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ECONOMIC ANALYSIS WITHIN THE FARMING SYSTEM RESEARCH AND TECHNOLOGY DEVELOPMENT METHODOLOGY: AN EMPIRICAL APPLICATION IN CENTRAL AMERICA

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INTRODUCTION

The Tropical Agricultural Research and Training Center (CATIE) has been working on programs that are on-farm-oriented and which attempt to integrate an understanding of the farmer's production systems and their economic rationale, since 1974 with small farmers in the mandate region: Central America, Panama and recently, the Dominican Republic. The research approach, often called Farming Systems Research (FSR), has been complemented with narrowly focused Technology Development (TD) activities. In cooperation with different national and international organizations, CATIE has established several working groups in areas representing the dominant ecological conditions of the region.

The objective of this paper is to discuss the role and contributions of applied economic analysis to the FSR/TD general methodology as practiced by CATIE. Our working methodology is under constant adjustment as the empirical results from different areas are incorporated into all phases of our methodology.

This paper summarizes our experience with the application of economic analysis to our FSR/TD methodology focusing on a specific technological problem in the humid lowlands of the Atlantic region of Costa Rica. The first section describes the general methodologies approach of FSR/TD as established by CATIE. The second part describes the application and contribution of economic analysis to each phase of the FSR/TD methodology. Empirical results illustrate the second section, including estimates of adoption by farmers.

METHODOLOGICAL FRAMEWORK

The general FSR/TD methodology that CATIE has assembled is based upon field work with small farmers; analysis and further conceptualization are built on that empirical analysis. Nevertheless, due to the great variability on both ecological and socioeconomic environments within CATIE's mandate region, our methodology must be presented in general terms, leaving details of the adaptation to the area's implementation team (Escobar and Moreno, 1984; Moreno, 1984). Thus, it has been essential for us to formalize a general theoretical construct to use as a guide for our field teams.

Figure 1 gives a static representation of the major components of CATIE's working methodology. Both the FSR and TD activities are contained implicity in this overview. FSR emphasizes the physical unit of production organized in a hierarchical manner (region, farm agroecosystem, and crop systems levels) as well as a dynamic record keeping program, while TD emphasizes technology design, on-farm trials,

basic supporting biological research, and the validation phase. The diffusion phase is the application of the previous effort and depends on the appropriateness of the technological alternative. This phase includes specific extension and communication techniques to be supplied by specialists within the multidisciplinary implementation teams.

The target systems level is the farm (production unit) which includes specific cropping, animal or mixed production subsystems. The objective is to develop improved production technologies tailored to the farmers's specific circumstances. This implies that technological alternatives must be effective with respect to the physical, biological, and socioeconomic characteristics at both the regional and the farm level.

The area selection is completed by combining a set of selected indicators to assign priorities according to both technical and socioeconomic circumstances. A revision of secondary source data is usually performed for selecting the working area, and specific criteria is defined with national agricultural authorities, as well as researchers and extensionists with experience in the potential working areas.

The characterization phase is intended to provide a fairly detailed information of the farm as the target system for research and technology development. In order to better understand the farm system, a hierarchical order which includes the area and the agroecosystem is established for characterization of the main technical, ecological, social, and economical relationships. Direct data collection is usually required subsequently to determine such characteristics.

The process of alternative technology design begins with the theoretical construction of production alternative technologies, such as changing the chronological or space cropping arrangements of a given production system, adding or subtracting new species, or changing production inputs. Further on-farm experimental trials enriched with the knowledge obtained from the supporting biological research and the dynamic record keeping activities test such designs establishing a cycle which repeats itself up to the moment in which an agroeconomic viable alternative to farmer's cropping systems is sustained in the field.

Promising technological alternatives go to the validation, which tests these alternatives with a larger number of producers under the farmer's own management at a semi-commercial level. Successful alternatives (as compared to the levels of production achieved by the existing technology of the region's own farmers) are subject to a continuous monitoring of selected farmers in order to generate further data for evaluating the adoption of improved technologies. Technologies that appear successful by the above criteria according to our validation phase are selected for massive diffusion to the small farmers. Technological alternatives with inferior production or economic results, are subject to additional tuning through research efforts, and should successfully complete the validation phase before massive diffusion.

Economic analysis is used at every phase of the FSD/TD methodology. The functions of this analysis are twofold: assessing the farmer's own

economic rationale for allocating production factors within his own production constraints; and evaluating TD to ensure that technological alternatives provide farmers with higher production and/or productivity levels than the traditional technology while conforming to regional and farm limitations, as well as the farmer's objectives. Such analyses include farm management and production economics applied to the farm and the agroecosystem levels, cost effectiveness, budget, and microeconomic analysis focused on evaluation of the appropriateness of the new technological alternatives to the farmer's production limitations.

The role of economic analysis is not familiar to most agricultural scientists who tend to be oriented toward more specific technical problems. For this reason, the implementation of the FSR/TD methodology requires multidisciplinary teams that bring scientists, economists, and extensionists together. In the same sense, the economic analysis must be simple because the methodology must be reproducible at the field level by various national institutions who generally work under limitations of time, money, and technical expertise. Moreover, it has been demonstrated that the simple microeconomic evaluation procedures applied to cropping systems research yield the same essentail results as more sophisticated quantitative oriented economic analysis (CATIE, 1979).

EMPIRICAL APPLICATION

The case that we use to illustrate the role and contribution of the economic analysis within the FSR/TD methodology deals with the development of a technological alternative for weed control and land preparation applied to a maize production system. This case involved technical expertise and support from both CATIE and the International Plant Protection Center (IPPC) of Oregon State University (Figure 1).

Area Selection

The North Atlantic Zone of Costa Rica was identified in conjunction with the Central government of that country as a region with particular agricultural problems. Three main selection criteria were established for final selection: presence and characteristics of small farmers, technological potentiality of the area for improvement, and convenience and concordancy with the national agricultural policy. After separation and qualification of these criteria, the districts of Guacimo and Pococi were selected for the FSR/TD project implementation.

