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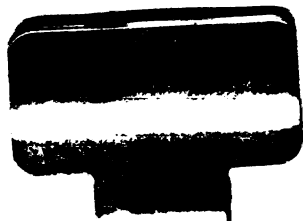


Consultant Final Report
IICA/EMBRAPA-PROCENSUL II
OPERATIONS RESEARCH ANALYSIS

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OPERATIONS RESEARCH ANALYSIS

Consultant Final Report
IICA/EMBRAPA-PROCENSUL II

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Roy Nord

Brasília, junho de 1989

INSTITUTO INTERAMERICANO DE COOPERAÇÃO PARA A AGRICULTURA
EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA

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APRESENTAÇÃO

A reprodução e difusão dos Relatórios de Consultores, no âmbito restrito das Diretorias das Unidades do Sistema Nacional de Pesquisa Agropecuária, vinculado à EMBRAPA, tem como objetivo principal o de divulgar as atividades desenvolvidas pelos consultores e as opiniões e recomendações geradas sobre os problemas de interesse para a pesquisa agropecuária.

As atividades de consultoria são realizadas no âmbito do Projeto de Desenvolvimento da Pesquisa Agropecuária e Difusão de Tecnologia na Região Centro-Sul do Brasil - PROCENSUL II, financiado parcialmente pelo Banco Interamericano de Desenvolvimento - BID e a EMBRAPA conforme os contratos de Empréstimo 139/IC-BR e 760/SF-BR, assinados em 14 de março de 1985 entre o Governo Brasileiro e o BID.

As opiniões dos consultores são inteiramente pessoais e não refletem, necessariamente, o ponto de vista do IICA ou da EMBRAPA.

A coordenação dos Contratos IICA/EMBRAPA agradecerá receber comentários sobre estes relatórios.



Horacio H. Stagno
Coordenador Contratos IICA/EMBRAPA

INTER-AMERICAN INSTITUTE FOR COOPERATION ON AGRICULTURE
IICA/EMBRAPA CONTRACT

CONSULTANT FINAL REPORT

1. Consultant's full name: *Roy A. Nord*
2. Specialist in: *Operations Research Analysis*
3. Title of IICA Project: *2.SB.3*
4. EMBRAPA Program for which consultancy is provided:

PROGRAMA: *PROCENSUL II*

SUB-PROGRAMA: *09-AVALIAÇÃO EX-POST*

IICA Project Activity Code: <i>2.SB.3.09</i>		Administrative Code: <i>R 4884 B1B 03109</i>	
Title of Activity of IICA Project corresponding to this consultancy	<i>Cooperation with EMBRAPA for the definition of an ex-post evaluation system for PROCENSUL II.</i>		
CONSULTANT CONTRACT PERIOD	DUTY LOCATION (Center)		
<i>August 7th. to 27th., 1988</i>	<i>SEP/CPL-EMBRAPA</i>		
CONTRACT EXTENTION PERIOD (If any)	DUTY LOCATION (Center)		

5. Financial support: *PROCENSUL II*



6. ACTIVITIES UNDERTAKEN BY THE CONSULTANT AND RESULTS

6.1 RESEARCH DONE UNDER DIRECT RESPONSIBILITY OF THE CONSULTANT

Research activities developed	Results Achieved
<p>1a. Undertake preliminary empirical analyses of currently available files to assess current state of human capital stocks and flows at EMBRAPA.</p>	<p>1b. A general descriptive analysis of the data focusing on EMBRAPA's senior research staff was completed. A preliminary analysis of trends in human capital acquisition and formation at EMBRAPA was also completed. The results of these analyses were presented at a seminar for EMBRAPA researchers on August 17, and are summarized in the attached paper.</p>

6.2 SUPPORT TO RESEARCH UNDERTAKEN BY OTHER ENBRAPA RESEARCHERS

Research activities developed	Results achieved
<p>1a. Worked with staff from EMBRAPA's Human Resources Department to identify data sources and research strategies that would be most useful in supporting both the Human Capital research undertaken under this contract and the ongoing in-house research on personnel issues.</p>	<p>1b. Historical personnel records as well as files containing information on post-graduate education activities of EMBRAPA employees were examined. Variables of potential use for research purposes were identified, and arrangements were made for the preparation of extracts from the files. Preliminary plans for collaboration on several aspects of the human capital project were also developed in the course of several meetings between EMBRAPA human resources staff, myself, and Dr. Vosti.</p>

6.3 TRAINING ACTIVITIES DEVELOPED BY THE CONSULTANT

Date	Training subject matter	Type of event*	Number of beneficiaries	
			From ENBRAPA	From other institutions
Aug. 17	Human Capital Research -- Seminar (with Dr. Vosti)		30	5

* Short courses, seminars, conferences, etc.

