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Methodology of Identification and Characterization of Farming Systems in Irrigated Agriculture: Case Study in West Bengal State of India

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ABSTRACT

Targeted extension for heterogeneous farming systems is a challenge in developing countries. Farm type identification and characterization based on estimates of income from different farm components allows simplifying diversity in farming systems. Use of multivariate statistical techniques, such as principal component analysis (PCA) and cluster analysis (CA), help in such farm typology delineation. Using this methodological approach, the present study conducted in West Bengal, India, identified four distinct farm types, namely, farms growing food grain and jute, farms with animal husbandry and fishery based diversification with high off-farm income, farms with crop based diversification with off-farm income, and farms growing vegetables and fruits. Such typology delineation helps in differentiated, holistic, and broad-based extension intervention to address the need of different identified farm types and a reduced transaction cost in the agricultural research and extension system.

Keywords: Cluster analysis, Economic characterization, Farm heterogeneity, Farm typology, Principal component analysis.

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INTRODUCTION

Technology transfer of agricultural innovations is considered as a measure of efficiency of an agricultural research and extension system and is of central interest to policy making (Bozeman, 2000). There are examples galore on the failure of technologies with great potential that have not been accepted by the smallholders of developing countries. These technologies often do not match the complex and heterogeneous smallholder systems (Emtage and Suh, 2005). Unfortunately, both in agricultural and social sciences, complexity and diversity have been under-perceived and undervalued, resulting in their neglect, under-estimation and exclusion from government statistics and policy framework (Chambers *et al*., 1989). The archetypal Green Revolution technologies and ‘transfer-of-technology’ paradigm has also historically failed to cater to the needs of resource poor agro-ecosystems of the developing countries (Pender and Hazell, 2001).

During the farming system research and extension paradigm, Recommendation Domain (RD) was conceptualized to simplify this heterogeneity of farming systems. A RD is a group of farmers whose circumstances are similar enough that they are eligible for the same recommendation (Harrington and Trip, 1984). Technology managers could make informed decisions on what recommendation to be made for a

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group of farms for ensuring higher rate of technology integration in smallholder systems. Classification of farming systems (styles) used by the farmers across a farmland has also been suggested by some authors (Goswami *et al.*, 2012). However, these were practiced as part of time-bound projects and were hardly mainstreamed in the national research and extension systems (Frankenberger *et al*., 1989).

Participatory research and extension –that grounds technological intervention on participatory exercises with stakeholders– is far from mainstreamed in National Agricultural Research and Extension System in India and state-governed extension system is not prepared to deal with the need of small farms in diverse ecosystems (Glendenning *et al*., 2010) leading to low adoption of agro-technology and large yield gap (Aggarwal *et al*., 2008). Although there has been experimentation with reorganized and decentralized system of technology assessment and refinement and revitalized public extension system, development of sound analytical tools for targeting extension intervention has remained undermined till date. One of such sound analytical tools might be standard methodology to classify farming systems into manageable number of farm types to be targeted by extension agencies. A sound methodology of farm typology delineation may improve rapid transfer of appropriate technology, precise extension support, and development of supportive policy for the diverse smallholder farms of eastern India.

Farm typology study recognizes that farmers are not a monolithic group and face differential constraints in their farming decisions depending on the available resources and their lifestyle (Soule, 2001). Ellis (1993) described that small farmers are always and everywhere typified by internal variations among many lines. Although every farm and farmer is unique in nature, farm/farmers of a given type are different from that of other types. Developing a typology constitutes an essential step in any realistic evaluation of the constraints and opportunities that exists within farm households and increase efficiency of undertaking appropriate policy interventions (Vanclay, 2005).

Unfortunately, most of the farm typology studies have focused on socio-economic and agro-ecological factors for classification of farms. Economic factors have been less used, especially in small-scale studies, for classifying farms (Briggeman *et al*., 2007).