Characterization

Data from both secondary and primary sources were used to characterize, using a hierarchical systems approach, the area, farm, and maize cropping systems (Banta, 1982 and Escobar, 1981). This region has elevations from 40 to 300 masl, and flat topography. The climate is humid, with annual precipitation ranging from 3200 to 5000 mm and temperatures ranging between 25 and 27° C. A major sociological attribute to the region is the existence of an agricultural frontier under expansion, with strong land concentration due to the presence of large banana plantations (Ginni coefficient 0.771). Nevertheless, there

exists an important small farmer subsector (65% of farms are smaller than 20 ha) with an average area of 17.4 ha.

Labor for agricultural production appears to be a critical factor limiting regional production due to demand for labor in banana plantations. This issue also was detected at the farm level, and it affects the total land area under production. The intensity of labor use is correlated with the precipitation distribution pattern (Figure 2).

Small farmers devote the most productive land to livestock and annual crops for which a fairly adequate supply of both inputs and credit exists. A market for maize is guaranteed by a government program, but this is not the case for dairy products. At the time this project began, a difficult access road existed, but a new main highway for rapid access to the national capital is under construction.

At the small farm level, approximately 39% of farmland was in fallow, 32% in pasture 17% in annual crops, and 12% in perennial crops. Land in maize represented 77% of the land in annual crops. The average farmer plants 3.6 ha of maize in the first cropping season, and 1.2 ha in the second season for an average area of 2.4 ha per year. Other important agricultural products in addition to livestock and maize are cassava, maize and cassava grown together, and other root crops. Cocoa, peach palm, and plantain are the most common perennial crops (Escobar and Moreno, 1984). Family labor provides about 50% of the total labor used in the farm. The level of technology used by various farmers was highly diverse, perhaps as a result of the relatively recent agricultural development of the region. The farmers are from different places of the country, each with different technologies and agricultural customs developed in a large variety of ecological environments. Farm income is derived basically from livestock and maize-based cropping systems: net maize income represents about 58% of total net farm income, suggesting its economic importance.

Crop losses due to aerial insects are very small, but precipitation levels appeared to be a major constraint with maize production, especially during the second growing season. Credit supply and commercialization channels were not determined to be important constraints to maize production.

Weed control seemed to be the main production problem at the maize cropping systems level. Approximately 45% of total labor is used for weeding, and 40% of cash expenditure goes to herbicides. We defined agroeconomic constraints in terms of our hierarchical characterization: labor supply was short at both the level of region and farm; weed control was the major limitation at the cropping system level. These were constraints that were necessary to take into account when designing any technological alternative.

Alternative Technology Design

The diagnostic from the characterization phase suggested that we concentrate our efforts on vegetation management improvement, with the possibility of deriving new technologies useful in several cropping

systems. Weed control techniques practiced by farmers were related to soil preparation patterns. These two aspects were selected to focus technological improvement in the subsequent methodological problems.

The initial design to introduce changes only on vegetation management practices was maintained for four years, but some other production components were incorporated from time to time in response to results from on-farm experimental trials. For example, new maize varieties and fertilization levels were added in several experiments and soil insect control became a permanent component of crop management along with weed control practices. CATIE's agricultural scientists grouped the small farmers according to the predominant type of weeds, and the soil preparation techniques (e.g. mechanized vs non-mechanized, annual weeds vs perennial weeds) for on-farm experimental trials.

Moreover, CATIE in collaboration with other international agencies, decided to develop a more comprehensive set of technological alternatives using vegetation management and soil preparation technology as a part of the more complex alternative. The vegetation management experience is the subject of this analysis in order to keep it simple and more illustrative.

On-Farm Experimental Trials

Immediately after the design phase several experiments were conducted on the farms located throughout the working area. Table 1 is an example of the type of experiments done and the basic economic results obtained.

Results of the experimental trials for each cropping season were analyzed for economic effectiveness in a very straightforward manner, including estimates of: 1) net income; 2) production return to cash and labor invested; and 3) farmer's reactions to experiments they helped to conduct. These simple indicators were compared with similar estimates for the farmer's own existing technologies on their own maize plots, as well as with baseline comparison data obtained during the characterization phase. Data from the dynamic farm record keeping should feed these analyses, but at that time the methodological development did not include this activity.

The technological alternative was approved for the validation/transference phase if the trial results were found to be significantly higher than those for the farmer's own fields, reasonably stable over time, and reproducible at various sites. Economic analysis was applied to help decide which of these treatments yielded the most promising results on actual farms. An example of the application of this analysis is given for the case of technological alternatives for perennial weed control in Figure 3.

We estimated a production function using a two variable regression fit to all comparable experimental results during almost four years of experiments. Cost functions were derived from this data and the optimum production level was estimated, as shown in the bottom part of Figure 3.

We found that five of the experimental treatments gave results that were not significantly different from the theoretical optimum level of 3988 kg/ha within the 95% confidence interval of this, assumed normal, yield distribution. These data are shown in Table 2. Since fertilization levels did not contribute to yields in these particular experiments, treatments 1 and 2 became similar and the cheapest alternatives among the optimum experimental results.

Comparison of several economic indicators demonstrated the advantage and the attractiveness of the selected treatment. As given in Table 3, the least cost optimum alternative (treatment 1 or 2 in Table 2), the average of all optimum treatments, and the lower yield replication of the least cost treatment, compare favorably in every indicator to the most common farmer's technology for the maize cropping systems.

We included in the simple economic analysis an estimate of the cost constrained net cash income maximization, using the local bank maximum maize production loan to cover variable costs which does not include labor costs. We evaluated this hypothetical situation to account for farmers with no working capital and no family labor. In this case, farmer's actual technology appears slightly superior in all indicators by the rate of return to cash costs.

Validation

Following the methodological sequence, we initiated the validation phase in the first cropping season with 35 farmers who planted maize under the technological alternative of weed control and weed control + insect control with plot size of 1000m2 each. At the same time they conserved their own technological pattern in the rest of the land devoted to maize. Data summarizing basic agroeconomic results in the first cropping season are given under columns headed with A in Table 4.

