ASSESSING ADOPTION OF TECHNOLOGY AMONG SMALL FARMERS:

CLASSIFICATION AND PROFILE ANALYSIS

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Technological change among small farmers has long been a topic of interest among applied researchers, and social scientists. Experiences have demonstrated that technological change does not occur simply because an improved production technology is available for farm use, but numerous factors condition the acceptance of new production techniques (Steven's , 1977). These factors have caused researchers, planners and government institutions to incorporate into their analysis concepts such as farming systems, risk-sharing and buffer institutions.

An important limitation to studying the adoption of improved technology by small producers is the lack of generalized theoretical models and applied analytical methods, not only to explain farmer's behavior, but to classify and predict farmer's response to new technological patterns. This is a very difficult constraint to overcome, because of the great difficulty in isolating and measuring intangible and exogenous factors which may condition expected farmers behavior.

One means to better understand a farmer's response to technical change is to monitor farmers' reactions to improved technology after they have had the opportunity to test and participate in the production process utilizing improved production methods. This simple approach should permit the identification of some farmer characteristics which could be considered as an approximation to the concept of thresholds for adoption.

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Considerable literature exists reporting attempts to explain adoption of technology by observing groups of small farmers who have already accepted technological innovations. Feder, Just and Zilberman (1981) have grouped studies according to factors most frequently mentioned as affecting technological innovations. They include farm size, land tenure, labor availability, credit, risk and uncertainty, human capital, and other sociological factors. Other researchers have considered socio-personal and socio-phychological variables by using score systems, and analysing farmers' altitudes through a profile analysis methodology (Somasundaram and Singh 1979, Subramaman et al 1981, Vijayaragharan and Somasundaram 1979).

The purpose of this paper is to relate farmers' adoption responses to selected grouping characteristics which might be used for further classification of farmers into adoption groups. Also, it is expected to determine possible economic rationality for technical change among those farmers who do accept improved production techniques.

A set of farmers from the area where an on-going farming systems research program is being carried out by the Tropical Agricultural Research and Training Center (CATIE) was selected for the purposes of this analysis. This sample included farmers possessing some of the conditions reported in the literature as important factors for adoption of technology (Feder et al 1981) extensive prior information, knowledge of the production techniques, an economically viable technological alternative, and a known final product price.

The Technological Alternative

The concept of appropriate technology is considered as critical for adoption of new technology by small farmers (Flinn and Lagemann 1980, Ruttan 1977). A technical innovation is considered appropriate if it facilitates the substitution of relative abundant factors for relative scarce factors of production, at a given price structure. This implies that a technical alternative for farmers should be consistent with a set of elements such as their objective function, factor endowment and efficiency, both at the technical and market levels within their diversified farm activities. These are indeed requisits to be considered by agricultural researchers from the viewpoint of technology design, and the socio-economic environment in which small farmers make decisions for agricultural production.

One approach to appropriate technology development is the on-farm, farming system research (FSR). This methodology involves the farmer from the beginning of the process of technology generation and also includes several joint evaluations during the process to ensure the generation of technological alternative as suitable to farmers as possible (Navarro, 1979). This paper reports the assesment of farmer responses to a vegetation management weed control technology which was developed during five years of cooperation between personnel of the International Plant Protection Center (IPPC) of Oregon State University, CATIE, and small maize growers from the Atlantic humid lowlands of Costa Rica.

In terms of net changes to the farmer's practice, the technological alternative involves adjustments in timing and rate of chemical products that are already widely utilized by small farmers in the area (Escobar and Shenk, 1981). It also introduces the use of an inexpensive spray shield enabling earlier herbicide applications. This weed control technology was developed following CATIE's FSR methodology which included characterization, technology design, on-farm experimental trials, validation (farmer evaluation) of the best experimental results and a continous agronomic analysis incorporating feedback within the process.

Analyses have shown that the technology meets several of the prerequisites found important for this area: it is economically attractive and labor-saving to farmers (Escobar and Shenk, 1981); it is focussed on weed control which is perhaps the most limiting technical production factor (Escobar and Shenk, 1981), it represents a simple modification of common practices, and its use apparently introduces a structural change in the economics of maize production by shifting the production curve upwards (Escobar and Shenk, 1982).

The validation phase of the FSR methodology included the evaluation of the final recommended alternative during two maize cropping seasons by 32 small farmers of the area. During this period, some climatic, pedological, economic and social characteristics were recorded through weekly visits, including all farm input-output activities, a control trial, and human and capital inventories. Farms were monitored in the planting season following the validation trials to determine the degree of utilization of the improved practices.

