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Research Note

Rice Ecosystems and Factors Affecting Varietal Adoption in Rainfed Coastal Orissa: A Multivariate Probit Analysis[§]

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Abstract

The spread of modern rice varieties in different water regimes and the factors affecting adoption of modern varieties have been studied using information collected from farmers in the rainfed coastal Orissa. The coverage of modern varieties has been found to be only 37 per cent in mediumland plots and 11 per cent in lowland plots. A multivariable probit model has been used to study the factors affecting adoption of modern varieties. The important factors influencing adoption of a modern variety have been found as hydrology, tenurial status and irrigation. But, the most important factor emerged from the present study is 'hydrology'. Therefore, a wider spread of modern rice varieties in these areas depends on the development of new varieties that are specifically adapted to these environments. The study has suggested that development of new varieties and irrigation along with adoption of land reform measures will facilitate a faster spread of modern rice varieties in the rainfed coastal Orissa.

Key words: Hydrology, Coastal Orissa, Rice, Probit analysis

JEL Classification: Q15, Q16

Introduction

Adoption studies on agricultural technologies are important because they (a) improve the efficiency of technology generation, (b) assess the effectiveness of technology transfer, (c) improve the understanding about role of policy in adoption of new technology, and (d) demonstrate the impact of investing in technology generation. The majority of population of less-developed countries derives livelihood from agricultural production and the new technologies seem to offer opportunities to increase production, income and employment. Technology-driven farm production has a direct impact on the poor (Adato *et al.*, 2007), but the introduction of many new technologies has met with only partial success, as measured by the observed rates of their adoption because of various constraints faced by the farmers.

The green revolution technologies, developed during 1960s, have increased production of rice significantly in the irrigated areas, but they have largely bypassed the unfavourable growing situations like droughts, floods, submergence, salinity, toxicity and nutrient deficiencies, resulting in low and uncertain yields in the eastern India (Khush, 1990). Uncertain yields present a major challenge for agricultural researchers to technology generation and transfer (Anderson and Hazell, 1994; Anderson, 1995). Although scientists have defined broad lowland ecosystems, individual farmers in such areas usually manage land, distributed across local landscapes that include a diverse and dynamic range of rice environments (Fujisaka, 1990). Therefore, it has

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§ The paper has been extracted from a broader NATP project on 'Socio-economic dynamics of changes in rice production systems in eastern India'.

Table 1. Rice area by ecosystems and by seasons in eastern states of India

(Area in lakh ha)

State	Rainfed *kharif*				Irrigated		Total
	Upland	Shallow (0-30 cm)	Intermediate (30-100 cm)	Deepwater (> 100 cm)	*Kharif*	*Rabi*	
Assam	5.44	6.30	5.14	0.42	4.13	1.17	24.90
Bihar*	5.10	17.99	6.74	2.72	18.73	0.81	53.93
Madhya Pradesh*	8.40	32.28	-	-	9.94	-	50.62
Orissa	8.53	10.36	8.92	0.67	13.41	2.15	44.03
	(19.4)	(23.5)	(20.3)	(1.5)	(30.5)	(4.9)	(100.0)
Uttar Pradesh*	5.49	13.52	9.25	2.18	25.70	-	56.15
West Bengal	8.40	23.24	11.45	2.53	3.55	8.96	58.13
All India	50.60	119.85	44.47	13.64	155.37	41.23	425.16

Source: Huke and Huke (1997)

Notes: *The states of Bihar, Madhya Pradesh and Uttar Pradesh include Jharkhand, Chhatisgarh and Uttarakhand, respectively. Figures within the parentheses indicate percentage of total rice area in the state.

been argued to develop location-specific technologies in eastern India (ICAR-IRRI, 1978; Singh, 1990).

Rice is grown under various water regimes in India (Table 1). The *rabi/summer* rice is grown under fully irrigated conditions, while *kharif* rice is grown under both rainfed and irrigated conditions. The rainfed ecosystem is further classified into four broad ecosystems according to the water depth in major part of the life-cycle of the crop.