The technological alternatives including insect control and the use of fertilizer, in addition to the weed control, did not yield economic results that appear attractive to small farmers. For this reason, we recommended to continue on-farm experimental trials to tune-up such an alternative. This issue materialized the feedback process between the experimental trials and the validation phase, demonstrating the contribution of both the validation trials and the simple applied economic analysis as a decision-making tool.

Due to the evaluation of participating farmers and the available experimental support, during the second cropping season we submitted to validation trials a technological alternative combining the weed and the soil insect controls, while we kept the weed control and the farmer's technology in the same fashion of the first cropping season. Corresponding data appears in the columns headed with B in Table 4. In general, the overall comparison does not show significant cash income differences among technological alternatives, but the farmer's production strategy for this season is far less expensive than the two proposed alternatives. These findings suggested that not all technological alternatives yielded the expected agroeconomic results obtained during on-farm experimental trials. Based on these data, the weed control

alternative was selected as the only promising validated alternative for the first cropping season which happens to be the major maize season of the year.

Further analysis of the validation trials included the separation of results in Table 4. We learned that the weed control alternative presented differences according to the predominance of annual or perennial types of weeds in each farm: perennial weed control requires a higher cash expenditure and returns to input costs are lower than those obtained in annual weed control (Escobar and Shenk, 1981).

The former differences became evident when the promising alternative is compared with the farmer's own technological pattern. As presented in Table 5, a partial budget analysis for the proposed alternative shows a negative additional return in farms with predominant perennial weeds, while the rate of return on additional costs is about 60% in farms where annual weeds are predominant.

From the previous analysis, we concluded that as far as the cropping production systems is concerned, the only technological alternative feasible for farmer's implementation is the weed control alternative for farms in which annual weeds predominate. All other alternatives examined in the validation trials as well as the perennial weed control, must return to the design-field research process. Another validation round will be needed before these alternatives could be released for massive diffusion to farmers.

Dynamic Farm Records

This activity was completed during the validation phase although it is designed to feed all TD phases. In the case of the Costa Rica Atlantic zone, the methodological development was not completed as presented in Figure 1, by the time of the on-farm trials implementation.

The farm record consists of an input-output set of data recorded through weekly visits during the two validation cycles, and sparce visits to participating farmers in the following cropping year for monitoring adoption of weed control practices.

Two basic products are obtained from these farm records: a) the technical coefficients of every farm production system; and b) the evaluation of farmers who have totally or partially adopted the weed control techniques to which they were exposed during the validation phase. The technical coefficients permit the evaluation of the technological alternative within the entire farm system context as implied by the selection of the target system for the FSR/TD activities. The record of adoption of the technological alternative allows the orientation and planning of the technology diffusion by the corresponding national extension institution.

The role of economic analysis is more active in evaluating the appropriateness of the validated technological alternative at the farm system level. However, the selection of an evaluation method simple enough to be repeated by field teams is very important. Economists could

approach such an evaluation from different perspectives utilizing fairly sophisticated analytical tools. For this specific case we decided to follow the simplified programming method due to its simplicity and the actual reliability, since there is no major reason to expect very different results by using other linear analytical methods.

The results of the programming presented in Table 6 include the technological alternative for maize production in plots where annual weeds are predominant. It must be mentioned that the evaluation at the entire farm level as shown in Table 6 did not allow variations in perennial crops; we assumed, for simplicity, that decision and investment in perennial crops are not likely to be changed in the short run, due to the nature of the production activity. Nevertheless, accounting for all annual crops and livestock, the optimal farm plan includes the weed control maize production system for the first production cycle, but kept the farmer's traditional technology for the second cycle; these results are consistent with the economic evaluation of the results obtained from the validation phase.

The reliability of this programming technique was checked by a linear programming algorithm with the same basic results in terms of the activities included with optional farm plan solution. (Escobar and Moreno, 1984). From the applied economic analysis viewpoint, this is a meaningful result since the simplicity of the manual programming brings about the capacity of replication of the analysis, keeping in mind the restriction and limitation of the linear models.

The other major concentration of the farm record keeping is the monitoring activity which is intended to evaluate the adoption of specific production techniques by those farmers who were exposed to the technological alternative during the validation phase. Data recorded during the following cropping year allowed the classification of farmers into four adoption groups, as shown by the bars in Figure 4. This classification goes from a group of non-adopters of any of the recommended practices (Group 1), to a group of full adopters (Group 4). The separation between the second and third group depends upon the use of a handmade herbicide application shield which was provided to farmers during the validation phase.

The partial and total adoption groups in Figure 4 (Groups 3 and 4) represent about 62% of the expected population of adopters. However, the difference between groups 3 and 4 is given by the rate of chemicals used by farmers in relation to the recommended levels. This aspect could be very important for farmers to attain economic optimum due to the cost of chemicals and the labor use involved in the weed control.

Some site and economic characteristics were analysed in association with the adoption behavior. An illustration with lines appears in Figure 4, besides the bars representing the adoption groups. There seems to be a direct relation between the degree of technology adoption and the labor use maximization, judging by the increment in the returns to total farm labor and family labor devoted to maize with the adoption groups. These findings are consistent with the seasonal labor constraint determined during the characterization phase which could induce farmers to maximize

the use of this production factor. On the contrary, we found that other indicators like the return to farm cash cost does not follow the same path since it decreases for groups 2 and 3 in comparison with the non-adopters group. For the full adopter group, however, we found the higher returns to both labor and cash production costs.

Several options exist to pursue the analysis of the adoption of the technical alternative which could be helpful for the phase of massive diffusion through extension techniques. We have used a linearized discriminant function to obtain classification coefficients to predict the adoption behavior of a farmer, based upon a set of twelve variables including farm site, factor utilization, and personal characteristics (Escobar and Moreno, 1984). However, we feel the need for developing a less sophisticated analytical tool that could be applied by a field technical team. A method using the accumulated knowledge available to researchers and extensionists should be explored before the application of standard multivaried statistical techniques.

