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DETERMINANTS OF TECHNOLOGY ADOPTION IN CULTIVATION OF WINTER RICE IN ASSAM: AN ORDERED LOGIT ANALYSIS

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Abstract

The largest agrarian state in India's North-East, Assam exhibited varied growth of agrarian technology at regional level since 1950. The growth of modern technology in agriculture is expected to work as impetus to agricultural productivity and farmers' welfare. Adoption of technology such as improved seed variety and use of machine has resulted in increase in yield of winter rice. Striking difference in yield could be observed between adopters and non-adopters of technology. Ordered Logit model is applied to estimate the impacts of different factors on the adoption of agricultural technology. The result reveals that cultivated area, yield and the experience of farmers have significant positive impacts on the adoption of modern technology for the cultivation of winter rice. The findings are in support of building agrarian infrastructure and facilitation for adoption and suitable technological transformation for the enhancement of yield and sustainable agricultural progress.

Key words: *agricultural modernisation, winter rice, adoption of technology, ordered logit, yield*

INTRODUCTION

Adoption of technology in cultivation is important for increasing agricultural productivity, household income, and ultimately food security [21, 24, and 12]. Use of improved technology especially agro-implements helps completion of work at required pace, and with great precision that resulted in better output. However, application of such modern technology (seed-fertiliser-irrigation-implements) in some regions is adversely affected due to the fragmented land holdings, lack of capital and credit at the appropriate time that hinder use of tractors and other machines, lack of trained personnel, lack of cheap fuel, lack of necessary capital for investments significantly limit the use of machines [23 and 37]. Adoption of improved varieties generally has positive effects on yield and farmers' welfare. Adoption of modern technology is influenced by several other factors rather than land-labour ratio and responsible for growth of agriculture. Genesis of theories of development in agriculture both in developed and developing countries lay emphasis not only on evolution of farming system but also on other factors such as institutional, environmental, and social factors too [4]. Various institutional factors such as extension services, rental markets for farm machinery, and cooperatives play important roles in mechanisation of small-farms in South-Asian countries [7, 8 and 17].

Assam, the largest agrarian state in North-East India is blessed with various agro-climatic endowments and substantial agricultural diversities. The agroclimatic conditions of the state are very conducive for agricultural activity, mainly for the cultivation of rice. Rice is the staple food of the people of Assam and its importance is undeniable as the single most important crop. It shares 60.71 percent of gross cultivated area and 92.27 percent of the total food grown production of the state during 2020-21. Winter rice constitutes 78.96 percent of total rice production of the state. Though seed-fertiliser-irrigation technology in mainland India is over 5 decades old and that has been further modified with genetically modified seeds, organic culture in some places, its use is still at very low level in Assam and thus can be considered as modern technology in this state. The state has not yet registered noticeable growth in the use of modern technology in agriculture. Due to lack of such technological innovation, yield of crop is solely dependent upon natural fertility of soil and the toil of the farmers [36]. For the sustenance of long-term growth in agriculture reliance must be placed on the judicious use of progressive technology [11].

Green Revolution in India started in the mid-1960s when Indian agriculture was transformed into an industrial system due to gradual commercialisation process, adoption of farming technology as reflected from the increasing use of high yielding variety (HYV) seeds, tractors, irrigation facilities, pesticides, and fertilizers. Although Green Revolution led to an increase in food grain production, such development was confined only to a few states, like Punjab, Haryana. It reached Assam much later and very slowly. Comparing with other top paddy producing states of India (Punjab, Uttar Pradesh and West Bengal) in terms of area under irrigation, HYV rice, intensity of fertilizer use, availability of farm power, productivity of food grains and cropping intensity, Assam shows poor record in almost every section. In Assam HYV area of rice is about 70 percent of the total area under rice, while it is 100 percent in Punjab and about 76 percent all-India average as recorded in 2017-18.

In Assam 12.30 percent of total cropped area was under irrigation as against all India average of 51.90 percent during 2017-18 and it was the highest (99 percent) in Punjab. Per hectare consumption of fertilizer in Assam was only 73.70 kilogram as against 133.10 kilogram all India average and 224 Kg/hectare in Punjab. Availability of farm power per area (kW/ha) is also very less as compared to developed agricultural states, which is another indicator of farm modernisation having a positive relationship with productivity. Assam has 0.993 kW/ha farm power availability with yield of rice at 2,153 Kg/ha and cropping intensity of 147. While Punjab has 3,580 kW/ha farm power availability with the highest yield of rice at 4,132 Kg/ha and cropping intensity of 191. All India average farm power availability is however 2,025 kW/ha with cropping intensity being 145 and yield of rice at 2,638 Kg/ha.