Rice is grown in an area of 4.4 Mha in the state of Orissa, which accounts for more than 75 per cent of the total area under cereals and 46 per cent of the total cropped area in the state. It is mainly grown during the *kharif* season, which accounts for 94 per cent of the total rice area and 89 per cent of the total rice production. Only one-third of the *kharif* season rice is irrigated and the coverage of modern varieties (MVs) in Orissa is 69 per cent (Government of Orissa, 2008). The rainfed rice is grown under diverse agro-ecosystems. In India, the rainfed shallow and intermediate rice ecosystems cover about 164.3 lakh ha area and this type of rice ecosystems are predominant in the eastern states of India (Table 1). These types of rice ecosystems cover about 19.3 lakh ha in Orissa state, which accounts for 44 per cent of the total rice area. The unfavourable rice ecosystems are largely covered by the traditional varieties.

The objectives of the paper are: to analyze the adoption pattern of modern and traditional rice varieties in different hydrological conditions in the coastal Orissa; to find out the important factors influencing adoption; and to test the hypotheses that spread of MVs is equal across all the rice ecosystems.

Data and Methodology

A multistage sampling procedure was followed to select districts, blocks, villages and farmers in the coastal Orissa. In the first stage, two rainfed districts (Balasore and Kendrapara) were selected using the criteria of less than 40 per cent irrigated area in the district. In the second stage, the irrigated blocks from the selected districts were eliminated using the same criteria and two blocks were selected from the remaining blocks randomly. In the third stage, two villages from each block were selected by simple random sampling technique. The farmers from each village were classified into 4 groups according to the landholding size, viz. marginal (up to 1 ha), small (>1-2 ha), medium (>2-4 ha) and large (>4 ha). In the last stage, 25 farmers from each village were selected using the technique of stratified random sampling with probability proportion to size. Data were collected from each farmer with the help of a structured questionnaire. Thus, the sample was consisted of 98 marginal, 53 small, 28 medium and 14 large farmers, making a total sample of 193 farmers.

Farmers have evolved their own system of classification of rice-growing environments on the basis of water regime such as upland (no standing water), mediumland (water depth up to 30 cm) and lowland (water depth > 30 cm). This classification has been taken into consideration to facilitate data collection from the farmers. The information about age, education and farm size of each farmer, different cultivated land types (up, medium and low), crops grown on each plot, variety of rice grown on each plot, irrigation, and tenurial status of each plot was collected. The non-farm income of each selected farm family was also computed and used in the study. The data collected pertained to the cropping year 2000-01.

The adoption behavioural model is frequently used as a conceptual framework to examine variables associated with technology adoption. The qualitative dependent variables have been used by Adesina and Zinnah (1993), Adesina and Seidi (1995), Shakya and Flinn (1985), and Pandey (2002) to study the adoption of modern rice varieties in Sierra Leone, Guinea Bissau, Nepal and Laos, respectively. Feder *et al.* (1985), Amemiya (1981) and Pindyck and Rubinfeld (1983) have reviewed the range of statistical methods used to analyze adoption behaviour and have recommended both probit and logit models for estimating the probability of an event (such as adoption) that can take one of the two options (adopt, don't adopt). The probit model follows cumulative normal distribution in comparison to logit model, which follows logistic distribution (Maddala, 1986). Hence, probit model was selected for use in this study.

The empirical model to estimate the parameters was specified as per Equation (1).

$$I = b_0+b_1X_1+b_2X_2+b_3X_3+b_4X_4+b_5X_5+b_6X_6+b_7X_7 \quad \ldots(1)$$

where,

X_1 = Farm size in ha

X_2 = Age of farmer in years

X_3 = Schooling of farmer in years

X_4 = Non-farm income in ₹

X_5 = Type of land / hydrology of a particular plot of land (0 = Lowland; 1 = Mediumland)

X_6 = Status of a particular plot of land with respect to ownership (0 = Leased-in land; 1 = Owned land)

X_7 = Status of irrigation of a particular plot of land (0 = Rainfed land; 1 = Irrigated land), and

$b_0, b_1, b_2, \ldots\ldots\ldots., b_7$ were the coefficients to be estimated.