The study of technology transfer and appropriate technology are now debated in the context of the role of institutions in differential economic growth under the aegis of New Institutional Economics (NIE). NIE considers institutional arrangement and institutional environment as a prerequisite to economic performance (North, 1990) and are now frequently drawn on in the literature on efficient extension mechanisms aiming for reduced transaction cost and enhanced economic efficiency (Birner and Anderson, 2007). The application of NIE has mostly concentrated on the budgetary constraints and institutional evolution, markets, and institutional development (Pal *et al*., 2003). We assume that the methodology for identification of farm types may prove beneficial to the institutional arrangement that reduces transaction cost in smallholder agricultural production by providing appropriate technology. This is even more important in the regime of open economy where smallholders will have to be served with less transaction cost for long term economic and environmental sustainability.

Although the methodology employed in this study is often used for typology delineation of farms, the present study assumed that classification of farms based on economic returns from farm enterprises will provide more effective insights in farm type identification where agriculture is practiced as entrepreneurial activity and not for subsistence. Thus, the aim of the study was to illustrate the applicability of multivariate methods for farm-typology study in Nadia district of West Bengal, India, where agriculture has been transformed into cash earning livelihood provision. This will help in targeting of appropriate technology and policy support for similar conditions.

MATERIALS AND METHODS

Study Areas

Based on climate, soil, and physiography, there are six agro-climatic zones in West Bengal, India (Gajbhiye and Mondal, 2008). Among these, New Alluvium Zone is the biggest zone with highest cropping intensity and crop diversity, covering part or whole of 11 districts of West Bengal, Nadia being one of them. The district is characterized by high population density and varied farming systems, posing a diversity of small farm conditions for study. Nadia district, the seat of the State Agriculture University and several other agricultural research and development organizations, has been exposed to varied choices of technologies to the farmers. Net cropped area of the district is 272,135 hectares. However, cropped area is decreasing slowly due to the conversion of agricultural land for other purposes (GoWB, 2005). Rice is the main crop cultivated in this zone over different land terrains and seasons. Spring rice (*Aus*), sesame and green gram in spring or early wet season; jute and rainfed rice (Aman) in kharif or wet season, and wheat, different oilseeds and pulses, potato etc. in winter months are commonly grown in this zone. *Boro* or summer rice and sugarcane are also important crops of the zone. Haringhata and Chakdah, the sampled Community Development Blocks, are two southernmost blocks of the district (Figure 1).

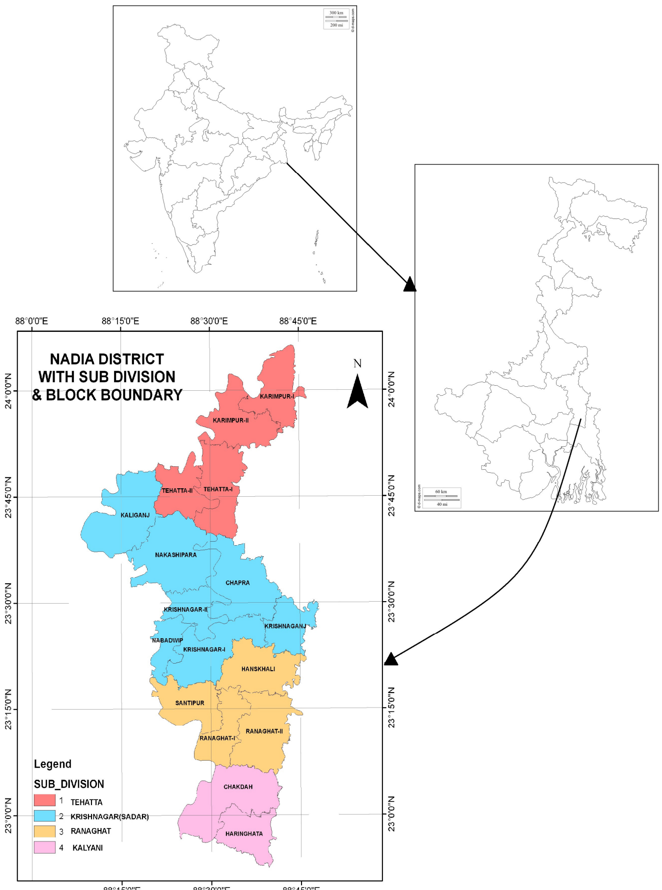

Figure 1. The study location under Nadia district of West Bengal state, India. Chakdah and Haringhata Blocks are shown inside the box.