Final Remarks

The application of economic analysis to the FSR/TD activities demonstrates, in our view, three main issues. First, economic analysis is a continuous activity during the entire process. This means that an economist or a biologist with training in applied economics should integrate the multidisciplinary team from the beginning of the FSR/TD. Second, results of the economic analysis must be interpreted according to the agronomic and biological results. This means that economic results constitute actual support information for decision-making but cannot replace biologists' results and farmers' reactions to real on-farm applications. Third, in order to make a contribution to the field team, the economic analysis must be farm applied and very simple. During the FSR the focus of the analysis is the farm system within the hierarchical order, and during the TD activities, the concentration of the economic analysis is on the technology generation and its evaluation. In both cases, the use of simple analytical tools is mandatory since every member of the multidisciplinary team has to interpret these results.

Several implications can be derived from the above considerations to link technology generation and extension. First, the extensionist who is a member of the FSR/TD team for a specific area is aware of agro-economic characteristics of the technological alternatives he/she is to diffuse; as a corallary, such a field team must be formed by researchers (biologists, social scientists, extensionists, and farmers). Second, the validation phase and the monitoring activity in which adoption behavior and some farm characteristics are analysed, improve the extension planning and programming capacity. Farmer's adoption strata could be identified by quantitative characteristics, and target farmer groups for the short and long run could be separated for diffusion purposes. Third, a continuous monitoring during the diffusion phase in conjunction with the simple economic analysis would allow for the determination of the final structural changes in the farm system strata. This would be very useful in improving the application of the FSR approach.

REFERENCES

Banta, G. 1982. Asian Cropping Systems Research: Microeconomic Evaluation Procedures. IDRC-197E. Ottawa.

Centro Agronomico Tropical de Investigacion y Enseñanza (CATIE). 1979. Descripcion de Una Alternativa para el Sistema Maiz-Maiz Practicado por los Agricultores de Guacimo y Pococi, Costa Rica. CATIE, Turrialba, Costa Rica.

Escobar, G. 1981. Delimitacion y Cuantificacion del Area de Trabajo en el Atlantico Norte de Costa Rica. Documento Interno de Trabajo IPPC/CA 333. CATIE, Turrialba, Costa Rica.

Escobar, G. y M.D. Shenk. 1981. Validacion de Dos Opciones Tecnologicas para el Sistema de Produccion Maiz-Maiz Utilizado por los Pequeños Productores del Atlantico de Costa Rica. Serie Tecnica. Informe Tecnico No. 23. CATIE, Turrialba, Costa Rica.

Escobar, G. y M.D. Shenk. 1982. Validacion de Tecnologia en Control de Malezas para Pequeños Agricultores: Analisis de Eficiencia Economica Relativa. Desarrollo Rural en las Americas No. 3.

Escobar, G. J. Henao y M.D.Shenk. 1983. Assessing Adoption of Technology Among Small Farmers: Classification and Profile Analysis. Paper presented in the Third Annual Farming Systems Research Symposium, Manhattan, Kansas State University. Oct 31-Nov.2, 1983.

Escobar, G. y R.A. Moreno. 1984. Desarrollo de Tecnologia para Sistemas de Produccion Agricola: Enfoque Metodologico y Applicacion. CATIE, Turrialba, Costa Rica.

Feder, G., R. Just and D. Zilberman. 1981. Adoption of Agricultural Innovations in Developing Countries: A Survey. World Bank Staff Working Paper No. 444. Washington, D.C.

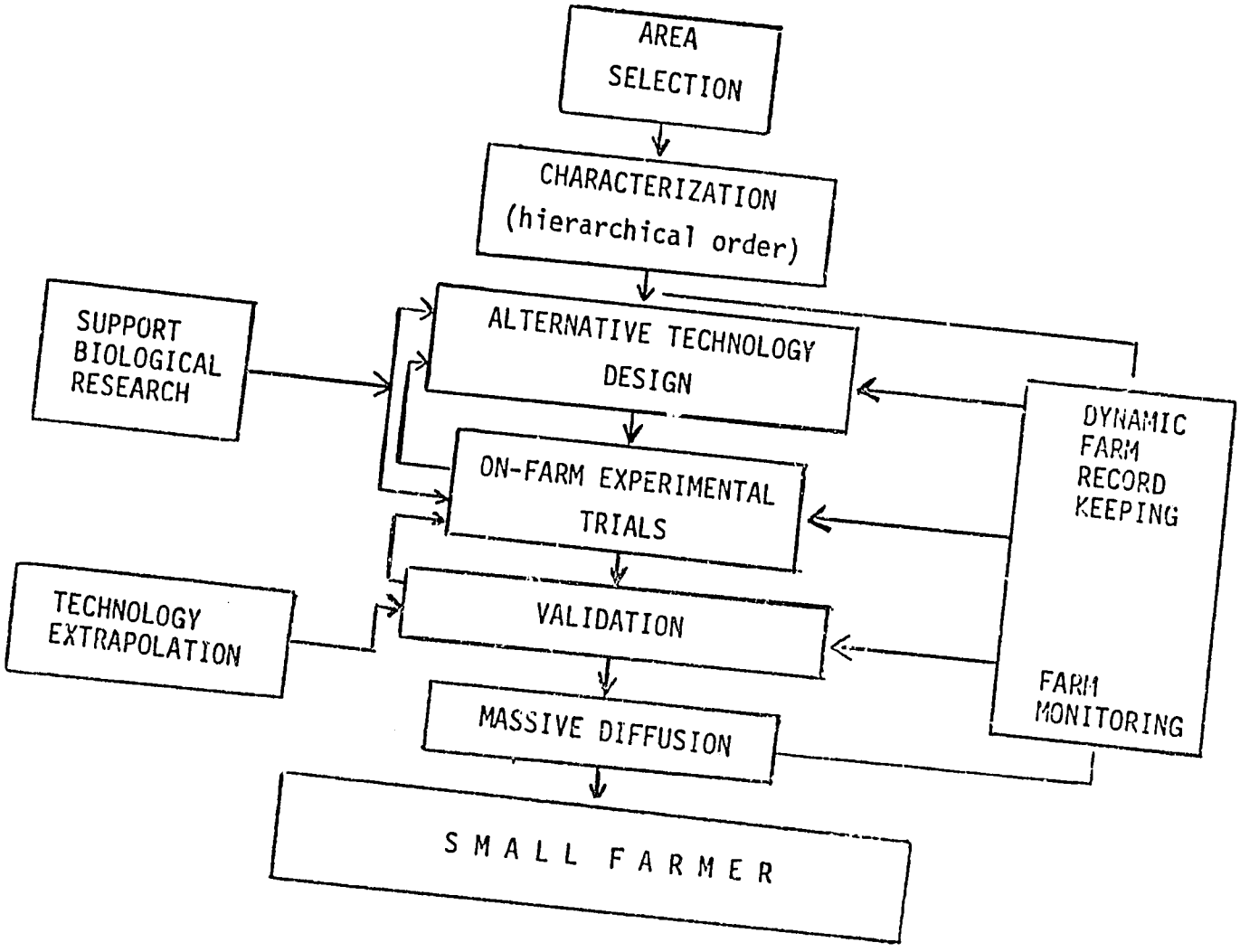
Moreno, R.A. 1984. Desarrollo de Tecnologia con Agricultores en el Tropico Bajo Humedo de Costa Rica. En impresion. CATIE, Turrialba, Costa Rica.