The Analitical Framework

The monitoring activity made it possible to differentiate level of adoption among maize growers. The simplicity of the weed control technology permitted the grouping of participating farmers into four categories: a) non-adopters (Group 1); b) low adopters: those farmers that adopted only the pre-planting vegetation management techniques (Group 2); c) medium adopters: those who use the technology in Group 2, and also the application shield which was provided during the validation phase (Group 3), and d) adopters of all practices and the rate of chemicals recommended in the weed control technology (Group 4).

Based on previous literature and on the area characteristics, a set of variables was hypothesized as key factors influencing adoption of improved technology by small farmers. These variables include farm resources and their use, with emphasis on labor which is the most limiting factor in this area, some measurements of the farmer wealth status, and some site and personal characteristics (Table 2).

Previous to the testing of this hypothesis, a factor analysis was performed to establish those variables explaining most of the variation among farms. This procedure had a twofold purpose: to check the potential explanatory power of the hypotesized variables, and to incorporate into this set of variables those with high communality. The factor analysis made it possible to select the final set of variables which explained 70% of total variation among farms. Three variables were eliminated from the original list because of their multicolinearity and low communality (Henao and Escobar, 1983).

A linear discriminant function was used as the statistical approach for testing the propossed hypothesis with the four adoption groups. This analytical tool was also utilized to assign farmers likely group membership. This permited the generation of two additional pieces of information: 1) the classification coefficients which may be used as prediction equations, given the value of the variables for a specific farmers, and 2) the profile of each exclusive group of adopters based on the selected variables. This helped understand the rationality for introducing or rejecting technological change for maize production.

The linear combination of the discriminant variables, and the classification function are of the general forms:

$$D_i = d_{i1} Z_1 + d_{i2} Z_2 + \dots + d_{ip} Z_p \quad \text{and}$$

$$C_1 = C_{io} + C_{i1} V_1 + V_2 + \dots + C_{ip} V_p$$

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Where: D_i = the score on discriminant function i

d's = weighting coefficients

Z's = values of p discriminant variables (X_1 to X_p in Table 2)

C_i - the classification score for group i

C_{io} = the constant

C_{ip} = classification coefficients

V's = scores on the discriminating variables (X_i to X_p)

With the exception of soil fertility, all variables were measured in cardinal bases to facilitate further application of classification coefficients as prediction weights. The use of indexes would have introduced several difficulties using these results as forcasting tools.

Empirical Group Classification

Results of the discriminant analysis and the classification procedure application are summarized in Tables 1 and 2. In Table 1, the initial farm classification based on the adoption recorded during the monitoring phase is compared with the classification based on the discriminant analysis. The fact that only two farmers out of the 27 are misclassified, suggests that the variables chosen were adequate to confirm the original selection and to classify farmers previously expossed to appropriate technological innovations given the production conditions of the study area.

This information suggests that the hypothesis regarding the relationship of adoption and some economic, personal and farm site characteristics was well founded. Whether or not this set of variables could be used as a threshold for technology adoption will depend on a further score construction needed to jointly measure variables with a multivariate distribution. The application of the linear discriminant function determines the differentiation of the sample in four mutually exclusive groups (1 to 4). Consequently, estimated coefficients constitute weights to assign a specific farm to any group. Significance of coefficients

Table 1: Farmer Classified by Adoption Groups According to the Discriminant Function, and the Classification Procedures.

Nº of Farm	Initial Group Classif.	Functional Group Classific.	Probability of Membership in Each Group			
			1	2	3	4
1	4	4	0.0148	0.0000	0.0000	0.9852
2	2	2	0.0000	0.9989	0.0011	0.0000
4	3	3	0.2179	0.2680	0.2728	0.2413
6	3	3	0.0000	0.0227	0.9737	0.0000
7	3	3	0.0000	0.0248	0.9752	0.0000
8	1	1	0.9956	0.0000	0.0000	0.0044
9	3	3	0.0000	0.0003	0.9997	0.0000
10	2	2	0.0001	0.9132	0.0867	0.0000
11	2	2	0.0000	0.9942	0.0058	0.0000
12	4	4	0.0049	0.0000	0.0000	0.9950
13	3	3	0.0011	0.0637	0.8407	0.0945
14	2	3*	0.0000	0.1806	0.8194	0.0000
15	4	4	0.0005	0.0000	0.0000	0.9995
16	2	2	0.0141	0.4974	0.4157	0.0728
17	3	3	0.0000	0.0141	0.9858	0.0000
18	2	2	0.0000	0.9992	0.0008	0.0000
19	2	2	0.0000	0.9291	0.0696	0.0013
21	3	3	0.0000	0.4400	0.5600	0.0000
23	1	1	0.9984	0.0000	0.0000	0.0016
24	1	1	0.9811	0.0000	0.0000	0.0189
25	4	4	0.0005	0.0000	0.0000	0.9995
26	4	4	0.0002	0.0007	0.0569	0.9422
27	4	4	0.0031	0.0001	0.0007	0.9962
29	3	3	0.0009	0.0458	0.7743	0.1790
30	3	3	0.0000	0.2375	0.7625	0.0000
31	3	3	0.0000	0.0696	0.9303	0.0001
32	4	1*	0.8742	0.0001	0.0007	0.1250