Given the above scenario, productivity of rice in Assam is notably lower than that of all India average and agriculturally advanced states. Thus, it becomes pertinent to know the real status of application of modern technology in the agriculture of Assam and its effect on yield and output. Adopting newer technology, it is possible to attain sustainable yield growth and agricultural development. Application of improved varieties of seeds, synthetic fertilisers, scientific agricultural management, use of implements are essential for the continuous growth of productivity. Along with the utilisation of improved inputs, modern technology consists of integrated farm management practices such as application of organic fertiliser, intercropping, use of machine for levelling, and straight-row transplanting in case of rice. However, in Assam, modern method of cultivation has been limited to improved variety of rice and use of limited machine only. Use of agricultural technology requires capital, and not all the farmers are capable to adopt such technology. Lack of credit facility, market constraints such as information asymmetry, absence of effective agricultural extension services are reported in the study area. So, adoption of technology in this study have been contextualised with the use of HYV seeds and machinery. The objective of the paper is to analyse the factors responsible for adoption of modern farming technology in Assam.

Literature review

A brief review of literature on technology adoption, its determinants, and impacts have been emphasised in this section. However, introduction of improved variety alone does not boost yield. The core of Green Revolution was reliance on improved variety of seeds, application of fertilizer, and irrigated lands; the complete package which revolutionised the improvement of yield of crops in Asia [15]. [3] conducted study on adoption pattern of farmers in cultivation of improved variety of rice and sorghum in Burkina Faso and Guinea. Out of the various socio-economic factors, demographic and institutional factors taken under consideration, technological characteristics significantly affect the adoption decisions of improved variety of crops. Adoption of modern technology which is viewed as innovation with the introduction of new varieties of seeds, new types of fertilisers, or pesticides for adoption has brought changes in productivity and economic growth [35 and 38]. Adoption of improved varieties generally has resulted in increasing yield, and welfare of farmers by increasing household income, food security and reducing poverty [20, 21 and 44].

However, it is not that all farmers are in the position to adopt improved techniques. Determinants such as poor accessibility of information through extension services, supply side factors such as unavailability of quality seeds, fertilisers, and credit crunch are the constraints in adopting modern technology [39 and 9]. Besides risk aversion nature of farmers, inadequate farm size, insufficient human capital, inadequate incentives associated with farm tenure managements, and inappropriate infrastructure are also mentioned [14].

Adoption of improved variety does not always result in increased yield, but significant reduction in costs have increased the profitability for those who have adopted improved variety. Thus, adoption of improved variety is also done taken into consideration profitability, and efficiency aspects of farming as compared to traditional variety. Awareness of farmers with proper training facility about the improved variety, appropriate soil testing facility through extension services is the need of the hour [43]. Extension service is a critical part of decisions to adopt new agricultural practices [42]. However, such facilities are provided by the government and the public extension system is basically inefficient [40]. Satisfaction of farmers with the available extension services should be taken into consideration with the frequency of visits made by the extension agents, focused should also be placed taking into consideration not only on supply side but also demand driven approach of extension services [13].

Influence of social capital and networking of farmers is positive on the adoption of modern technology. Social capital represents the institutions, relationships, and norms that shape the quality and quantity of society's social interaction [42]. In the context of agricultural production, social capital basically represents the membership of farmers' association, the number of relatives the household can rely for support and seeking assistance which helps in adopting advanced technology and modern inputs [19].

Attainment of education helps farmers in increasing their resource base for the acquired knowledge and rising awareness about the benefits due to the adoption of modern technology. This would further encourage them to use extension services effectively [16]. Adoption affects the income of the household significantly and positively. Adoption of technology is capital intensive in nature, and thus households with higher incomes have more chances of adopting modern technology in comparison to the low-income households [41]. Accessibility to credit is also another determinant that facilitates adoption of modern technology; making use of timely inputs which they cannot afford as their resource base is small. Asset ownership such as livestock, family size, and land usually are proxies to explain wealth status which will help to increase their resource base, provide labour in times of need [6]. Besides, factors such as information asymmetry due to uncertainty of perceived benefits of adoption of such technology, environmental regulations, are some of the factors impeding the use of technology such as precision framing [46].