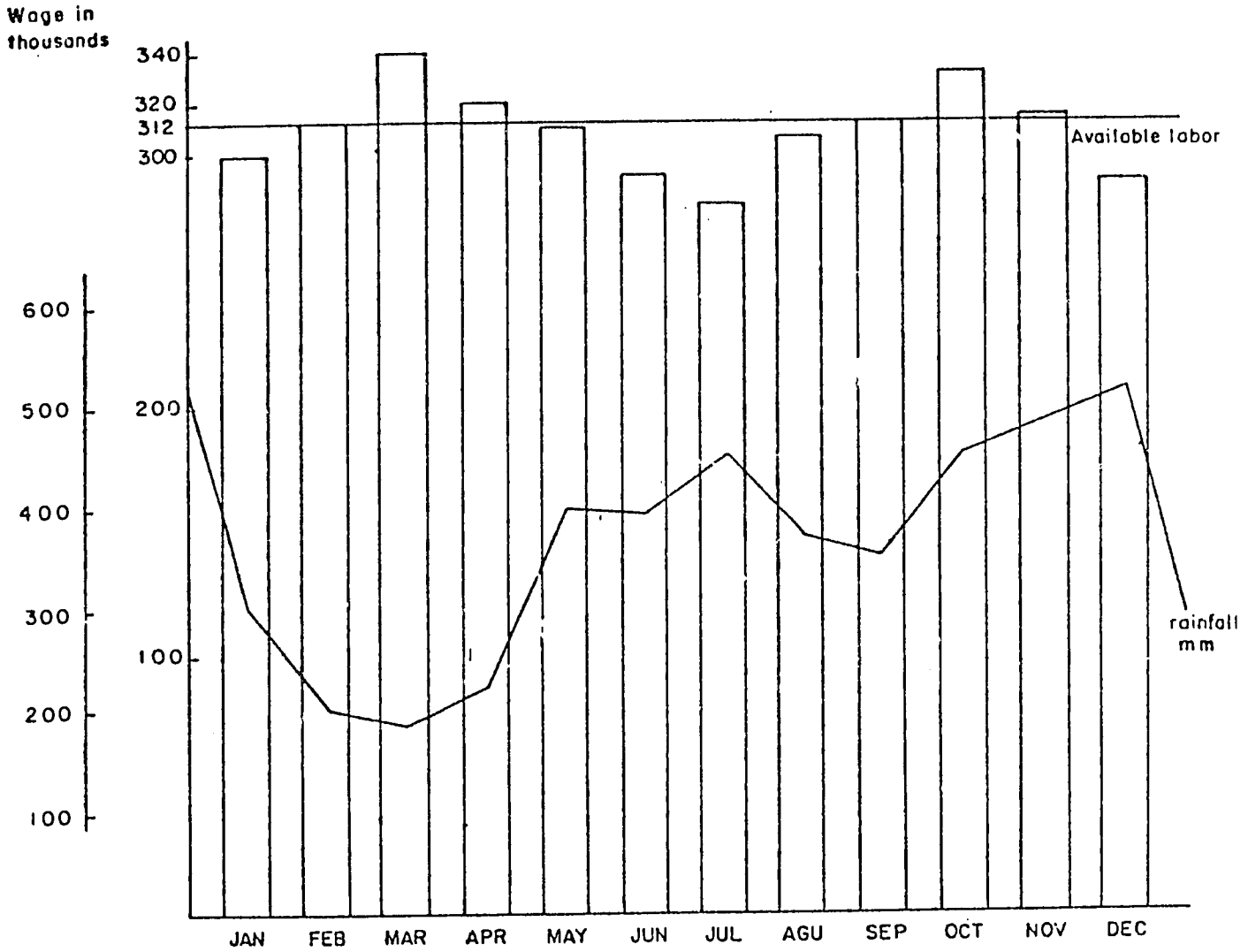
Navarro, L.A. 1979. Seleccion y Caracterizacion de Areas como Guia a la Investigacion Agricola Aplicada. CATIE, Turrialba, Costa Rica.

Plucknett, D.L., E.J. Rice, L.C. Berril, and H.H. Fisher. 1976. Approaches to Weed Control in Cropping Systems. In: Proceedings. Symposium on Cropping Systems Research and Development for the Asian Rice Farmer. International Rice Research Institute. Sept. 21-24, 1976.