Sampling

A multi-stage survey method using random stratified sampling procedure was followed for both quick as well as detailed survey. Two blocks, namely, Chakdah and Haringhata, were randomly selected from 17 blocks of Nadia district. Then, three villages from each of these blocks and 20 farmers from each of the village were randomly selected. Care was taken that these 20 farmers came from marginal (0-0.67 ha), small (0.67-1.0 ha), medium (1.0–1.5 ha) and large (> 1.5 ha) groups. A quick survey on these 120 households was done with a focus on socio-economic information and farm income from different crops and husbandries. This information was used for identification of predominant farm types of the region based on farm economy. After cluster analysis with the extracted PCs (see Data Analysis for details), half of the members from the identified clusters were selected randomly and were interviewed for the characterization of these farm types. That means 60 farmers were interviewed for characterization of farm types. This helped us to avoid detailed and time consuming interviewing with all 120 respondents.

Data

Based on an extensive review of literature, initial case explorations in the field, and expert counsel, two pre-tested structured interview schedules were developed for the study. Data was collected in two phases: first, a quick survey on 120 farms for typology delineation; second, a detailed survey on 60 farms for characterization of individual farm type. For the first phase, the questionnaire had two sections: socio-economic information and a detailed income data on all the components of farming system such as individual field crops (cereals, oilseeds and jute), horticultural crops (fruits and vegetables), and animal husbandry, fishery and off-farm income. For the second phase, the questionnaire consisted of three sections: socio-economic information including cropping pattern, cost of cultivation/management for all farm components, and revenue earned from all components of the farming system including off-farm income.

Although data were collected on both socio-economic variables and variables related to income from farm enterprises in the first phase, variables on income from different crop enterprises were used in the PCA. These were income from *Aman* rice, *Boro* rice, oilseed, jute, vegetables, fruits, spices, livestock, fishery and off-farm income. This is because the study wanted to classify farms based on some crop enterprise related parameters only. Moreover, Nadia district was relatively more advanced in agriculture and was predominated by well-endowed ecosystem. Hence, income from crop enterprises was the most important determinant of farming system heterogeneity (Ghosh and Kuri, 2005). Since the impact of off-farm income on technology adoption was well-reported (Nehring *et al*., 2005), the present study considered off-farm income as a factor for classification.

Statistical Analysis

Multivariate statistical techniques have been widely used in farm typology study (Guto *et al.*, 2010), particularly when an in-depth database is available. Usually, a combination of PCA and CA, called the pattern analysis, has been used. PCA is effective for reduction of the number of original (input) variables followed by CA to identify farm types. We performed PCA on standardized variables to condense all the information from the original interrelated variables to a smaller set of factors called principal components (Abdi, 2007).

Factors were rotated using orthogonal rotation (varimax method) (Gorsuch, 1983) so that a smaller number of highly-correlated variables might be put under each factor and interpretation becomes easier (Field, 2005). In accordance with Kaiser's criterion, all factors exceeding an eigenvalue of one were retained and interpreted (Kaiser, 1958).

In the second stage, the sampled farms were clustered by CA based on the four principal components identified by PCA.

To determine the number of clusters, hierarchical method and K-means clustering method were employed. For hierarchical clustering, Euclidian distance and Ward's computation method was considered. The number of clusters retained from Ward's method (four in this study) was used as starting values in the K-means method. Number of clusters deemed most realistic and meaningful was chosen for the final solution. All data analyses were performed using SPSS 17 software (SPSS Version 17, SPSS Inc., Chicago, Illinois).

RESULTS

Six major types of farming systems were identified based on the sources from which farmers earned maximum gross income. These were: rice based (30 households), fruit based (38 households), vegetable based (40 households), jute based (8 households), livestock based (2 households), and fisheries based farming system (2 households). The farm size distribution of these farm types in two study blocks is given in Table 1.

In both study blocks, a large number of sub-farming systems were found (Table 2). The label of enterprises in a given sub-system was given according to their contributions to the gross farm income. For example, 'Rice+Jute+Vegetables' sub-system denoted that rice contributed highest to the farm income, followed by jute and vegetables. In Chakdah Block, 60 farmers represented 30 different sub-farming systems; for Haringhata Block, this number was 21. Had we used maximum income from an enterprise for identifying farm types, diversity of farming systems would have been grossly undermined. For example, it is difficult to understand the importance of fishery and animal husbandry in different

Table 1. Distribution of farm types by highest sources of farm income under different size categories.

