	88	292	31	2180	5891	23	10	152	1	0	0
	STDV	1661	158	17	57	6	1415	940	12	4	76	1	1	0
							T. Aman							
	Min	1497	16	50	227	12	0	3742	4	0	39	0	0	0
Khulna	Max	7784	660	194	586	49	8227	20209	60	18	790	1	1	1
	Mean	5118	144	97	427	33	1654	6708	24	7	143	1	1	1
	STDV	1116	90	27	75	7	2393	2359	14	4	91	0	0	0
							Boro							
	Min	3144	22	45	262	7	4940	3368	0	0	50	0	0	0
	Max	8982	297	355	726	49	43832	23952	60	18	363	1	1	1
	Mean	6211	116	118	522	27	15999	7233	24	7	123	0	0	0
	STDV	1154	52	55	127	9	5469	3375	14	4	60	1	0	0
							T. Aus							
	Min	2827	20	40	144	21	0	1115	3	0	22	0	0	0
	Max	5928	540	311	463	49	6587	9880	60	15	680	1	1	1
	Mean	4628	163	104	269	36	1756	7025	27	6	136	1	0	0
	STDV	706	125	43	56	7	1417	2758	15	4	105	0	0	0
							T. Aman							
	Min	2799	40	23	139	16	0	2964	1	0	30	0	0	0
Chattogram	Max	6587	480	235	496	49	9880	20209	65	17	402	1	1	1
	Mean	4562	159	93	314	34	742	9363	31	4	140	1	0	1
	STDV	819	85	37	83	9	1743	2967	15	4	57	0	1	0
							Boro							
	Min	1830	14	34	173	10	4117	3088	3	0	13	0	0	0
	Max	8049	658	283	823	49	30875	38903	70	22	340	1	1	1
	Mean	5354	164	97	357	32	13663	10682	30	4	138	1	0	0
	STDV	855	94	38	89	11	4737	3865	14	4	61	0	0	0
							T.*Aus*							
	Min	2668	10	25	147	20	0	2021	2	0	20	0	0	0
	Max	8084	5412	202	396	50	20163	11179	55	18	1037	1	1	1
	Mean	5003	260	103	273	39	2928	7021	20	7	167	1	0	0
	STDV	992	637	35	54	7	3442	1509	12	5	129	0	0	0
							T. Aman							
	Min	2668	10	25	147	20	0	2021	2	0	20	0	0	0
Rajshahi	Max	8084	5412	202	396	50	20163	11179	55	18	1037	1	1	1
	Mean	5003	260	103	273	39	2928	7021	20	7	167	1	0	0
	STDV	992	637	35	54	7	3442	1509	12	5	129	0	0	0
							Boro							
	Min	1778	10	45	148	12	2316	1871	2	0	28	0	0	0
	Max	10260	1600	225	662	50	28068	22455	70	40	2020	1	1	1
	Mean	6225	208	101	399	36	13133	7353	23	7	180	1	0	0
	STDV	1263	177	32	104	7	5957	2458	12	5	181	0	0	0

Region	Stat	Yield	RL	Lab	NPK	Seed	Irri	PTC	Exp	Edu	FS	Extn	ATCR	Train
							T. Aus							
	Min	1347	33	0	192	0	0	1497	3	0	43	0	0	0
	Max	7485	1197	232	1292	50	7485	9980	55	18	297	1	1	1
	Mean	4746	207	123	454	35	3026	6580	26	7	152	1	0	1
	STDV	1182	145	47	196	9	1922	1420	13	4	60	0	1	1
							T. Aman							
	Min	1198	0	4	110	0	0	748	2	0	33	0	0	0
Jashore	Max	6886	1320	393	926	49	9880	56136	62	18	677	1	1	1
	Mean	5032	195	128	467	32	4232	8587	27	6	157	1	1	1
	STDV	1084	127	60	163	10	2565	6778	14	5	76	0	0	0
							Boro							
	Min	1461	0	56	99	11	4259	2582	0	0	30	0	0	0
	Max	12968	798	906	8371	49	37424	224545	65	24	957	1	1	1
	Mean	5598	195	150	612	34	12266	10479	26	6	159	1	0	0
	STDV	2176	129	70	803	8	6196	18346	16	5	112	0	0	0
							T. Aus							
	Min	1729	40	49	169	25	0.01	3040	4	0	21	0	0	0
	Max	9880	380	247	458	49	19760	19297	60	16	463	1	1	1
	Mean	4809	160	95	300	36	2822	8013	26	5	169	0.93	0.14	0.82
							TiE							
	STDV	1941	75	39	71	7	3969	3038	14	4	87	0.26	0.35	0.38
							T. Aman							
	Min	1383	20	51	208	19	0.01	1853	3	0	20	0	0	0
	Max	5928	450	243	509	49	9263	36021	60	16	510	1	1	1
	Mean	3900	138	101	332	36	1854	9355	29	5	163	0.86	0.64	0.77
Barisal	STDV	1074	81	34	62	6	2063	4956	15	4	81	0.35	0.48	0.42
							Boro							
	Min	1317	20	41	61	16	4117	1853	2	0	40	0	0	0
	Max	11526	540	234	658	49	30875	32933	70	45	520	1	1	1
	Mean	5776	154	98	326	36	13632	8627	28	5	145	0.94	0.15	0.78
	STDV	2125	85	39	113	8	6268	4279	15	4	63	0.24	0.36	0.42
							T. Aus							
	Min	1976	10	45	156	14	0	3705	5	0	50	0	0	0
	Max	6904	297	153	484	49	8233	9880	54	18	295	1	1	1
	Mean	4283	121	97	312	31	2628	6342	26	6	125	1	0	0
	STDV	1302	79	24	76	9	1581	1371	14	5	65	0	0	0
							T. Aman							
	Min	1270	10	48	202	16	0	838	1	0	28	0	0	0
Rangpur	Max	6982	594	222	683	49	22455	9976	60	22	461	1	1	1
	Mean	4450	133	117	338	32	3157	6079	24	6	120	1	0	0
	STDV	1378	106	26	82	9	3297	1330	13	5	75	0	0	0
							Boro							
	Min	1497	20	62	75	7	4117	2223	2	0	15	0	0	0
	Max	12844	1173	299	641	49	20209	74100	60	50	882	1	1	1
	Mean	5872	150	139	309	27	12321	7346	25	7	137	1	0	1
	STDV	1996	136	44	117	9	3579	6039	14	6	92	0	0	1