Shenk, N.D., J. Saunders, and G. Escobar. Labranza Minima y no Labranza en Sistemas de Produccion de Maiz (Zea mays) para Areas Tropicales Humedas de Costa Rica. Serie Tecnica. Boletin Tecnico No. 8. CATIE, Turrialba, Costa Rica.

Figure 1. Phases of the CATIE's Farming Systems Research and Technology Development Methodology.





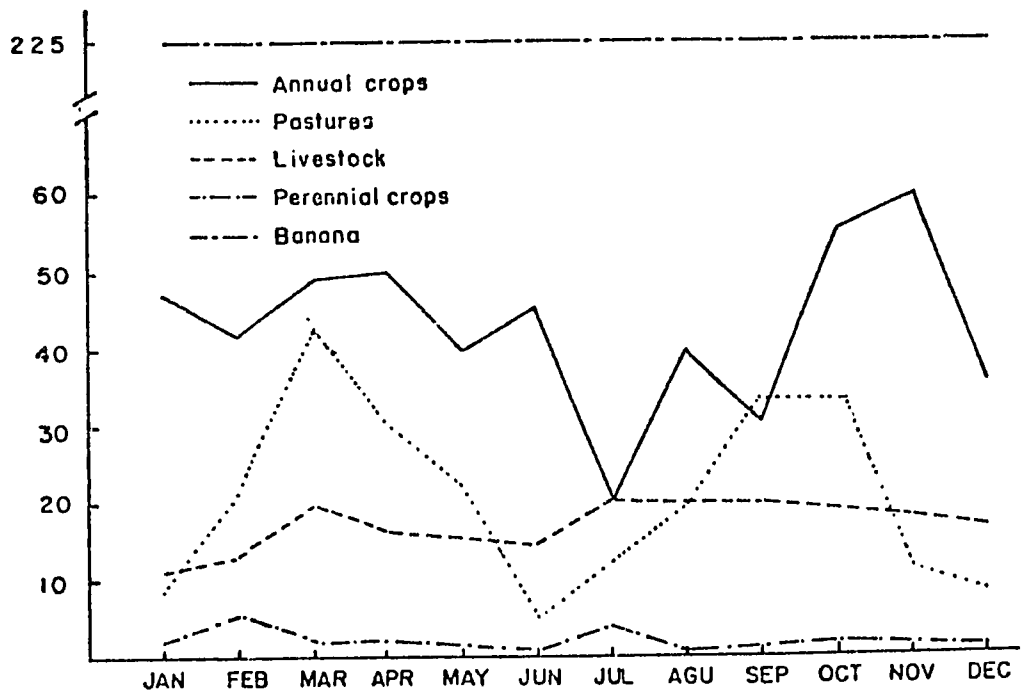
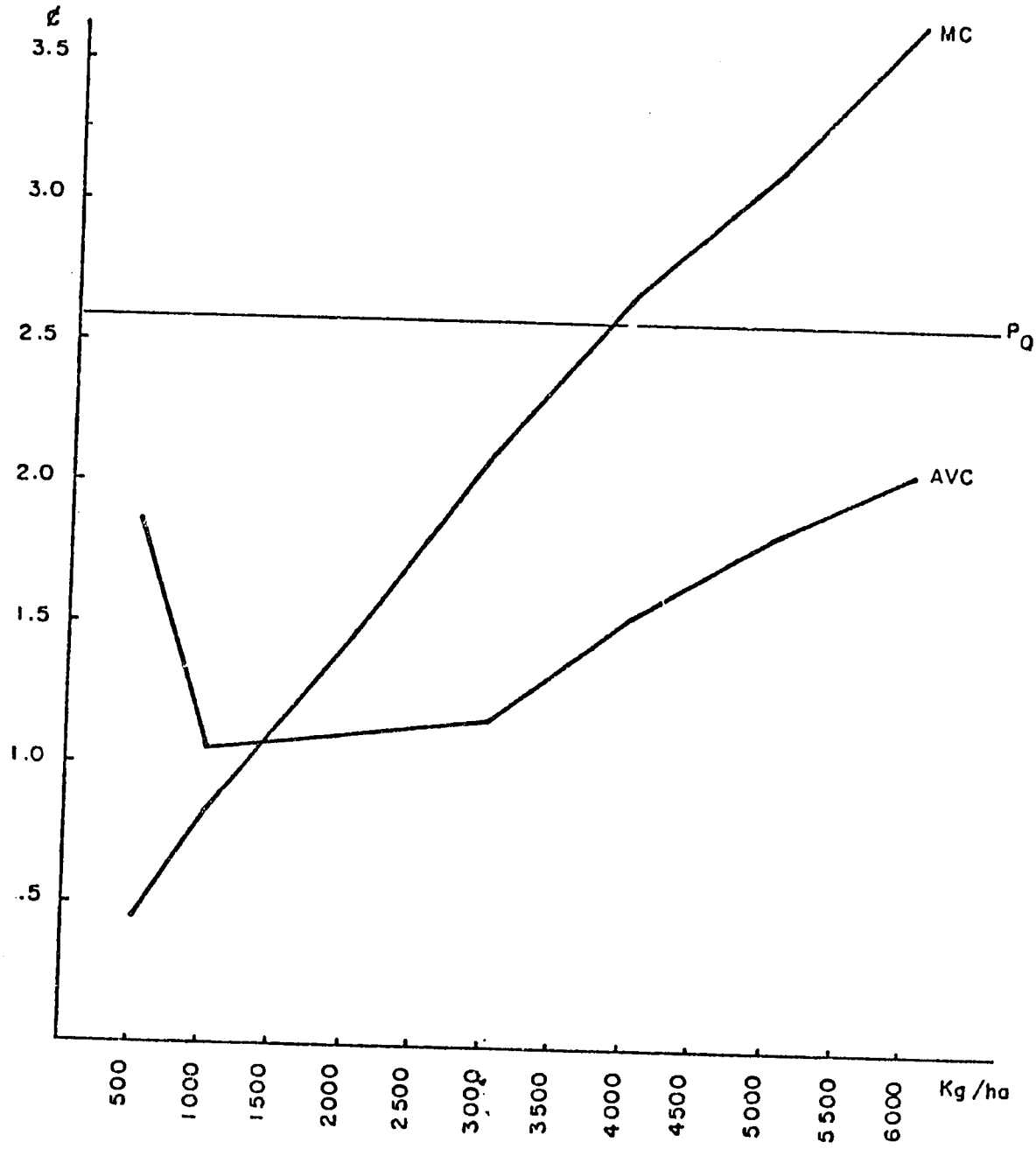