	Chakdah					Haringhata					All farms
	Marginal	Small	Medium	Large	Total	Marginal	Small	Medium	Large	Total	
Rice-based	2 (11.11 [a], 9.09 [b])	8 (44.44, 36.36)	6(50.00, 27.27)	6(50.00, 27.27)	22 (36.67 [a])	2(11.11, 6.67)	2 (11.11, 6.67)	2(16.67, 6.67)	2(16.67, 6.67)	8(13.33 [a])	30 (25.00 [a])
Fruit-based	4 (22.22, 28.57)	4(22.22, 28.57)	6(50.00, 42.86)	-	14 (23.33)	6(33.33, 25.00)	8(44.44, 33.33)	8(66.67, 33.33)	2(16.67, 8.33)	24 (40.00)	38 (31.67)
Vegetable-based	6 (33.33, 50.00)	-	-	6(50.00, 50.00)	12 (20.00)	10(55.56, 35.71)	8 (44.44, 28.57)	2 (16.67, 7.14)	8(66.67, 28.57)	28 (46.67)	40 (33.33)
Jute-based	2 (11.11, 25.00)	6(33.33, 75.00)	-	-	8(13.33)	-	-	-	-	-	8 (6.67)
Livestock-based	2(11.11, 100.00)	-	-	-	2 (03.33)	-	-	-	-	-	2 (1.67)
Fishery-based	2(11.11, 100.00)	-	-	-	2 (03.33)	-	-	-	-	-	2 (1.67)
Total	18	18	12	12	60	18	18	12	12	60	120

Figures in parentheses are percentages; [a]: Percentage to column marginal, [b] Percentage to row marginal.

Table 2. Predominant sub-farm types under each farm type. Sub-farm types are arranged according to their decreasing contribution towards overall farm income.

Farming system	Sub-farming systems	
	Chakdaha	Haringhata
Rice-based	Rice+Jute+Vegetable	Rice+Jute+Vegetable+Livestock
	Rice+Vegetable+Jute+Fruit+Oilseeds	Rice+Vegetable+Jute+Fruits+Livestock+Goatery+Poultry
	Rice+Vegetable+Oilseeds+Livestock+Jute+Goatery	Rice+Oilseeds
	Rice+Jute+Fruit+Vegetable+Oilseeds+Livestock	Rice+Vegetable+Fruits+Livestock+Poultry
	Rice+Oilseeds	
	Rice+Vegetable+Livestock+Oilseeds+Poultry	
	Rice+Jute+Vegetable+Livestock	
	Rice+Jute+Fruits+Livestock+Vegetable+Poultry	
	Rice+Jute+Livestock+Fisheries	
	Rice+Vegetable+Jute+Fruits+Livestock+Goatery+Poultry	
	Rice+Vegetable+Fruits+Livestock+Poultry	
Fruit-based	Fruit+Rice+Vegetable+Livestock+Poultry	Fruit+Vegetable+Rice+Spices+Livestock+Poultry
	Fruit+Livestock+Jute+Vegetable+Rice+Oilseeds+Poultry	Fruit+Vegetable+Spices+Jute+Rice+Fisheries+Livestock
	Fruit+Rice+Vegetable+Oilseeds+Livestock	Fruit+Vegetable+Rice+Livestock
	Fruit+Vegetable+Rice+Livestock+Poultry	Fruit+Vegetable+Livestock+Rice+Poultry
	Fruit+Vegetable+Rice+Livestock+Fisheries+Poultry	Fruit+Rice+Vegetable+Jute+Livestock
	Fruit+Rice+Vegetable+Oilseeds+Fisheries+Livestock	Fruit+Rice+Jute+Livestock
	Fruit+Fisheries+Livestock+Poultry	Fruit+Fishery+Livestock+Poultry
		Fruit+Livestock+Goatery+Poultry
Vegetable-based	Vegetable+Rice+Livestock+Oilseeds	Vegetable+Fruits+Rice+Jute+Livestock
	Vegetable+Jute+Rice+Oilseeds+Poultry	Vegetable+Rice+Fruits+Jute+Goatery+Poultry
	Vegetable+Cereals	Vegetable+Rice+Livestock
	Vegetable+Fruits+Rice+Fisheries+Oilseeds+Livestock+Poultry	Vegetable+Fruits+Rice+Spices+Fisheries+Livestock
	Vegetable+Fruits+Rice+Livestock	Vegetable+Rice+Livestock+Jute
	Vegetable+Fruits+Livestock	Vegetable+Rice+Spices+Livestock+Goatery+Poultry
		Vegetable+Poultry
		Vegetable+Fruits+Fisheries+Rice+Jute+Poultry
		Vegetable+Fruits+Rice+Jute+Fisheries+Spices+Livestock+Poultry
Jute-based	Jute+Rice+Vegetable+Livestock+Oilseeds+Goatery	
	Jute+Spices+Poultry	
	Jute+Vegetable+Rice+Fisheries+Oilseeds+Poultry	
	Jute+Vegetable+Rice+Goatery+Poultry	
Livestock-based	Livestock+Vegetable+Fruits+Fisheries+Rice	
Fishery-based	Fishery+Vegetable+Rice+Livestock	