Region	Stat	Yield	RL	Lab	NPK	Seed	Irri	PTC	Exp	Edu	FS	Extn	ATCR	Train
							T. Aus							
	Min	2635	27	69	183	14	0	1853	1	0	19	0	0	0
	Max	7465	600	283	504	49	24700	11856	75	22	382	1	1	1
	Mean	4875	177	125	307	36	3636	7094	27	5	105	1	0	0
	STDV	967	114	29	56	8	4610	1687	16	4	66	0	0	1
							T. Aman							
	Min	1976	0	61	206	10	0	2305	1	0	3	0	0	0
Cumilla	Max	7904	630	289	679	49	7719	9880	70	18	497	1	1	1
	Mean	4843	143	127	371	36	2710	6895	27	4	114	1	0	0
	STDV	846	102	36	62	8	1446	1369	15	4	72	0	0	0
							Boro							
	Min	1317	4	60	129	12	1647	1853	1	0	3	0	0	0
	Max	9880	623	253	952	49	27444	20583	65	70	679	1	1	1
	Mean	5962	147	137	469	36	14913	7356	28	6	128	1	0	1
	STDV	1164	126	37	134	8	4079	2217	15	6	96	0	0	0
							T. Aus							
	Min	1192	10	0	29	0	0	1115	1	0	16	0	0	0
	Max	9880	5412	583	1630	50	45620	26347	75	22	1215	1	1	1
	Mean	4662	198	110	315	35	3086	6943	25	6	146	1	0	0
	STDV	1203	256	43	124	8	3897	2167	14	5	101	0	0	1
							T. Aman							
	Min	1198	0	4	110	0	0	748	0	0	3	0	0	0
Poo led data	Max	7904	1400	1377	926	50	25204	56136	70	30	1522	1	1	1
	Mean	4594	171	112	366	34	2564	7643	27	6	149	1	0	1
	STDV	1050	121	54	99	9	3239	3727	14	5	97	0	1	1
							Boro							
	Min	1317	0	34	62	7	1647	1853	0	0	3	0	0	0
	Max	12968	1600	906	8371	50	43832	224545	70	70	2020	1	1	1
	Mean	5964	171	119	416	33	13475	8265	26	6	148	1	0	0
	STDV	1606	126	48	303	10	5418	7198	14	5	104	0	0	1

RL: Rice land (dec), Lab: Labour, NPK: urea, TSP and MoP, Irri: irrigation, Exp: experience, Edu: Education, ATCR: Access to credit, Train: training, STDV: standard deviation.