Access to market for input and output involves transaction costs. Transaction costs acts as negative impetus for participation in such markets and this explains the reason for market failure in developing countries [19, 20 and 5]. Agricultural intensification is typically power-intensive which helps in timely completion of agricultural operations such as land preparation, irrigation, and threshing too. Thus, mechanization helps to intensify agricultural production for agricultural development, it reduces the drudgery of farm labour, reduces cost of production, making farming attractive to the youth [10 and 31]. Small farmers have low resource base, thus availing machine on custom hiring basis will greatly be beneficial to use agricultural machinery [7 and 10].

MATERIALS AND METHODS

Data Sources

In Assam, average rainfall during the growing period of winter rice is 2,346 millimetres, and the mean temperature ranges between 21.98 ºC to 30.04 ºC. For the micro level analysis of technological adoption by farmers, primary data has been collected. Multi-stage sampling procedure is employed to select the sample units and collect data. Three districts are selected based on the intensity of HYV area of paddy, fertilizer consumption, and irrigation in terms of percentage of total area under cultivation as the best, average and worst. From each district, advanced and backward blocks are chosen by using the same method. From each chosen block, one village is selected by simple random sampling method for collecting primary information.

The following formula is used to determine the sample size for this study [18], which comes to around 384. But for the convenience and limitation of time, sample size has been kept at 300.

$$n_0 = \frac{z^2 pq}{e^2} = \frac{(1.96)^2 * 0.5 * 0.5}{(0.05)^2} = 384 \ldots\ldots\ldots (1)$$

where:

n_o is the sample size, z^2 is 95 percent confidence interval, p is the estimated proportion of an attribute that is present in the population, q is $1\text{-}p$ and e is the desired precision level.

Since the villages selected are more or less identical in size, 50 households from each village have been selected as final sample units from all the households by simple random sampling without replacement. Each selected household head is interviewed by using a schedule, which consisted of questions related to various socio-economic and demographic variables and agricultural activities e.g., age, occupation, income, educational level, land holding, ownership and tenancy, use of various agro-implements, area of crops and output.

Analytical Techniques

The model uses a set of technological attributes, farm-specific socio-economic characteristics and regional characteristics as explanatory variables which are assumed to influence farmers' level technology adoption. For each technology choice, the values are set as T_0H_0, m = 0; T_1H_0, m = 1; T_0H_1, m = 2; and T_1H_1, m = 3. Choice of the explanatory variables is based on the adoption status of modern technology. The dependent variable adoption of technology (m = 0, 1, 2, 3) is a combination of both use of tractor and HYV variety by the household. T_0H_0 – Household adopting traditional method of ploughing and traditional seed; T_1H_0 - Household adopting machine for ploughing with traditional winter paddy seed; T_0H_1 – for adopting traditional method of ploughing but HYV winter paddy seed; T_1H_1 – for adopting machine and HYV seed of winter paddy. The dependent variable in this analysis is an ordered categorical variable depicting farmers' decision-making processes to adopt technology and thus, an ordered response model is required [30]. Here, Ordered Logit model has been used to examine the impacts of adoption of various technologies, of farm-specific socio-economic and regional characteristics.

The model considered here can be written as:

$$Y_j = X_j\beta_j + u_j \ldots\ \ldots\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where:

$Y_j$is a $(N \times 1)$ vector of j^{th} adoption technology used by the households

α is the constant

$X_j$is a $(N \times k)$ matrix of explanatory variables

β_j is a $(k \times 1)$ vector of estimated coefficients for X_j

u_j is a $(N \times 1)$ vector of error terms $[\mu_j \sim n(0, \sigma^2{}_j)]$

The ordered logit model assumes an underlying latent (unobserved) variable Y_j*, such that:

$Y_j^* = X_j\beta_j + u_j$… … ….......................... .... (3)
with $Y_j=0$ if $Y_j^* \leq 0$
$Y_j=1$ if $0<Y_j^* \leq \tau_1$
$Y_j=2$ if $\tau_1<Y_j^*< \tau_2$ and
$Y_j=3$ if $\tau_2 \leq Y_j^* < \tau_3$

where:
Y_j^* is the response variable and τ_j is the cut off-point or threshold that would indicate the level of inclination to adopt improved practices.
The probability associated with coded responses of an ordered probability model is as follows:

$Pr(Y_j=i) = Pr(\tau_{i-1} < Y_j^* \leq \tau_i) = Pr(\tau_{i-1} < X_j\beta_j + u_j \leq \tau_i)$ … … … ....(4)

where:
i represents the observation of adoption technology. The random error 'u_j' is such that:

$Pr(Y_j=i) = Pr(\tau_{i-1} < Y_j^* \leq \tau_i) = F(\tau_i - X_j\beta_j) - F(\tau_{i-1} - X_j\beta_j)$… … … ....(5)

In ordered logit, F(x) is specified as the logistic distribution function given by

$F(x) = \frac{exp(x)}{[1+exp(x)]}$ … … … ....(6)

Finally, the marginal effect of a unit increase of an independent variable for the i[th] response can be expressed as

$\frac{\partial \Pr[Y_j=i|X]}{\partial X_j} = \beta_j[F'(\tau_{i-1} - X_j\beta_j) - F'(\tau_i - X_j\beta_j)]$ ....
...(7)[26 and 45].

Explanatory Variables

The explanatory variables for this study is selected using information from the previous studies and priori expectations [3, 25, 33, 34 and 2]. The descriptions of the explanatory variables used in this model are given in Table 1. The dependent variable in this Ordered Logit model is status of adoption of technology ($ADOP_{TECH}$). The explanatory variable comprises of a set of both continuous and binary variables which represents household related, farm specific and extension related characteristics. It is hypothesised that age can positively or negatively related to adoption decision. There is no agreement in the literature regarding direction of the effect and it is purely location or technology specific [22 and 32]. Older farmers with experience in cultivation are able to assess the benefits of adoption of technology better than the younger farmers. However, older farmers are also more risk averse than the younger farmers so have lesser chance to adopt modern technology and take risk. Household specific characteristics e.g., sex of the head of household and household size would have positive or negative impact on the decision to adopt. Here sex of the head of household is considered to capture its social role.

Table 1. Description of Explanatory Variables

Description of Variables	Abbreviation	Expected Sign
Age of the household head (years)	AGE_{HH}	+/-
Sex of Household Head (Male =1)	SEX_{HH}	+/-
Education of Household head (years)	EDU_{HH}	+
Primary Occupation of head if cultivator (Yes =1)	$OCCUP_{HH}$	+
Farming Experience (Years)	*FRMEXP*	+
Training (Yes =1)	*TRAINING*	+
Yield (Kg/hectare)	*YIELD*	+
Access to Credit (Yes =1)	*CREDIT*	+
Total Livestock (Nos.)	*LVSTK*	-
Total Cultivable Land (Hectare)	*TOTLAND*	+
Total HH Income (Rs.)	INC_{HH}	+
Ownership of Land	$OWNSHP_{LAND}$	+
Proportion of Other HH Members Attended School	$EDUOTHH_{MEMBR}$	+
Distance to Input Market (Kms.)	*DIST*	-
Hired Labour Cost (Rs/hectare)	$PRICE_{WP}$	+

Note: Total Number of Observations = 300.
Source: Field survey, 2021-2022.

Generally, it is perceived that male headed farm households are often endowed with more resources than that of female headed. Education of the head of household and other members may positively influence technology

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adoption by the farmers as more education and experience exhibit more exposure to new ideas and help effectively making decision for adoption of technology [29].

Experience of farmers in adoption of technology is expected to be related to the ability of farmer to obtain, process and use information relevant to cultivation. Thus, it is hypothesised that a positive relationship would exist between experience and adoption of modern technology. Such positive relationship between experience and adoption of technology was also confirmed in the study of [3]. It is also hypothesised that training have positive impact in exposing farmers to new information related to technology and thus on adoption. Farmers with large farm size, higher yield and higher income are more likely to have positive significance on adoption of modern technology [27]. Of course, in return better technology used in cultivation would enhance yield, which may be suitably examined using a time series data. Livestock although is an asset for farmers but more livestock in the form of bullock, which if used in cultivation may lead to lesser adoption of mechanical devices (i.e., tractor). Access to credit is also expected to have positive influence on adoption of technology. Ownership of land and better occupation of household head are hypothesised to positively influence the decision to adopt modern farming technology. Farm owners are encouraged more than the tenants for adopting modern technology to derive own benefits. Distance to input market from home may have adverse effect on the chance of adoption of modern technology since proximity and availability of inputs in time would facilitate and thus chance of adoption of modern technology. It is also expected that cost on hired labour positively affect adoption of modern technology where normally hired labour is substituted by the machine labour.