The model contained four continuous variables and three dummy variables. The model was applied using maximum livelihood (ML) method to estimate the coefficients. The regression coefficients of ML were asymptotically efficient, unbiased and normally distributed in comparison to ordinary least square method (Maddala, 1986; Judge *et al.*, 1982).

The adoption of a modern variety of rice depends on several farmer's and farm-specific characteristics. As farmer's cultivated area is distributed in different locations with different hydrologies, the dependent variable in this study was adoption of a modern variety at plot level, i.e. it took the value of 1, if adopted on a particular plot and 0, if not adopted. As the study area did not have rice crop on uplands, the rice-growing plots were classified into two categories, viz. mediumland (value 1) if water depth was within 30 cm and lowland (value 0) if the water depth was > 30 cm during the growing period. Mediumland offers a better growing environment for rice in comparison to lowlands and therefore, it was hypothesized that the sign will be positive for the variable of hydrology. The sign of age and farm size could be either positive or negative (Feder and Slade, 1985; Feder *et al.*, 1985). The signs of other variables like education, non-farm income, owned land, irrigated land were expected to be positive (Feder *et al.*, 1985; Adesina and Zinnah, 1993; Adesina and Seidi, 1995).

Results and Discussion

Coastal Orissa is dominated by medium (water depth 0-30 cm) and low (water depth > 30 cm) lands. The average area of medium and lowlands possessed by the sample farmers was 65 per cent and 35 per cent, respectively. The average age of household-head was 50 years and the period of schooling was 5 years. The average operational holding size of the sample farmers was 1.81 ha with 0.49 ha of leased-in land (Table 2). The irrigation coverage of the cultivated land was 23 per cent. Rice was the sole crop during the *kharif* season. During the *rabi* season, pulses, oilseeds and vegetables were taken, wherever some amount of irrigation was available. The average non-farm income per household was ₹ 27613 per annum and it increased with increase in farm-size.

Table 2. Land particulars, age, education and non-farm income of sample farmers by farm-size

Particulars	Marginal farm	Small farms	Medium farms	Large farms	All farms
Age of household-head	48.0	50.9	52.2	60.4	50.3
Education of household-head (years in school)	4.4	5.5	6.2	7.8	5.2
Operational holding size (ha)	1.15	1.71	2.69	5.05	1.81
Non-farm income (₹)	20950	31078	36222	43924	27613
Owned land (ha)	0.45	1.36	2.63	6.29	1.44
Leased-in land (ha)	0.70	0.37	0.15	0.11	0.49
Per cent irrigated land	28	19	24	25	23

Table 3. Adoption of modern varieties of rice (*kharif*) by land type in coastal Orissa

(in per cent)

Land type	Marginal farms	Small farms	Medium farms	Large farms	All farms
Mediumland	32	36	51	32	37
Lowland	7	9	22	6	11
All lands	25	27	40	22	28

The adoption level of MVs in medium and lowlands has been presented in Table 3. On an average, the percentage coverage of MVs was only 28 per cent. Across land types, the coverage of MVs was 37 per cent in mediumlands and 11 per cent in lowlands. It was due to better growing conditions for MVs in mediumlands than lowlands. There was no definite trend in adoption of MVs by farm type. But, it was observed that the adoption of MVs increased up to the holding size of 4 ha and declined thereafter. '*Swarna*' was the single dominant modern variety cultivated in mediumland, and it covered 18 per cent of the total rice area during the *kharif* season (Table 4). Other modern varieties grown in medium land were: *Mahsuri*, *Parijat*, *Lunishree*, and *Chandrika*, which covered only 2.5 per cent, 1.0 per cent, 0.9 per cent and 0.9 per cent of the total rice area, respectively. In lowlands, the modern variety which covered maximum area was CR-1018 (0.7 %). Other MVs grown to a limited extent in lowlands were *Mahalaxmi*, *Savitri* and *Pankaja*. The dominant local varieties taken up by farmers in mediumland were: *Bhaluki*, *Sola* and *Udasiali*, which covered 16.0 per cent, 15.8 per cent and 7.8 per cent of the total rice area, respectively. The dominant traditional variety covering maximum area in lowlands was *Panisaanla*. The lowlands were largely covered by a number of local varieties. It was due to unavailability of suitable MVs for these agro-ecological situations.