Table 34: Descriptive statistics of MFs in rice growing and regions

Region	Stat	Yield	RL	Lab	NPK	Seed	Irri	PTC	Exp	Edu	FS	Extn	ATCR	Train
							T. Aman							
Dinajpur	Min	1796	109	49	139	9	0	3431	2	0	145	0	0	0
	Max	6982	825	165	534	49	3742	14970	60	16	1010	1	1	1
	Mean	4514	347	94	318	32	765	9011	25	7	357	1	0	0
	STDV	991	171	29	74	9	1342	2060	16	5	158	0	1	1
							Boro							
	Min	2371	50	53	181	7	4940	2470	2	0	63	0	0	0
	Max	9281	900	166	848	50	24700	12350	50	16	714	1	1	1
	Mean	6823	438	97	430	24	13226	6723	25	7	330	1	1	1
	STDV	1558	180	31	134	10	5292	1787	14	5	115	0	0	1
							T. Aman							
Mymensingh	Min	1900	43	52	228	10	0	1900	3	0	61	0	0	0
	Max	6587	890	170	475	49	5170	9880	73	22	1205	1	1	1
	Mean	4417	329	104	347	28	963	7123	30	6	408	1	0	1
	STDV	938	187	25	58	11	1402	1388	15	6	196	0	0	0
							Boro							
	Min	3447	35	52	160	10	4433	4446	4	0	231	0	0	0
	Max	8042	1032	172	628	48	19211	14465	60	16	1094	1	1	1
	Mean	5560	351	102	410	30	12023	6784	31	6	428	1	0	1
	STDV	996	214	27	111	10	4327	1527	15	5	182	0	0	1
							T. Aman							
Sylhet	Min	2635	178	60	222	20	0	4940	3	0	235	0	0	0
	Max	5646	2250	163	478	49	4940	9880	64	12	730	1	1	1
	Mean	4560	622	97	330	38	497	7633	33	4	408	1	1	0
	STDV	763	361	21	52	5	1163	1165	14	4	123	0	1	0
							Boro							
	Min	2635	36	50	190	8	4117	2927	3	0	60	0	0	0
	Max	7684	10654	199	583	49	19211	11964	60	16	705	1	1	1
	Mean	6328	728	128	356	38	10320	7854	28	6	362	1	0	1
	STDV	1256	1380	41	79	7	4847	1883	14	4	131	0	1	1
							T. Aman							
Khulna	Min	1976	33	54	307	22	0	3742	3	0	78	0	0	0
	Max	6916	650	231	735	49	4940	12350	50	16	612	1	1	1
	Mean	4424	336	83	418	32	730	6567	27	8	318	1	0	0
	STDV	1282	166	30	80	7	1438	1653	10	4	109	1	0	0
							Boro							
	Min	2823	0	0	171	10	4940	2245	3	0	67	0	0	0
	Max	8233	726	163	4192	45	22455	22455	68	18	660	1	1	1
	Mean	5845	318	82	623	30	12137	7545	25	7	306	1	0	0
	STDV	1135	178	32	603	9	3517	4034	15	6	116	0	0	0

Region	Stat	Yield	RL	Lab	NPK	Seed	Irri	PTC	Exp	Edu	FS	Extn	ATCR	Train
							T. Aman							
	Min	1441	50	49	139	9	0	2882	7	0	48	1	0	0
	Max	6080	725	189	432	49	6587	14970	70	12	1010	1	1	1
	Mean	4570	361	103	309	36	582	8854	31	6	340	1	0	0
Chattogram	STDV	897	180	32	61	8	1197	2387	15	4	143	0	0	0
							Boro							
	Min	1647	64	62	221	10	4234	5146	5	0	100	0	0	0
	Max	8982	1200	196	523	49	15438	11239	68	17	668	1	1	1
	Mean	5626	400	112	353	35	9371	8799	34	6	351	1	0	1
	STDV	1251	240	31	77	10	3569	1549	17	4	115	0	1	0
							T. Aman							
	Min	2695	16	34	203	9	0	2117	2	0	24	0	0	0
	Max	6587	895	210	576	50	5041	9820	55	25	677	1	1	1
	Mean	4731	349	98	358	36	1652	7051	25	7	289	1	0	0
Rajshahi	STDV	951	220	33	74	9	1663	1810	13	6	142	0	0	0
							Boro							
	Min	2075	25	36	147	15	1403	1853	1	0	41	0	0	0
	Max	8892	792	170	617	50	28068	14820	50	25	2854	1	1	1
	Mean	6226	305	96	409	34	13292	6419	22	9	365	1	0	0
	STDV	1297	211	30	122	7	6446	2496	13	5	382	0	0	1
							T. Aman							
	Min	1198	66	56	280	15	0	4574	2	0	92	0	0	0
	Max	7280	1000	307	1034	45	7485	9880	54	22	875	1	1	1
	Mean	5192	419	135	483	33	3221	6782	25	10	429	1	0	1
Jashore	STDV	1035	237	49	160	8	2033	1103	14	5	163	0	0	1
							Boro							
	Min	1815	0	0	171	12	4700	2245	3	0	67	0	0	0
	Max	8383	1122	180	4192	45	18712	19813	52	18	798	1	1	1
	Mean	5697	395	108	564	32	10849	7221	20	8	356	1	0	1
	STDV	1625	224	40	599	8	3713	2952	12	5	158	0	0	1
							T. Aman							
	Min	1482	71	45	246	20	0	1976	5	0	107	0	0	0
	Max	9880	893	173	485	49	7410	20583	55	16	989	1	1	1
	Mean	4374	306	88	372	33	1172	7877	28	6	404	1	1	1
Barisal	STDV	2165	182	28	64	8	1856	4695	14	4	193	0	0	0
							Boro							
	Min	1482	30	46	132	16	4940	2305	1	0	148	0	0	0
	Max	9880	800	210	580	49	24700	65867	65	12	788	1	1	1
	Mean	5506	325	92	295	33	11590	11282	26	7	377	1	0	1
	STDV	1727	181	36	116	10	5801	12263	17	4	146	0	0	0