6.5 ACTIVITIES IN SUPPORT OF RESEARCH STRATEGY AND PLANNING

Research subject matter	Research program to which subject matter is concerned
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- 1a. Clarification of EMBRAPA's perceptions and concerns with respect to human capital issues and problems.
- 1b. Extensive discussions were held with both management and research personnel to determine the human capital issues of greatest importance to the intended users of the results of the human capital components of this research effort. This activity was considered essential both to insure that the research effort is focused on problems of interest to the organization and to bring institutional knowledge of those problems to bear on the research design.
- The results of these discussions are summarized in the attached paper.

6.7 PUBLICATIONS AND REPORTS UNDERTAKEN WITH THE CONSULTANT'S PARTICIPATION

Author(s)*	Title of publication or Report and other bibliographic identification
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Roy Nord and Stephen A. Vosti, "Quantity, Quality, and Productivity of Human Capital at EMBRAPA: An Analytical Approach and Some Preliminary Results", IFPRI Mimeo.

* Personal, Institutional, etc.

7. OTHER NATIONAL SYSTEM CENTERS, APART FROM DUTY STATION CENTER, ASSISTED BY THE CONSULTANT

Research center	Area of assistance provided by the consultant
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Visited the CPAC (Cerrados Research Center) to discuss human capital issues, and develop a better understanding of the day-to-day processes involved in doing research at EMBRAPA.

B. CONSULTANT'S SUGGESTIONS AND TECHNICAL OR INSTITUTIONAL RECOMMENDATIONS FOR THE
IMPROVEMENT OF THE RESEARCH SERVICE

I encountered some minor problems in obtaining the proper visa prior to departure from Washington, but Horacio Stagno was most helpful and efficient in obtaining the necessary upgrade after my arrival in Brasilia.

Overall, I found my visit very productive, and am grateful for the assistance of IICA's staff in Brasilia in making it so.

9. AGREEMENTS OR COMMITMENTS ESTABLISHED WITH EMBRAPA RESEARCHERS IN-SERVICE OF
THE FUTURE DEVELOPMENT OF RESEARCH IN THE CONSULTANT'S FIELD OF SPECIALIZATION

As noted earlier, the foundations for continued collaboration with EMBRAPA staff in the human resources area were laid. I look forward both to the completion of the research outlined in the attached paper, and to continued development of the collaborative efforts begun during this visit.

10. CONSULTANT'S COMMENTS ON CIRCUMSTANCES WHICH AFFECTED THE CONSULTANCY WORK

As noted earlier, I believe my time in Brasilia was well spent. I am most grateful to the many individuals at EMBRAPA who provided assistance and cooperation as well as hospitality during my stay. I hope to continue the fruitful partnership developed during this visit.

Date:

12/5/88

Signature

Roy D. Moul



A N E X O

COMMENTS

The IICA/EMBRAPA Contract PROCENSUL II finances part of the activities considered in the EMBRAPA/IFPRI Collaborative Research Program. The Consultant Dr. Nerd is member of the EMBRAPA/IFPRI team, and is co-author of several publications on studies developed by the last mentioned contract.



QUANTITY, QUALITY AND PRODUCTIVITY OF HUMAN CAPITAL
AT EMBRAPA: AN ANALYTICAL APPROACH AND SOME
PRELIMINARY RESULTS

Roy Nord
Steve Vosti
September 25, 1988

INTRODUCTION

This paper describes a study intended to investigate some important aspects of the formation, change, and development of human capital within an applied agricultural research organization. The project will be undertaken as a collaborative effort between researchers from the International Food Policy Research Institute and from Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA). The study has two primary purposes: first, to provide information that can be used by EMBRAPA managers to improve their planning and management of human resources within the organization; and second, to develop and test the utility of some new approaches to analysis of human capital policies within applied research organizations in general. The research will focus on two important aspects of human capital management: a) changes in the quantity and quality of human capital stocks over time, and b) factors that affect the productivity of human capital -- that is, the effectiveness with which human capital potential is transformed into useful research products.

The study has three general objectives. First, within the constraints of currently available data, to analyze the current status and historical trends of human capital stocks at EMBRAPA, and to explore the determinants of productivity of human capital within

EMBRAPA. Second, to identify areas where additional data or new measures of inputs and outputs are needed to complete the analysis, and devise methods to obtain that data. Finally, we hope to use the analysis to develop recommendations for human resource policy, and managerial and resource allocation changes needed to ensure the continued effectiveness of EMBRAPA as a research organization.