FIGURE 2. Labor distribution at the area level (upper) and by farm activities (lowers)

FIGURE 3. AVERAGE VARIABLE COST AND MARGINAL COST CURVES FOR MAIZE PRODUCTION PERENNIAL WEEDS. MAY 1.980 PRICES.

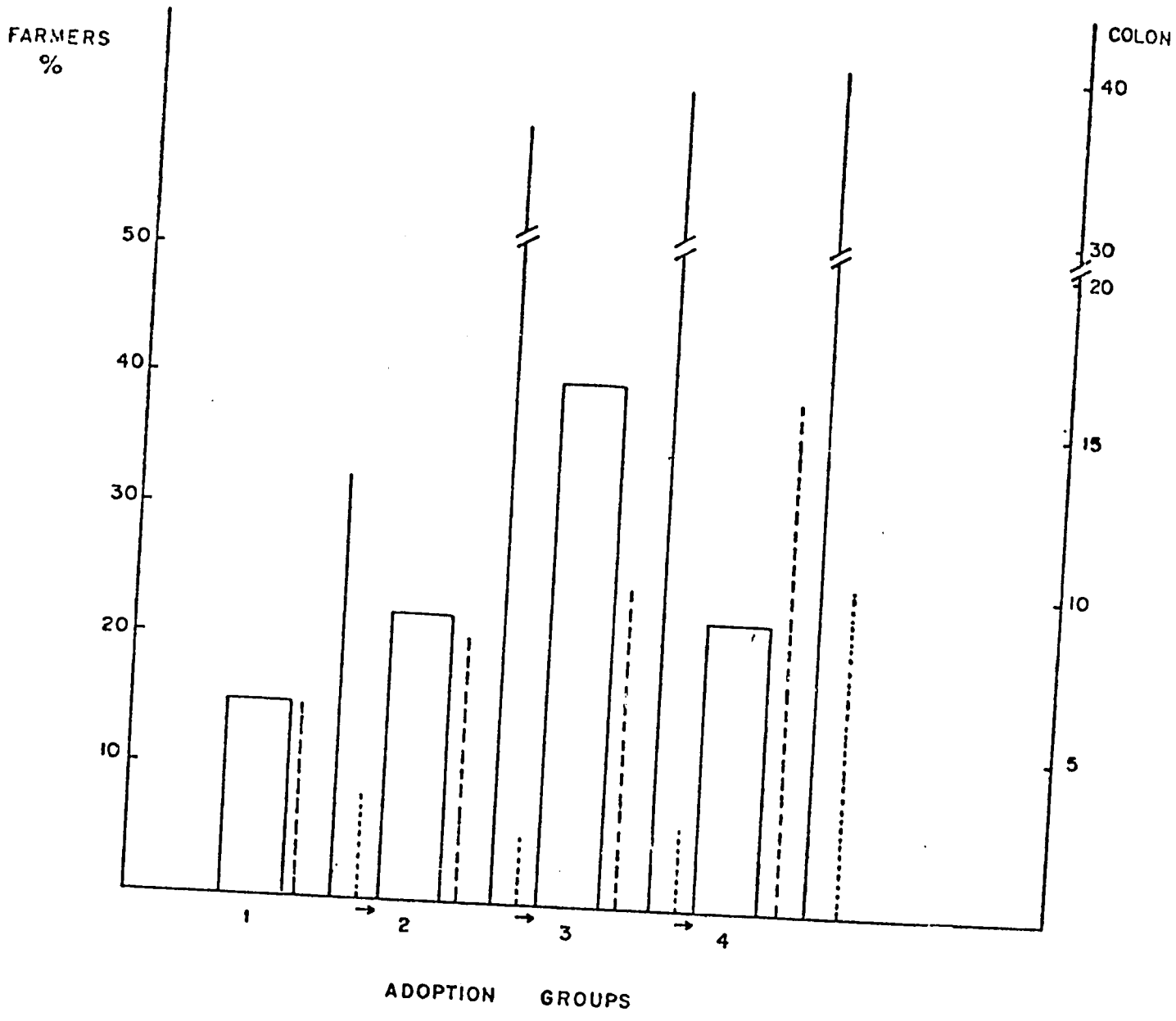


$Q = 250.996\ L^{.445}\ K^{.004}$ $R^2 = .637$

$C = 600 + .0016\ Q^{1.82}$

$MC = P_Q$ at 3987.5 Kg/ha

FIGURE 4. DISTRIBUTION OF MONITORED FARMERS BY ADOPTION GROUPS. NORTH ATLANTIC COST A COSTA RICA. 1.983



------ RETURN TO TOTAL FARM LABOR (¢/HOUR)

——— RETURN TO FAMILY LABCR INTO MAIZE PRODUCTION (¢/HOUR)

..... RETURN TO FARM CASH COST

Table 1. Maize yield, weed control cost expressed both as Colons/ha and as percentage of the cost of existing technology for farms with predominant annual weeds. Cariari, Costa Rica. August 1977 and January 1978.