farming systems if we go by the numbers in Table 1 (only four out of 120 farms earning highest income from these two enterprises). This large number of sub-systems is difficult to be addressed individually through precise extension intervention. Since the sub-systems are large in number and a single crop/enterprise-based classification would oversimplify farm heterogeneity, we employed a combination of PCA and CA for identification of farm typology.

The Principal Component Analysis

In total, 10 variables were included in PCA, of which 4 principal components with eigenvalues greater than 1 were retained for further analysis (Table 3). Rotated factor (Varimax) matrix of independent variables with differential factor loadings is also given in Table 3. The communality column shows the total amount of variance of each variable retained in the factors. The four PCs explained 77.09% of total variability. The first principal component (PC 1) explains 29.58% of the total variance and is correlated substantially with the income of *Aman* rice, *Boro* rice, and Jute. Thus, the component represents income from food grain and one traditional cash crop. PC 1 represents the traditional cropping pattern of the region (for long time Aman rice is generally grown for subsistence purposes and jute for cash earning) with some market orientation (Boro rice, in general, is used for sale in the market). Principal components 2, 3, and 4 explain 17.62%, 14.97%, and 14.92% of the total variance, respectively. PC 2 is correlated mainly with income from vegetables and spices representing the crop and income diversification of the area. PC 3 is associated with livestock and fishery and embodies non-crop enterprises of the farm. PC 4 is associated with off-farm income and represents farm to off-farm shift in rural employment in the study areas. Thus, when we use these PCs for cluster analysis, we employ a large number of variables for classifying the farms.

Cluster Analysis

The first four principal components were used for hierarchical clustering using Euclidean Distance as distance measure and Ward's technique as agglomerative clustering. The *K*-means clustering method resulted in 4 clusters, the distribution of which is given for the study locations (Table 4). Chakdah Block is predominated by farms receiving income from vegetable and spices (66.67%) followed by animal husbandry,

Table 3. The first four principal components (PCs) obtained by PCA with loadings for income from individual crop enterprises and percent cumulative variance explained.

Variables	PC 1	PC 2	PC 3	PC 4	Communality
Aman Rice	.722	.076	-.247	.102	.599
Boro rice	.738	.121	.083	-.412	.736
Oilseed	.309	-.133	.327	-.456	.650
Jute	.865	-.147	-.047	.052	.774
Vegetables	.070	.872	.019	-.091	.775
Fruits	.007	.332	.464	.522	.599
Spices	-.059	.853	-.096	.035	.742
Livestock	-.087	-.126	.680	-.147	.508
Fishery	-.092	.030	.775	-.103	.621
Off-farm income	.155	-.291	-.178	.751	.705
Eigenvalues	2.08	1.872	1.730	1.028	
Cumulative explained variance	29.58	47.20	62.17	77.09	

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Table 4. Clusters identified by CA demonstrating farm types in two study blocks of Nadia districts.[a]