RESULTS AND DISCUSSIONS

Descriptive Statistics

Table 2 and Table 3 display descriptive statistics of the socio-economic, farm related variables, and institutional characteristics of the respondents of the non-adopters, partial adopters, and adopters of technology. Mean age of household head is almost similar in terms of both non-adopter and adopter of technology. Mean years of schooling, farm experience, yield of winter rice, and income of the household are higher for adopter group as compared to the non-adopter and partial adopter of technology.

Table 2. Descriptive Statistics of Variables on Adoption of Technology

Variables	T_0H_0	T_1H_0	T_0H_1	T_1H_1	*All*
AGE_{HH}	44.28 (11.53)	40.27 (10.46)	47.68 (13.25)	46.92 (10.47)	46.54 (11.54)
SEX_{HH}	1 (0)	0.90 (0.29)	0.93 (0.24)	0.91 (0.27)	0.93 (0.26)
EDU_{HH}	7.35 (3.00)	8.90 (2.24)	8.62 (3.38)	9.41 (3.17)	9.04 (3.20)
$OCCUP_{HH}$	0.64 (0.49)	0.59 (0.50)	0.66 (0.47)	0.62 (0.48)	0.63 (0.48)
FRMEXP	23.57 (10.27)	20.45 (9.29)	23.43 (9.69)	24.78 (9.06)	23.99 (9.36)
TRAINING	0.14 (0.36)	0.04 (0.21)	0.10 (0.31)	0.12 (0.33)	0.11 (0.32)
YIELD	314.29 (74.49)	325 (71.96)	498.69 (176.16)	539.70 (181.07)	500.86 (183.24)
CREDIT	0 (0)	0 (0)	0.17 (0.38)	0.19 (0.39)	0.16 (0.37)
LVSTK	8 (2)	7 (2)	8 (4)	7 (3)	7 (3)
TOTLAND	5.98 (6.13)	4.43 (1.77)	10.31 (21.11)	10.25 (8.91)	9.65 (13.63)
Small	0.85 (0.36)	0.95 (0.21)	0.65 (0.47)	0.44 (0.49)	0.56 (0.49)
Large	0.14 (0.36)	0.04 (0.21)	0.35 (0.47)	0.55 (0.49)	0.43 (0.49)
INC_{HH}	16,800.5 (6,125.84)	18,396.91 (22,762.05)	37,605.24 (36,857.93)	52,072.28 (49,575.49)	43,520.18 (44,606.93)
$OWNSHP_{LAND}$	1.21 (0.42)	1.13 (0.35)	1.31 (0.57)	1.33 (0.54)	1.31 (0.53)
$EDUOTHH_{MEMBR}$	0.88 (0.14)	0.88 (0.15)	0.94 (0.11)	0.94 (0.12)	0.93 (0.12)
DIST	10 (11.65)	12.18 (12.00)	5.73 (8.30)	4.59 (7.70)	5.75 (8.69)
$HRDLABOR_{COST}$	686.35 (750.11)	682.95 (747.35)	942.56 (674.89)	962.40 (638.16)	923.25 (665.67)
No of Observation	14	22	92	172	300

Note: Figures in parentheses represent standard deviation.
Source: Field survey, 2021-2022.

Adopter group is significantly distinguishable in terms of access to credit facility, total land size, and distance to input market.

However, cost on hired labour also differs between the categories of farmers with varied adoption of modern technology. Adopters of technology have nearest distance to input market as compared to non-adopters and partial adoption of technology.