Systems 1/	Maize yield (kg/ha) 1977	1978	% Improvement 1977	1978	Weed control cost (₡ ha) 2/	Cost as a % of the cost of farmer's existing technology
Plow + manual weeding 25 DAP	2277	4280	66	15	770	107
Plow + atrazina pre (2.0 kg/ha)	2414	--	76	--	729	101
Plow + paraquat 25 DAP (0.5 kg/ha)	2626	4431	92	19	719	100
Mulch + manual weeding 25 DAP	2613	4302	91	16	630	88
Glyphosate 8 DBP (1.3 kg/ha)	3177	4769	132	29	645	90
Paraquat 8 DBP (0.75 kg/ha)	2487	4381	82	18	342	48
MSMA 8 DBP (5.0 kg/ha)	1831	4117	34	11	378	53
Paraquat 8 DBP and 25 DAP (0.5. kg/ha each)	--	4563	--	23	561	78
CV%	19.0	10.0				
MSD (.05) (kg)	702	n.s.				

1/ DAP = days after planting
DBP = days before planting
Pre = preemergence
2/ US$1= 8.54 ₡

Source: Shenk, M.D. et al (12)

Table 2. Experimental yields that are not significantly different from the estimated oprimum production level for farms with predominant perennial weeds, May 1980 prices.

Treatments	kg/ha	Cash[1/] Costs	Cash cost without[2/] fertilizer
Glyphosate (1.3 kg/ha) 8 DBP + Paraquat (.2 kg/ha) 45 DAP 40-28-9	4090	5062.2	3920.9
Glyphosate (1.3 kg/ha) 8 DBP + Paraquat (2. Kg/ha) 45 DAP 0-0-0	4180	3895.9	3895.9
Glyphosate (1.3 kg/ha) 8 DBP + Paraquat (.2 kg/ha) 45 DAP 40-0-0	4250	4821.1	3965.9
Glyphosate (1.3 kg/ha) 8 DBP + Paraquat (.2 kg/ha) 45 DAP 40-0-0 + Carbofuran (.5kg/ha9	4350	5437.3	4582.1
Glyphosate (1.3 kg/ha) 8 DBP + Paraquat (.2 kg/ha) 45 DAP 40-28-9 + Carbofuran (.5 kg/ha)	4280	5678.4	4537.1
x all treatments	4230	4974.9	4285.4

1/ Includes imputed value to family labor accroding to the current wage rate in the area.

2/ Fertilizer costs are not taken into account due to the statistical analysis showing no significant difference in yield attributable to fertlization levels.

Table 3. Cash net income and return to production factors in maize. Promissing technological alternatives, least experimental yields, farmer's technology and constrained cost output maximization. May 1981 prices/ha.

Indicators	Least cost optimum treatment	Average of all optimum treatments	Farmer's technology	Level yield of least cost treatment	Cost constraint optimum treatment (VC = ₡2500)
Input cash costs	2076	2350	1959	2076	1184
Labor (man-days)	40	43	33	40	32
Total variable costs[1/]	3876	4285	3444	3876	3242
Gross income	10634	10998	6804	8840	5642
Net cash income	8558	8647	4845	6764	4458
Return to land	4475	4127	1885	2680	1697
Return to cash cost	6158	6113	2760	4364	2400
Rate of return to cash cost (%)	297	260	141	210	203
Return to total labor	7750	7813	4051	5956	3740
Return to man-day	194	182	123	149	115

Table 4. Agroeconomic results of two technological alternatives for the maize production system, cropping seasons (A & B) and prices of 1981 (standard deviations in parenthesis).

Alternatives	N		Kg/ha		(Colons/ha)		(hours/ha)		Net Cash Income 2/	
	A	B	A	B	A	B	A	B	A	B
Weed control	32	22	3075[a] 1/ (764)	2386[ce] (561)	2819[f] (1283)	1286[i] (843)	197[k] (91)	244[l] (67)	3698.5	2827.6
Weed control + soil insect control + fertilization	32	--	3272[a] (909)	--	4985[g] (710)	--	235[k] (70)	--	2659.7	--
Weed control + soild insect control	--	27	--	2248[de] (762)	--	964[i] (689)	--	273[l] (57)	--	2833.3
Farmer's actual technology	34	33	2617[b] (770)	2032[d] (438)	1959[h] (1001)	548[j] (379)	198[k] (81)	255[l] (84)	3360.2	2822.7

1/ Different letters are significantly different at $\alpha = 0.05$. or less, ordered by columns.

2/ Total labor was priced at 1981 wage rates for net cash income estimation.

Table 5. Partial budget analysis for the weed control alternatives for maize production, separated by predominant type of weeds. 1981 prices.

	PERENNIAL WEEDS		ANNUAL WEEDS	
Additional Costs				
Insectice	1049.8		141.5	
Fertilizer	684.5		437.6	
Herbicide	1310.3		253.4	
Labor	106.4		---	
Land preparation	---		252.6	
TOTAL ADDITIONAL COSTS		3151.0		1067.1
Reduced Costs				
Land preparation	145.8		---	
Herbicide	---		158.9	
TOTAL REDUCED COSTS		145.8		158.9
Net Additional Costs		3005.2		908.2
Additional Receipts				
Value product	1167.9		1445.7	
TOTAL ADDITIONAL RECEIPTS		1167.9		1445.7
Addition receipts - net additional costs		-1837.3		536.5
Return on net additional cost (%)		---		59.2

Table 6. Optimal farm plan including annual weed control technological alternative. Simplified programming solution prices 1984. (Colons).

RESOURCES / ACTIVITIES	LAND (has)		LABOR		CAPITAL		System Net Income
	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	
Maize cycle I.Technologial alternatives	3.8	-	111.7	-	8449	-	27009.4
Main cycle II.Farmer's technology	-	3.8	-	115.3	-	3785	5943.6
Livestock (10 cows and 7 calfs)	-	-	24	24	1529	1529	29977.8
Pasture	5.5	5.5	25	17	413.6	279.5	-
Peach Palm	.38	.38	21.2	10.1	592.9	148.4	2024.5
Cocoa	1.4	1.4	25.8	25.8	438.7	438.7	653.4
Land in bushes	6.5	6.5	-	-	-	-	-
Unused Resources	-	-	50.5	36.6	44.2	.23	-
Total Net Income							65608.7