	Farm types				Total
	Cluster 1	Cluster 2	Cluster 3	Cluster 4	
Chakdah	0 (0.00)	18 (30.00)	40 (66.67)	2 (3.33)	60 (50.00)
Haringhata	12 (20.00)	0 (0.00)	32 (53.33)	16 (26.67)	60 (50.00)
Total	12 (10.00)	18 (15.00)	72 (60.00)	18 (15.00)	120 (100.00)

[a] Numbers in parentheses are percentages of farms.

and fishery with vegetables (30.00%), whereas, Haringhata Block is predominated by diversified farms (53.33%) followed by farms receiving income from vegetables and fruits (26.67%) and food grain and jute (20.00%). Overall, the major farm types of the district is predominated by diversified farms where major income comes from vegetables, fruits and off-farm income (60.00%) followed by farms receiving income from animal husbandry, fishery with vegetables (15%), farms receiving income from vegetables, fruits, and off-farm incomes (15%) and farms receiving income from food grain and jute with off-farm income (10%).

Characterization of Identified Farm Types

Table 5 helps in understanding the characteristics of identified clusters in terms of some background variables and economic performance indicators.

Cluster I includes 10% of farm households. The cluster is comprised of households having large land holding, low family education, and moderate crop diversification. In terms of economic performance indicators, this cluster is characterized by low gross return, moderate cost of cultivation, moderate system net return and low cost-benefit ratio. These households, on average, secured high income from summer and winter rice, and Jute. However, income from vegetables and fruits were also found to be decent. Furthermore, the farms belonging to this cluster had managed low off-farm income.

Cluster II is comprised of 15% of the farm households. The cluster members had small landholding, moderate family education, and high crop diversification. In terms of economic performance indicators, this cluster is characterised by low gross return, low cost of cultivation, and low system net return and moderate cost-benefit ratio. These households secured substantial proportion of income from animal husbandry and fishery apart from high income from vegetables and fruits. The cluster members had high off-farm income to offset low farm income. These farms may be called diversified farms based on animal husbandry and fishery with high off-farm income.

Cluster III includes 60% of the sampled households. This cluster is characterized by small land holding, low family education, and high crop diversification. These farms have emerged as integrated farms to generate higher income with minimal risks. They used to receive small income from a large number of farm enterprises and from off-farm income. This cluster is again characterized by relatively high cost-benefit ratio since these farms are less dependent on external inputs for higher integration among the enterprises. They have shown high gross return, moderate cost of cultivation, and high system net return. The cluster members also had moderate off-farm income.

Cluster IV includes 15% of the farm households. The cluster members had medium land holding, high family education, and moderate crop diversification. These households secured high income from vegetables and fruits. These farms showed highest system gross return, high cost of cultivation, high system

Table 5. Characteristics of identified clusters of farm households and p-value of one way analysis of variance (equality of group mean) for variables used for characterization of farm types.[a]

	Cluster 1: Food grain and Jute based farms (N= 6)	Cluster 2: Animal husbandry fishery based diversified farms with high off-farm income (N= 9)	Cluster 3: Crop based diversified farms with off-farm income (N= 36)	Cluster 4 Vegetables and fruits based farms (N= 9)	P-value
Farm size (ha)	1.98^{a}	1.02^{b}	0.91^{b}	1.28^{b}	0.00
Education index	1.75	2.18	1.77	2.28	0.42
Crop diversification index	0.24	0.33	0.38	.27	0.89
System gross return (Thousand Rs)	124.86^{b}	71.33^{c}	191.27^{ab}	212.99^{a}	0.00
System cost of cultivation (Thousand Rs)	51.49^{b}	31.93^{b}	85.10^{ab}	93.34^{a}	0.00
System net return (Thousand Rs)	73.37^{b}	39.41^{c}	106.17^{ab}	120.08^{a}	0.00
Cost-benefit ratio	2.08	2.23	2.39	2.20	0.78
Income from Aman Rice (Thousand Rs)	24.98^{a}	3.41^{b}	7.07^{b}	9.43^{b}	0.00
Income from Boro rice (Thousand Rs)	62.53^{a}	18.31^{b}	10.87^{b}	15.86^{b}	0.00
Income from oilseed (thousand Rs)	8.04^{a}	6.51^{a}	1.16^{b}	0.00	0.00
Income from jute (Thousand Rs)	63.74^{a}	8.45^{b}	12.18^{b}	10.56^{b}	0.00
Income from vegetables (Thousand Rs)	42.03^{b}	33.94^{b}	25.85^{b}	127.44^{a}	0.00
Income from fruits (Thousand Rs)	44.40	39.70	42.89	83.49	0.53
Income from spices (Thousand Rs)	0.00	0.00	0.28^{b}	13.85^{a}	0.00
Income from livestock (Thousand Rs)	7.55	19.03	4.63	5.90	0.57
Income from fishery (Thousand Rs)	0.00	13.03	0.22	4.33	0.35
Off-farm income (Thousand Rs)	12.38^{c}	52.64^{a}	32.99^{b}	15.08^{c}	0.00