Table 3. Descriptive Statistics of the Variables

Variables	*Mean*	*Std. Dev.*	*Min*	*Max*
AGE_{HH}	46.54	11.54	22	75
SEX_{HH}	0.92	0.26	0	1
EDU_{HH}	9.04	3.20	0	17
$OCCUP_{HH}$	1.52	0.78	1	4
FRMEXP	23.99	9.36	5	50
TRAINING	0.11	0.31	0	1
YIELD	500.86	183.24	200	800
$MECH_{COST}$	229.16	177.97	0	500
CREDIT	0.16	0.37	0	1
LVSTK	7	3.09	0	20
$TOTLAND_{SIZE}$	9.64	13.63	2.25	203
Small	0.56	0.49	0	1
Large	0.43	0.49	0	1
INC_{HH}	43,520	44,605	4,291	303,758
$OWNSHP_{LAND}$	1.31	0.53	1	3
$EDUCN_{MEMBRS}$	0.93	0.12	0	1.25
$DIST_{MRKT}$	5.75	8.69	1	25
$HRDLABOR_{COST}$	923.25	665.66	0	3,250

Source: Estimated from Field Survey, 2021-2022.

Adoption status of Modern Technology and Yield

It is observed that 57.33 percent of the respondents are adopters of both machine and HYV variety of winter rice, while only 4.66 percent of the respondents are non-adopters of technology and rest are medium adopters. Yield of winter paddy is higher for adopter of technology than the non-adopter of technology by 71.72 percent. It is 58.67 percent more when the farmers adopt only improved variety of seeds, and is increased by 3.40 percent when the farmers adopt only machine (Table 2). This supports the findings of [3] who has shown that adoption of technology increases yield.

Factors Affecting Adoption

The results of ordered logit model are portrayed in Table 5. The model χ^2 is statistically significant at 1 percent level. The estimated model has a pseudo R^2 value of 0.107, which indicates that 10.70 percent of the variation in modern technology adoption is explained by the explanatory variables. Table 4 displays the bivariate correlation among the explanatory variables. Hardly any significant correlation between any two variables is revealed excepting the correlation between the age and experience. Therefore, all the explanatory variables are considered in the model for analysis.

Among the explanatory variables, three have significant positive impacts on the modern technology adoption for the cultivation of winter rice in Assam. Coefficients of land size (area under winter rice), yield of winter rice, and farmers' experience are significant positive. On the other hand, coefficient of livestock is significant negative. The other variables like education of the head of household and other family members, household income, land ownership, and cost on hired labour also positively affect the level of adoption but not significantly.

Table 4. Correlation Matrix

Variables	AGE_{HH}	SEX_{HH}	EDU_{HH}	$OCCUP_{HH}$	***FRMEXP***	***TRAINING***	***YIELD***	***CREDIT***	***LVSTK***	$TOTLAND_{SIZE}$	INC_{HH}	$OWNSHP_{LAND}$	$EDUCN_{MEMBRS}$	$DIST_{MRKT}$
AGE_{HH}	1.000													
SEX_{HH}	-0.020	1.000												
EDU_{HH}	0.037	0.315	1.000											
$OCCUP_{HH}$	-0.130	-0.081	-0.195	1.000										
FRMEXP	0.802	-0.020	0.061	-0.146	1.000									
TRAINING	0.003	-0.020	0.038	0.097	0.036	1.000								
YIELD	0.103	0.025	0.153	0.161	-0.031	0.020	1.000							
CREDIT	0.122	0.022	0.058	0.006	0.125	0.122	0.243	1.000						
LVSTK	-0.067	0.103	-0.127	0.116	-0.012	-0.085	-0.015	0.034	1.000					
$TOTLAND_{SIZE}$	0.141	0.039	0.155	0.093	0.152	0.111	0.408	0.385	0.047	1.000				
INC_{HH}	0.178	0.101	0.396	-0.212	0.192	0.083	0.449	0.247	-0.180	0.355	1.000			
$OWNSHP_{LAND}$	-0.061	-0.052	-0.032	0.117	-0.094	0.028	0.182	0.125	-0.008	0.146	-0.030	1.000		
$EDUCN_{MEMBRS}$	0.027	0.063	0.181	-0.087	0.059	0.005	0.074	0.005	0.137	0.108	0.044	-0.014	1.000	
$DIST_{MRKT}$	-0.107	-0.069	-0.078	0.212	-0.038	0.220	-0.481	-0.090	-0.008	-0.219	-0.224	0.047	-0.276	1.000
$HRDLABOR_{COST}$	-0.030	-0.013	0.008	0.258	0.036	0.195	0.365	-0.045	-0.100	-0.058	0.117	0.071	-0.245	0.263

Source: Estimated from Field Survey, 2021-22.