* Misclassified farmers.

could be tested through cannonical analysis, but such information is redundant to this analysis.

The estimation of posterior probabilities measures the chance a farmer has to be classified in each of the four adoption groups. Excluding three cases, there is a high probability that farmers belong to the group to which they have been assigned through the functional analysis.

Estimated coefficients for each of the adoption groups (Table 2) seem heavily influenced by two site characteristics: total rainfall measured at the district level, and the soil fertility index as constructed from chemical analysis of a combined soil sample from each farm. Although these coefficients are difficult to interprete since they are not standarized, the importance of these factors is evident since the presence and agressiveness of some weeds are directly related to rainfall and the quality of the soil.

There are two geographical districts in the area with significant differences in rainfall, both annually and by cropping season (Escobar and Shenk, 1981).

Other variables with relatively high estimated coefficients are the farmer's previous cooperation at the time of the improved technology development, and the farmer's level of education. These variables have been reported in the literature as related to technological change (Feder at al, 1981). The active participation of farmers during the on-farm trial phase increased the degree of appropriatness of the technical innovation and could be taken as an indication of the importance of some factors like the risk attributable to the technology itself.

The proportion of farm land devoted to annual and permanent crops was also important for classification of adoption groups. This land allocation is apparently related to other site specific characteristics (rainfall and soil fertility), and the distance to the market places.

Apparent differences exist among adoption groups. In most cases, the coe-

Table 2: Estimated Classification Coefficients from the Linearized Discriminat Function for Determined Adoption Groups

Variables	Adoption Groups 1	2	3	4
Constant (x_0)	-267.80846	-230.57911	-222.51695	-284.61239
Total family labor (x_1)	0.10829	0.15127	0.11904	0.17799
Family labor available for farm use (x_2)	-0.28009	-0.24106	-0.22885	-0.31250
Previous cooperation with on-farm trials (X_3)	39.68600	32.01305	35.63871	39.46563
Farmer's age (x_4)	0.96902	1.05934	0.99616	1.
Farmer's formal education (x_5)	6.04192	6.02222	5.32911	5.91789
Total Farm area (x_6)	-2.93848	-2.53946	-2.95110	-3.26676
Proportion of land in annual crops (x_7)	1.45123	1.40304	1.36002	1.54060
Proportion of land in permanent crops (x_8)	0.58101	0.53955	0.57957	0.65434
Estimated total livestock value (x_9)	-0.00078	-0.00064	-0.00066	-0.00076
Rainfall district (x_{10})	151.27279	139.89251	136.18418	153.89574
Distance to closer supply/market center (x_{11})	2.85151	2.20146	2.39774	2.84959
Soil Fertility index (x_{12})	19.48735	18.44050	18.08689	21.81511

fficients for the group of adopters (Group 4) are greater than the coefficients of other groups. In the same sense, the lower coefficients values of the non-adopter group (Group 1) is evident in almost every variable.

Profile by Adoption Groups

The average value of discriminating variables which represent differenciating characteristics among farmers is shown in Table 3. However, individual elements of the set do not necessarily conform to such differentiation, since it is precisely the mutual interactions and combinations of those variables that makes the multivariable analysis meaningful as analytical instrument. This implies that the coefficients presented in Table 2 are to be utilized as a forcasting tool, rather than the variable values which could not be used as thresholds unless a group index is constructed using those average values.

Nevertheless, it is possible to detect some trends among groups relating to the introduction of technological changes. This is again the case of the proportion of land in annual and perennial crops which tends to be higher for farmers with a higher level of adoption. Total family and hired labor used for farmers also have a pattern which tends to relate the group of lower adoption levels with lower amounts of labor utilization.

The differentiating characteristics are complemented with the estimation of some economic indicators which are useful in explaining the economic behavior of farmers classified by adoption levels. These indicators are presented in Table 4.