[a] Cluster means denoted by different letters show significant mean differences (P< 0.05) among clusters as found by Duncan Multiple Test

net return and moderate cost-benefit ratio. The cluster members earned low off-farm income. These farms were capital intensive and developed in the face of growing food demand in the nearest city markets. A comparison of four identified farm types in terms of several variables has been given in Table 6.

DISCUSSION

Small and marginal farmers in the study areas followed vegetables and fruit based systems with more relative frequency than other farming systems (Table 1). This might be due to the pressing need to increase farm income from small fragmented holdings. The number of smallholders has increased in West Bengal (De, 2000) and there is also evidence of increased crop diversity on fragmented lands in the state (Bagchi *et al*., 2012).

The PCA resulted in four PCs representing the main and dominant dimensions of farm types of the region: component representing income from food grain and traditional cash crop, income from vegetables and spices, income from livestock and fishery, and off-farm income. The PC 1 represented situations commonly found in low-lying areas of this region of West Bengal where both paddy and jute suited well (Ghosh and Kuri, 2005). PC 2 was correlated with income from vegetables and spices and represented the commercial dimension of the farms. PC 3 was correlated with income from livestock and fishery representing the income from allied enterprises apart from agriculture. This pattern is common for the South Asian countries including India (Joshi *et al*., 2007) and in some parts of Nadia district, departure from traditional cropping pattern has been a trend for the last one and half decades (Goswami, 2007) mostly for enhancing income from fragmented land resources. PC 4, represented by off-farm income, has become a burgeoning reality of developing countries for improvements in economic structure (Namdar and Sadighi, 2013) and in rural India this has often become the largest source of income. This is also true for the state of West Bengal where per capita land availability has declined sharply in recent years. Based on these four PCs, the farms could be classified into four clusters; i.e. food grain and traditional cash crop growers, livestock and fishery based diversified farms with off-farm income, crop based integrated diversified farms, and vegetables and fruit based capital intensive farms. These farm types may be supported by differentiated extension support. The food grain growers may be focused for assured input supply and risk coverage; for the livestock/fishery based farms, extension needs to undertake integrated planning involving multiple organizations. Integrated

Table 6. Comparison of the four identified farm types.[a]

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Percentage of farm	10	15	60	15
Land holding	Large	Small	Small	Medium
Family education	Low	Moderate	Low	High
Crop diversification	Moderate	High	High	Moderate
Gross farm income	Low	Low	High	High
Cost of cultivation	Moderate	Low	Moderate	High
Net farm income	Moderate	Low	High	High
Benefit-cost ratio	Low	Moderate	High	Moderate
High income from	Rice, Jute	Animal husbandry and fishery	Integrated farming	Vegetables, fruits
Off-farm income	Low	High	Moderate	Low

[a] Classification was made following the rule: > Mean+SD= High/Large, Mean±SD= Medium/Moderate, < Mean± SD= 'Low'/'Small'

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farms will need local input sources and integration with markets through farmer cooperatives. The capital intensive farms might need access to credit and assured support throughout the value chains.