Table 4. Commonly grown rice varieties during *kharif* in rainfed coastal Orissa

Varieties	Area (ha)	Per cent of total rice area
Modern varieties		
Swarna	70.33	18.07
Mashuri	9.57	2.46
Parijata	3.92	1.01
Lunishree	3.64	0.94
Chandrika	3.41	0.88
CR-1018	2.84	0.73
Others	13.51	3.47
Traditional varieties		
Bhaluki	62.09	15.95
Sola	61.64	15.84
Udasiali	30.48	7.83
Panisaanla	19.84	5.10
Kakudimanji	9.46	2.43
Bhundi	8.93	2.29
Pateni	7.74	1.99
Champa	6.91	1.77
Others	74.88	19.24
Total rice area	389.20	100.00

Table 5. Number and percentage of plots covered by modern varieties, irrigation and owner cultivation by land type

Particulars	Mediumland		Lowland		Total land	
	No.	%	No.	%	No.	%
Modern varieties	285	38.9	44	13.2	329	30.9
Irrigated	154	21.0	26	7.8	180	16.9
Owner- cultivated	561	76.6	248	74.3	809	75.9

Table 6. Estimated results of probit model for the factors influencing adoption of modern rice varieties in coastal Orissa

Variable	Coefficient	Standard error	t- ratio
Farm size (X_1)	-0.13191E-01	0.10488E-01	1.258
Age of farmer (X_2)	-0.65153E-03	0.37192E-02	0.175
Schooling of farmer (X_3)	0.46917E-01	0.35001E-01	1.341
Non-farm income (X_4)	0.33201E-05	0.17716E-05	1.874
Type of land (X_5)	0.83392	0.10093	8.262**
Status of plot (X_6)	0.31192	0.10515	2.964*
Status of irrigation (X_7)	0.17847	0.77315E-01	2.308*
Constant	-1.5103	0.25433	5.938**
Likelihood ratio test statistics	100.3** (at 7 df)		
Per cent of right predictions	69.7		

Note: ** and * indicate significance at 1 per cent and 5 per cent levels, respectively.

Detailed data were collected for 1066 plots and details about average plot level percentage coverage of modern varieties, irrigated plots and owner-cultivated plots were computed and have been presented in Table 5. The coverage of modern varieties was 39 per cent in mediumlands and 13 per cent in lowlands, with an average figure of 31 per cent out of 732 mediumland and 334 lowland plots. The percentage of irrigated plots was 21 for medium and 8 for lowlands. The owner-cultivated plots were maximum, their overall percentage being 76. The rest of the plots were cultivated on leased-in (crop-sharing) basis.

Empirical Results of Model

The estimated coefficients of the probit model of MVs adoption are listed in Table 6. The log likelihood ratio test statistic was significant at the 1 per cent level and implied that the independent factors taken together influenced adoption of modern varieties. The model correctly predicted 70 per cent of the cases.

It was observed from Table 6 that variables other than farm size and age were positively related to adoption of MVs. The asymptotic test statistic revealed that variables like hydrology, owned- land and irrigation influenced MV adoption significantly. The estimated coefficients listed in the table were not comparable with one another because their magnitudes depended on the unit of measurement of each variable. Thus, they had little interpretive value unless the indices are calculated and transformed into probabilities.