The odds ratio of farmers experience is 1.049, which means that with a unit increase of experience of farmers, adoption of technology is increased by 1.049 times as compared to non- and partial adoption of technology, keeping all other factors constant. When the size of land is large, the odds of adoption of technology increases by 2.666 times as compared to non-adoption and partial adoption of technology keeping other variables constant. For one unit increase in yield of winter paddy, the adoption of technology increases by 1.002 times as compared to partial and non-adoption. Similarly, when livestock increases by one unit, the odds of adoption of modern technology decreases by 0.902 times as compared to non-adopters and partial adopters of technology.

Table 5. Estimates of Ordered Logit Regression

Variables	***Coefficient***	***Odds Ratio***	***Z-Score***
AGE_{HH}	-0.029 (0.179)	0.971 (0.017)	-1.62
SEX_{HH}	-0.638 (0.516)	0.527 (0.272)	-1.24
EDU_{HH}	0.045 (0.043)	1.046 (0.046)	1.03
$OCCUP_{HH}$	-0.145 (0.288)	0.864 (0.249)	-0.51
FRMEXP	0.047** (0.023)	1.049** (0.024)	2.02
TRAINING	-0.032 (0.432)	0.967 (0.418)	-0.08
YIELD	0.002* (0.001)	1.002* (0.001)	1.95
CREDIT	-0.104 (0.391)	0.900 (0.352)	-0.27
LVSTK	-0.103** (0.041)	0.902** (0.037)	-2.50
$TOTLAND_{SIZE}$ **(Base -Small)**			
Large	0.980*** (0.309)	2.666*** (0.824)	3.17
INC_{HH}	0.00001 (0.00004)	1.000 (0.00004)	0.44
$OWNSHP_{LAND}$	0.102 (0.236)	1.107 (0.262)	0.43
$EDUCN_{MEMBRS}$	1.384 (1.061)	3.992 (4.236)	1.30
$DIST_{MRKT}$	-0.018 (0.020)	0.981 (0.019)	-0.94
$HRDLABOR_{COST}$	0.0002 (0.0002)	1.002 (0.0002)	0.98
Threshold 1	-1.445 (1.314)		1.099
Threshold 2	-0.311 (1.309)		0.237
Threshold 3	1.674 (1.317)		1.271
LR $Chi^2(15)$	65.45		
Log likelihood	-272.08		
Pseudo R^2	0.107		
No. of Observations	300		

Notes: Figures in parentheses represent standard error; ***, **, and * indicate significance at 1%, 5% and 10% respectively.
Source: Estimated from Field Survey, 2021-2022.

Results of Ordered Logit model are further analysed to explain average marginal effects on dependent variable of non-adopter, partial adopter, and adopter of technology in cultivation of winter rice (Table 6). The average marginal effects for farmer experience indicates that a unit increase in experience of framers would decrease the likelihood of being non-adopter and partial adopter of modern technology by 0.002 and 0.004 percent respectively. Whereas, in case of adopters of modern technology, one unit increase in experience of farmers would increase the likelihood of being adopter of technology by 0.009 percent. A more experienced farmer appears to be more knowledgeable and thus likely to adopt technology.

Marginal effect of land size of large category suggests that large farm size decreases the likelihood of being a non-adopter of technology by 0.035 and partial adopter of technology by 0.005 percent for tractor and 0.118 percent for HYV variety respectively. The large size category farmers have chance of adopting modern technology significantly more than the small o marginal farmers. This finding resonates with the literature that farm size and adoption of modern technology are positively related [28 and 1].

The marginal effect of yield of winter paddy indicates that a unit increase in yield would decrease the likelihood of being non-adopter and partial adopter by 0.0001, and 0.0002 percent respectively. On the other hand, such likelihood of being an adopter of technology increases by 0.004 percent. Coefficient of yield is positive for adopter and significant, indicating that higher yield leads to better adoption of technology. As seen from the descriptive statistics (Table 2), yield of winter rice is higher for adopter so they likely use more machine, tools and improved variety of seeds to further raise yield. Use of machine helps timely tilling where farmers must complete sowing fast to avail monsoon. Hence adopting tractor/power tiller for preparing land for sowing helps timely completion of activities and raise earning through enhanced yield. The result is similar to that of findings by [3].