The farm types differed among themselves in terms of most of the income sources and economic indicators, showing the efficiency of the classification methodology employed. Cluster 4 showed highest system gross and net return perhaps due to the nature of crop grown (cash earning from fruits) and assured local markets for the produce. The identified farm types, however, did not differ in terms of education index, crop diversification index, cost-benefit ratio, and income from fruits, livestock and fishery. In Nadia district, crop diversification is already high due to the well-endowed eco-system with assured irrigation facility and significant difference was not observed among different clusters. Interestingly, smaller farms showed higher diversification in income, in line with available literature (De, 2003; Joshi *et al*., 2007). Increasing dependence on costly external inputs has rendered an increase in cost of cultivation, relative to system net return, irrespective of farm types (Vyas, 2001). That is why, significant differences in cost-benefit ratio were not observed. However, diversified farms showed a relatively higher cost-benefit ratio. All types of farmers in this district have recently shifted to fruit cultivation, owing to better irrigation and extension support (Mitra and Pathak, 2008). That is why contribution of fruits in the overall farm income has not shown significant difference. Livestock in these regions of the state is not extensively raised, intended mostly for family consumption and is not also commercial in nature (Thorpe *et al*., 2007). Reluctance to allocate cropland for fodder cultivation has also resulted in little encouragement for animal husbandry. Fishery is also largely traditional on account of small water bodies and little extension support available for modern fishery (Abraham *et al*., 2011).

CONCLUSIONS

This study departs from conventional methodology of economic characterization of predominant farming systems in India (classification based on land holding or discussion with stakeholders with little statistical rigor) in terms of at least two dimensions. First, it uses multivariate methods allowing numeric-based identification of farm types, and second, it uses a set of economic and non-economic variables for such classification. This methodology has reduced the time of data collection significantly, as quick survey was employed for farm type identification and only half of the households were interviewed in detail for their economic characterization. The methodology employed in this study can be modified under different circumstances of farm typology study. The variables used for PCA may be different, although they have to be numeric ones, rather continuous, as describing the nature of agro-ecosystem, agricultural practices, objective of classification (nutrient management, irrigation intervention, credit support, etc.). Variables may also vary when the focus of farm characterization is different from economic characterization only (e.g. these may be energy efficiency, ecological sustainability, etc.). The multivariate approach (algorithm) followed for the farm type delineation may also be used for the development of decision support system. The results from the analysis suggested four major farm types in the study areas. This asks for a differentiated farm planning and extension intervention than confining efforts to technology transfer alone. India, along with a large number of countries having agrarian society, has entered the open economy regime and need to establish economic efficiency for their smallholder system. The extension system must precisely target agricultural inputs, advisory services, credit access and critical information for identified farm types. The selection of beneficiaries for many public extension programs may also be guided by such farm typology. The study may not be extrapolated to the identified farm types universally. But, since the study locations are representative of irrigated production system of India, this may be generalized for nearly 57 Mha of cultivable lands with more than 50 million farmers operating under this system. Integration of the methodology in the formal policy or in the form of a web-based decision support tool may reach these people effectively.

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روش شناسایی و تعیین ویژگی های نظام های زراعی در کشاورزی آبی: مطالعه موردی در ایالت بنگال غربی در هند

س. چاترجی، ر. گوسوامی، و پ. باندیوپدهی‌یای

چکیده

در کشورهای در حال توسعه، ترویج برای گروه هدف در نظام های زراعی ناهمگون یک چالش است. با شناسایی نوع مزرعه و تعیین ویژگی های آن برپایه تخمین درآمد از مولفه های(اجزای) مختلف کشاورزی می توان تنوع نظام زراعی را ساده کرد. کاربرد روش های آماری چند متغیره مانند تجزیه به مولفه های اصلی (PCA) و تجزیه خوشه ای (CA) در مرزبندی گونه شناسی(typology) مزارع کمک می کند. با استفاده از این روش، در پژوهش حاضر که در بنگال غربی در هند اجرا شد، چهار نوع مزرعه متمایز شناسایی شد. این مزارع عبارت بودند از مزارعی که غلات خوراکی و کنف تولید می کردند، مزارعی با تنوع پرورش دام و ماهیگیری که در آمد خارج از مزرعه آن ها زیاد بود، مزارعی با تنوع کشت گیاهان زراعی همراه با درآمدهای خارج از مزرعه، و مزارعی با کشت سبزیجات و میوه ها. این مرزبندی گونه شناسی مزارع، در ارایه خدمات ترویجی تمایزی، جامع، و گسترده به منظور پاسخگویی به نیاز های انواع مزارع شناسایی شده و کاهش هزینه های تراکنشی در سامانه تحقیقات کشاورزی و ترویج کمک می کند.

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