The predicted probabilities about farmers' adoption of a modern rice variety with selected characteristics have been presented in Table 7. The method used to calculate this probability has been mentioned in Appendix 1. The probability of MV adoption was found to be 0.54 for an average farmer who cultivated his own land with irrigation facilities in the mediumland. However, the probability of adoption of MV dropped to 0.23 for the same farmer under lowland conditions. Similar was the situation in the rainfed mediumland plots. When an average farmer who cultivated his own rainfed land was considered, the probability of his/her adoption of MV was computed to be 0.47 and it dropped to 0.18, when the type of land was lowland. The probability of adoption further reduced to 0.11, when a lowland plot was leased-in from a landlord. This indicated that lack of suitable varieties for lowland conditions prevented the adoption of MVs in this type

Table 7. Predicted probabilities about adoption of modern rice variety by an average farmer in coastal Orissa

Landtype	Irrigated		Rainfed	
	Owner	Tenant	Owner	Tenant
Mediumland	0.54	0.41	0.47	0.35
Lowland	0.23	0.15	0.18	0.11

of land. Hence, the hypothesis set in this paper that 'the spread of MVs is equal in all the rice ecosystems' was rejected. There is a need for development of rice varieties for these rainfed diverse agro-ecosystems.

The results discussed above point towards three broad generalizations:

(1) The existing MVs are unsuitable for lowland situations, where excess water is the major problem. During the past one decade, some progress has been made by releasing three MVs, viz. *Durga*, *Sarala* and *Varshadhan* for lowland situations. The study area when revisited during *kharif* 2008 revealed that these varieties were not accepted by the farmers due to various abiotic and biotic stresses. Therefore, there is a need to develop broad-spectrum varieties which can tolerate both abiotic and biotic stress situations. Further, in the short-run, the existing breeding materials should be tried through farmers' participatory approach, so that some of them may find acceptability of the farmers under their land situation.

(2) The development of irrigation increases adoption of MVs. Therefore, government should encourage development of irrigation through shallow/ deep tube-wells in the coastal areas which will increase MVs adoption.

(3) The crop-sharing tenancy is widely prevalent in the coastal Orissa and the *kharif* produce is shared in the ratio of 50:50 by landlord and tenant, which discourages MVs adoption. Therefore, the government should enact laws for sharing of produce with favourable conditions for tenants, so that adoption of MVs could be encouraged.

Conclusions

The study has assessed the spread of modern varieties in the coastal rainfed Orissa in different land types and has found that the coverage of modern varieties is 37 per cent in mediumland and 11 per cent in lowlands. The important factors influencing adoption of modern rice varieties as examined through multivariate probit regression analysis have been found to be hydrology, tenurial status and irrigation. Though the latter two variables influencing MVs adoption are known in adoption literature, the most influential factor that has emerged in this study is 'hydrology'. Therefore, a wider spread of modern rice varieties in these areas having adverse agro-climatic conditions has been found to depend on development of new varieties that are specifically adapted to these environments. The study has observed that once the new varieties are available, development of irrigation and adoption of land reform measures will facilitate a faster spread of modern rice varieties in the coastal Orissa.

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Appendix 1

Calculation of probability of adoption of rice varieties in coastal Orissa

The predicted probabilities listed in Table 7 were calculated using the coefficients reported in Table 6. The index level, I, was calculated first (Equation 3) and this index was transformed into a probability using Z table (area under the normal probability curve).

Consider an average farmer (Table 2), who is an owner cultivator, with irrigation facilities in mediumland. The I value for this farmer is:

$$\begin{aligned} I &= b_0+b_1X_1+b_2X_2+b_3X_3+b_4X_4+b_5X_5+b_6X_6+b_7X_7 \\ &= -1.5103 - 0.013191\ (1.81) - 0.00065153\ (50.3) + 0.046917\ (5.2) + 0.00000332\ (27613) + 0.83392\ (1) + \\ &\quad 0.31192\ (1) + 0.17847\ (1) \\ &= 0.093009 \end{aligned}$$

Proportions of total area under the curve lying between the central ordinate and the value of I were derived from Z table. If $I > 0$, 0.5 was added to the tabulated figure, if $I < 0$, the tabulated value was subtracted from 0.5.

The corresponding value from the area under the normal probability curve (taken from Z table) for I=0.093 was 0.54. Thus, there was a 54 per cent chance that the farmer, as specified, would be an adopter of modern varieties in his / her data parcel.