A relevant relationship is the linkage between the adoption groups and returns to labor which is of paramount importance in this region, given that labor is the main resource constraint. This labor shortage is a seasonal problem which results in low family labor utilization over the production year, relative high hired labor use, and low off-farm labor activity due to the structure of the

Table 3: Average Value of the Discriminating Variables by Adoption Groups

Variables	Adoption Groups 1	2	3	4
Total family labor for farm use (man-days/year)	271.3	651.3	637.8	500.1
Family labor used in farming (man-days/year)	192.1	195.6	217.6	174.2
Previous cooperation with on-farm trials (frequency)	1	2	3	2
Farmer's age	44.0	38.7	45.0	44.3
Farmer's formal education (school years)	2.0	3.5	3.0	2.0
Total farm area (has)	16.9	19.8	18.8	18.0
Land in annual crops (%)	6.0	24.0	15.3	20.8
Land in perennial crops (%)	8.5	8.8	10.7	14.2
Estimated total livestock value (¢)	25433.3	28016.7	37636.6	30485.7
Distance to closer supply/market center (min.)	45.0	19.2	21.6	38.3
Soil fertility index (frequency)	1	3	1	4
Rainfall areas (mm)	Guácimo: 2500-3500		Cariari: 4000-5000	

banana plantation labor requirements whose prices dominate the regional market for labor (Tables 3 and 4).

Other variables such as the wealth-like indicators (farm, livestock and cash costs values), and other land uses show low values for the non-adopters (Group 1) in relation to other adoption groups. Although these variables could be interpreted as indicators of the implicit risk-adoption relationship reported in the literature, the tendency to change value with the level of adoption is not consistant in every case (Figure 1). A similar tendency seems to be present in the relationship between other economic efficiency indicators like net farm income, maize income and the adoption groups. These findings demonstrate, again, the limited use of the individual variable values to understand the multivariate effect of those farm characteristics over decisions involving adoption of improved technology.

In general, farmers with higher returns to labor and cash expenditure both at the farmer and the maize production system levels are adopting weed control recommended practices. This is also the case among those farmers obtaining the best benefit/cost relation (Figure 1). This seems to be the economic rationality for technological change among farmers under study. It would imply that these farmers might be labor use mazimizers which conforms both the regional labor market and the labor saving characteristics of the technological alternative.

Concluding Remarks

Monitoring of small farmer's response to an appropriate technological alternative within his farming activity appears to provide enough information to classify farmers into adoption groups. Through the use of multivariate analysis techniques, it is possible to select a reduced set of adoption related variables capable of yielding almost the same classification of farmers into mutually

Table 4: Average Value of Some Economic Characteristics of Farms by Adoption Group

Variables	Adoption Groups 1	2	3	4
Total hired labor (man-days/year)	154.5	249.6	331.4	326.3
Off-farm labor (man-days/year)	11.7	9.7	13.4	19.3
Estimated farm value (₡)	148333.3	322750.0	315080.0	237928.6
Area in pasture (%)	48.8	24.4	26.9	22.6
Area in bushes (%)	36.8	42.8	47.1	42.5
Area in maize production (has)	0.8	3.2	2.4	3.2
Total farm input cash cost/year (₡)	8842.9	17720.7	25924.5	16792.3
Net farm income/year (₡)	6230.2	21346.7	11657.5	13666.5
Net maize income/ha (₡)	1499.0	3888.1	4025.5	3348.7
Return to total farm labor (₡/hour)	5.9	8.1	9.7	15.8
Return to family farm labor (₡/hour)	5.9	13.6	7.2	9.3
Return to family maize labor (₡/hour)	13.0	35.9	38.2	40.2
Return to farm cash cost	3.1	2.1	2.5	10.1
Return to maize cash cost	4.9	4.3	4.0	5.8
Farm benefit/cost	2.4	1.9	3.3	10.8
Maize benefit/cost	4.4	3.9	3.6	4.3