Table 6. Results of Marginal Effects

Variables	*Prob(Y=0/X)*	*Prob(Y=1/X)*	*Prob(Y=2/X)*	*Prob(Y=3/X)*
AGE_{HH}	0.001 (0.0008)	0.001 (0.001)	0.002 (0.001)	-0.005 (0.003)
SEX_{HH}	0.027 (0.023)	0.036 (0.029)	0.062 (0.050)	-0.126 (0.101)
EDU_{HH}	-0.001 (0.001)	-0.002 (0.002)	-0.004 (0.004)	0.008 (0.008)
$OCCUP_{HH}$	0.006 (0.124)	0.008 (0.016)	0.014 (0.028)	-0.028 (0.056)
FRMEXP	-0.002* (0.001)	-0.002* (0.001)	-0.004** (0.002)	0.009** (0.004)
TRAINING	0.001 (0.185)	0.001 (0.024)	0.003 (0.042)	-0.006 (0.085)
YIELD	-0.0001* (0.00005)	-0.0001* (0.00007)	-0.0002** (0.0001)	0.0004** (0.0002)
CREDIT	0.0044 (0.002)	0.005 (0.022)	0.010 (0.038)	-0.020 (0.077)
LVSTK	0.004** (0.002)	0.005** (0.002)	0.010** (0.004)	-0.020** (0.007)
***TOTLAND*SIZE**				
Large	-0.035*** (0.012)	-0.005*** (0.017)	-0.118*** (0.042)	0.205*** (0.064)
INC_{HH}	-0.000007 (0.000001)	-0.000001 (0.000002)	-0.000001 (0.000004)	-0.000003 (0.000008)
$OWNSHP_{LAND}$	-0.004 (0.010)	-0.005 (0.013)	-0.010 (0.023)	0.020 (0.046)
$EDUCN_{MEMBRS}$	-0.059 (0.047)	-0.078 (0.060)	-0.135 (0.105)	0.273 (0.208)
$DIST_{MRKT}$	0.0008 (0.0008)	0.001 (0.001)	0.001 (0.001)	-0.003 (0.003)
$HRDLABOR_{COST}$	-0.00001 (0.00001)	-0.00001 (0.00001)	-0.00002 (0.00002)	0.00004 (0.00005)

Notes: Figures in parentheses represent standard error; ***, **, and * indicate significance at 1%, 5% and 10% respectively.
Source: Estimated from Field Survey, 2021-22.

Coefficient of marginal effect of livestock reveals an increase in likelihood of being non-adopter by 0.004 percent and partial adopter of technology by 0.005 and 0.010 percent respectively for tractor and HYV seeds. Whereas, likelihood of adopting overall technology decreases by 0.020 for adopter. The possible reason is that when farmers have livestock, they use bullocks for cultivation and use the organic manure.

CONCLUSIONS

Determinants of decision to adopt modern technology in agriculture to raise yield and revenue is influenced by several factors. The result of Ordered Logit model showed that farmers' decision of technology adoption is influenced by the level of farmers experience. The other significant factor is farm size of large category. Such results, lend support to the earlier findings of [28 and 1] on large farm size having positive impact on adoption of modern technology. Higher yield has also been found to be significant in facilitating the decision of the farmers to adopt modern technology. Also experience of farmers has significant positive impact on adoption of technology. With more experience farmers are likely to adopt technology. This finding supports the findings of [3].

Emphasis thus should be laid on the progress of modern technology in agriculture which leads to increase in yield of crops through more use of fertilizer and machine and ease up the cultivation activities through mechanization. As can be seen that those adopting technology have higher yield than that of non-adopter. Technological breakthrough is very crucial to benefit the farmers in the long run. However, risk-averse nature of farmers, meagre facility of extension services, lack of capital, ignorance, and prejudice are the possible reasons for such slow and uneven progress of modernisation of farms in Assam.

Although cultivated area has positive significant association with adoption of modern technology, in the study area majority of farmers are small and semi-medium. Further, farming is done mainly for subsistence and self-consumption. So, they mostly concern for the appropriate use of their limited resources instead of focusing on modern technology. It is thus a serious challenge to policy makers for promoting modern technology in agriculture.

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