ORGANIZATION

The paper is organized as follows:

The first section provides a conceptual overview of the role of human capital in the production of applied research. Section 2 summarizes the concerns of EMBRAPA managers about human capital issues. The third section presents some preliminary results from an analysis of the current status of EMBRAPA's human capital stocks. Section 4 describes a set preliminary strategies for analysis of unit-level productivity, the measurement of historical trends in human capital stocks, the estimation of a models of organizational mobility, and projection of changes over time in both human capital stocks and productivity. The fifth section outlines a pair of potential research efforts aimed at measuring the degree to which obsolescence and/or decay in human capital has occurred over time. The data for this analysis is of questionable usefulness at this point, and therefore this component of the analysis is merely speculative. Section 6 outlines an approach for identifying the gaps in currently available data, as well as some issues regarding the measurement of inputs and outputs in the production process for

applied agricultural research, and develops some suggestions for addressing these deficiencies. The final section summarizes some of the issues relating to the development of policy recommendations on the basis of the analyses.

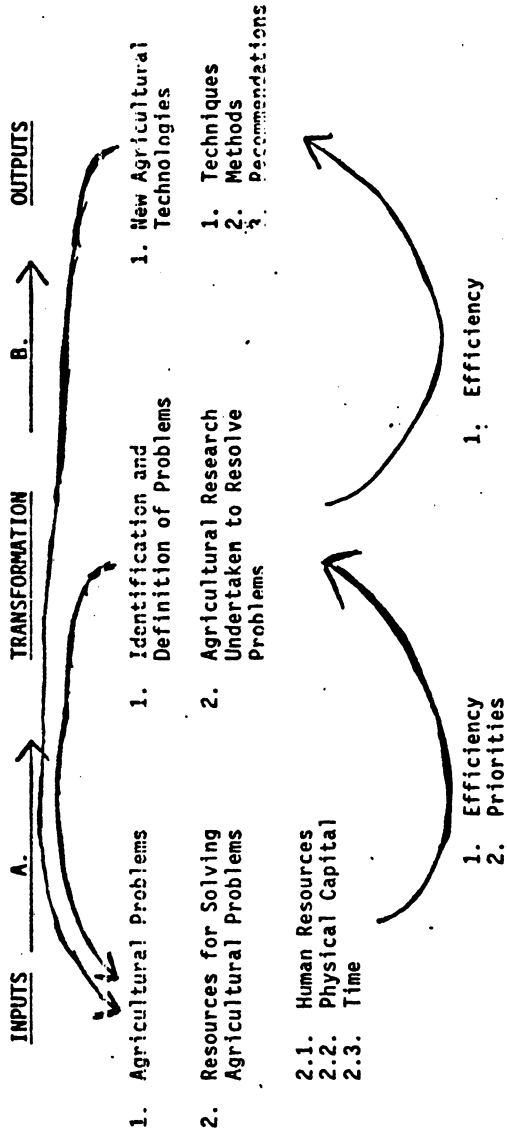
1. THE ROLE OF HUMAN CAPITAL IN APPLIED RESEARCH ORGANIZATIONS

The activity of applied research can be thought of as a production process in which human capital, computers, laboratory equipment, and other inputs are applied to agricultural problems to produce: a) knowledge about the problem, b) an understanding of how to solve it, and c) a technological solution. Figure 1 illustrates the process. (See figure 1). For our purposes, the "transformation" stage in this process, which produces knowledge about the problem and a theoretical understanding of how to solve it, may be described as "pure research". The second stage focuses on the application of the theoretical knowledge to devise practical technologies.

Note that while the analogy to a conventional production process is useful in conceptualizing the transformations necessary to produce practically applicable solutions to agricultural problems, there are numerous important differences between the process of producing applied research and more traditional manufacturing processes. First, and perhaps most important for our purposes, is the fact that relative to other inputs, human capital plays a much more important role in the production of applied research. Second, as illustrated in Figure 1, both stages of the process of

FIGURE 1

EMBRAPA'S PRODUCTION PROCESS



transformation produce raw materials in the form of new problems to be solved. The primary role of the "pure" research produced in the first stage is as an intermediate output to be used as an input into the process of producing technologies. However, the research produced at this stage has two other functions as well. First, in some cases, the understanding of the problem produced at this stage may lead directly to a practical solution, as is the case when a problem is identified as a member of a class of problems for which technological solutions already exist. Second, in other cases, the result of the "pure" research is simply a deeper understanding of the problem which generates both new problems to be solved and new opportunities for advancement.

The arrow leading from new technologies to new problems is intended to indicate the circularity of the process in another sense, that in which new technologies may either themselves breed new problems or uncover existing problems which limit the effectiveness of the new technology.