Region	Stat	Yield	RL	Lab	NPK	Seed	Irri	PTC	Exp	Edu	FS	Extn	ATCR	Train
							T. Aman							
	Min	1284	33	50	233	19	0	1729	5	0	69	0	0	0
	Max	6736	1221	180	463	45	17964	13473	55	18	990	1	1	1
	Mean	4475	412	109	355	29	2993	6052	27	8	382	1	0	0
Rangpur	STDV	1127	284	29	52	8	3671	1666	14	6	191	0	1	1
							Boro							
	Min	1778	50	72	122	8	4940	2470	3	0	63	0	0	0
	Max	9880	1188	189	529	45	24700	12350	50	18	704	1	1	1
	Mean	5921	393	121	356	26	12705	5994	31	7	338	1	1	1
	STDV	1511	202	32	94	8	4863	1515	13	5	117	0	1	0
							T. Aman							
	Min	1441	24	55	193	16	0	2635	5	0	48	0	0	0
	Max	6257	725	194	581	49	14820	20583	70	12	620	1	1	1
	Mean	4571	376	113	328	36	2131	8396	29	6	320	1	0	0
Cumilla	STDV	976	187	32	74	8	3055	3001	15	4	110	0	0	0
							Boro							
	Min	3293	60	73	137	16	4117	2470	5	0	37	0	0	0
	Max	9880	1020	209	787	49	20583	9880	55	12	768	1	1	1
	Mean	6253	434	130	487	33	15176	6246	32	6	363	1	0	1
	STDV	1292	223	24	139	10	3037	1683	12	4	126	0	0	0
							T. Aus							
	Min	2787	11	32	148	0	0	2245	4	0	38	0	0	0
	Max	9880	1584	219	1441	49	29939	32933	60	22	1584	1	1	1
	Mean	4680	424	104	310	36	3623	7835	27	6	383	1	0	0
	STDV	1059	286	32	123	7	4870	3346	13	5	175	0	0	1
							T. Aman							
	Min	1198	16	34	139	9	0	1729	2	0	24	0	0	0
Pooled data	Max	9880	2250	307	1034	50	17964	20583	73	25	1205	1	1	1
	Mean	4589	386	103	361	33	1479	7499	28	7	368	1	0	0
	STDV	1172	242	34	93	9	2211	2455	14	5	165	0	0	1
							Boro							
	Min	1482	0	0	122	7	1403	1853	1	0	37	0	0	0
	Max	9880	10654	210	4192	50	28068	65867	68	25	2854	1	1	1
	Mean	5970	415	107	420	32	12022	7455	27	7	361	1	0	1
	STDV	1412	540	36	282	10	4928	4593	15	5	183	0	0	0

Source: Field survey, 2019-20

Table 35: Descriptive statistics of LFs in rice growing

Region	Stat	Yield	RL	Lab	NPK	Seed	Irri	PTC	Exp	Edu	FS	Extn	ATCR	Train
							T. Aus							
	Min	2964	11	32	148	0	0	2470	5	0	72	0	0	0
	Max	7186	2971	179	599	49	6587	9880	52	16	3120	1	1	1
	Mean	4436	623	97	315	34	2053	5890	28	7	710	1	0	1
	STDV	968	655	32	115	9	1627	1891	13	5	492	0	0	1
							T. Aman							
	Min	2305	45	52	216	11	0	2470	2	0	60	0	0	0
Pooled data	Max	6817	7788	182	711	49	17964	10586	60	19	10059	1	1	1
	Mean	4686	937	107	377	34	1957	6929	27	7	1206	1	0	0
	STDV	859	1014	28	83	9	2739	1699	16	5	1304	0	0	1
							Boro							
	Min	1796	76	48	179	8	4411	3293	1	0	196	0	0	0
	Max	9880	3210	201	707	49	25204	29939	63	20	2445	1	1	1
	Mean	6017	869	109	416	32	13543	7249	30	10	1051	1	0	1
	STDV	1348	599	34	113	10	5425	3139	17	5	418	0	0	0

Source: Field survey, 2019-20

Pictorial view of the sub-project activities


















































PROBLEM?





