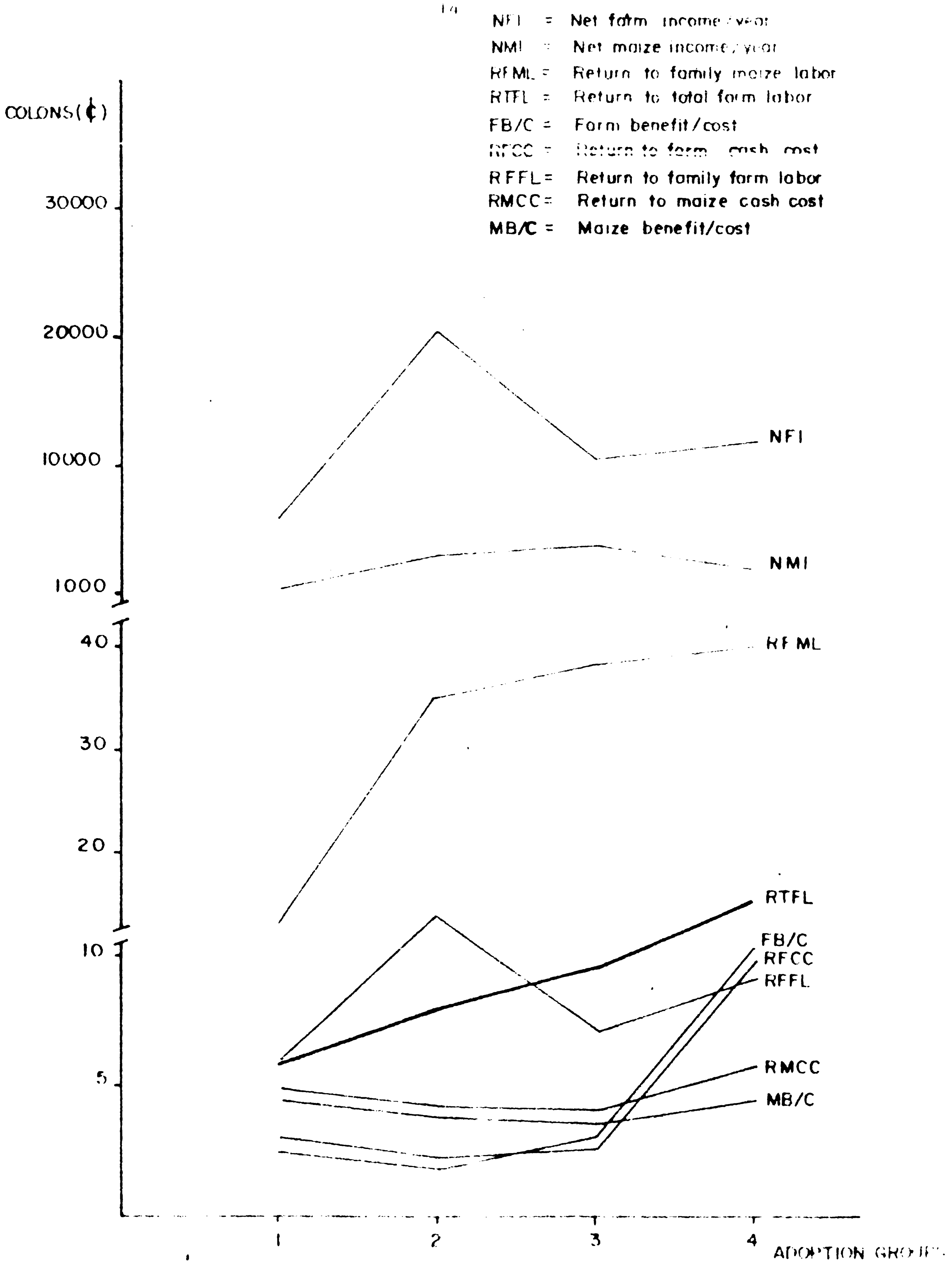

Figure 1: Relations between some economic indicator and adoption groups

exclusive groups, including posterior probabilities statements to evaluate likely membership to a specific adoption group.

In this case, this classification procedure brings about an adoption forecasting tool, that allows the classification of a given farmer into one of the adoption groups, even if the functional forms might be site specific to the study area. These prediction functions constitute an instrument for extension purposes, which is the next phase to be undertaken. Two major advantages of this instrument are: a) it permits a pre-evaluation of the success of the transference effort by identifying target groups which, in turn, allows the planning and budgeting of the activity, and b) it is simple and relatively cheap to implement due to the reduced set of variables that can be quantified at the farm level.

Farmer profile by adoption group does not show a definite pattern according to the levels of technology adoption. It is possible to distinguish some tendencies to variation through which it lower average values for the lower adoption group could be detected.

Likewise, the analysis of some economic indicators indicate a definite relationship between returns to labor and cash expenditure and the levels of adoption. This suggests that in this case the objective function of these farmers might be the maximization of their return to labor.

In general, this methodological approach seems worthwhile to be repeted elsewhere, looking for generalization, and repetitiveness in other areas with small farming systems.

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