A third important difference between applied research and other production processes is that the transformation process is non-linear, or sporadic, i.e., the time periods intervening between discovery of problems and the creation of new technologies are highly variable.

Finally, and this is most important with respect to applied research in the public sector, output prices are poorly defined or often non-existent. This creates difficulties with respect to

measuring either the efficiency with which inputs are transformed into outputs, or the efficiency of allocation of inputs among alternative activities.

It is also important to note a critical difference between organizations whose primary output is pure research, and those focused on the production of applied research. For pure research organizations, the second stage illustrated in Figure 1 is of less importance than the first, and the primary product being produced is new knowledge, or expansion of the frontiers of knowledge. Within applied research organizations, the most highly valued research output is that which involves the transformation of existing knowledge into practical solutions. This means that many of the conventional notions about measuring research quality in terms of its contributions to the current state-of-the-art may be inappropriate. It also means that while it is very important for applied researchers to be aware of new developments within their discipline, i.e., for them to be current in the literature, it is less important that they play an active role as producers of that literature.

1.1 Efficiency Measurement

We shall be concerned in this project with measuring several aspects of the efficiency with which human capital is acquired and utilized within an applied research organization. These processes, while interdependent, can be analyzed separately. In particular, we shall first be concerned with the question of the most efficient way to obtain human capital inputs. That is to say, with the question of

purchase versus production of human capital, and with the issues of maintaining and improving existing stocks of human capital. Second, we shall be concerned with the question of efficient allocation of human capital resources both among research tasks, and across organizational units. Third, we shall focus some attention on the question of measuring the efficiency with which human capital potential (as measured, for instance, by education and experience) is converted into the intermediate research products illustrated in Figure 2. Finally, we will explore the efficiency with which those research products are transformed into technologies. Note that one aspect of the process which we shall not examine in this research is the "marketing" aspect of the problem, i.e., the question of adoption of the newly developed agricultural technologies by farmers.

1.2 Factors Affecting Efficiency

There are a variety of potential constraints and determinants of the several aspects of efficiency discussed in the preceding paragraph. These include, perhaps most importantly, constraints on the efficiency of the transformation process imposed by external conditions. For example, budgetary constraints which may limit opportunities for compensation, acquisition, and training of human capital, and economic conditions such as unemployment and opportunity wages which affect the retention of existing supplies of human capital and the competition for those supplies in the labor market. The second important factor affecting the observable aspects of productivity is the difficulty of the problems upon which research is

focused. This is an unobservable, but critical component in the determination of the quantities of new technologies produced and the time lags which separate new innovations. A third critically important factor is the "quality" of human capital -- that is, the extent to which the researchers within the organization are current in their disciplines and committed to the production of usable research. A fourth factor which we shall examine is the role of management in the transformation process. This includes not only the management of incentives, monitoring and evaluation, and allocation decisions, but also the role of management in structuring the way problems are selected and defined.

A final important factor, closely related to management, is organizational structure. This factor can affect both the efficiency with which human potential is transformed into usable output, and the efficiency with which intermediate outputs are transformed into usable technologies.

2. PERCEPTIONS OF THE PROBLEM

This research was undertaken in response to a perception among EMBRAPA's management of three basic human capital problems: a decline in the productivity of human capital; the absolute loss of human capital through exit from the organization into either the private sector or other public sector organizations; and finally, a perception of a potential future problem in that EMBRAPA's current preparation to meet anticipated future needs for human capital may be

inadequate. Through extensive discussions with personnel from EMBRAPA's Department of Human Resources and Planning, among others, we clarified both the perceptions of these three problems and the hypotheses regarding the sources of the problems.

2.1 Productivity Decline

Figure 2 illustrates two aspects of the perceived problem of obsolescence and decay in researcher quality. The problem of obsolescence is illustrated by the two production frontiers indicated as T_1 and T_1' , and T_2 , T_2' . These are meant to represent the frontiers of a discipline at two points in time. The axes defining the space may be thought of as attributes describing the current state of knowledge relevant to the discipline. For purposes of clarity, the figure displays these frontiers in two dimensions. In practice, several dimensions would be required.

The distribution of points in the interior of this figure represents the distribution of researchers with respect to that frontier. The problem of obsolescence is caused by researchers' remaining stable in this space as the frontier moves from T_1 , T_1' to T_2 , T_2' . For example, the individual depicted in point 1/2 has remained in the same position in both time periods.

The problem of decay is illustrated in Figure 2 by the points 1^* and 2^* . Note that 1^* was close to the frontier at time 1, but has moved not only relatively but absolutely away from the frontier in time 2. This transformation reflects an absolute loss of knowledge as opposed to simple stationarity over time.

FIGURE 2

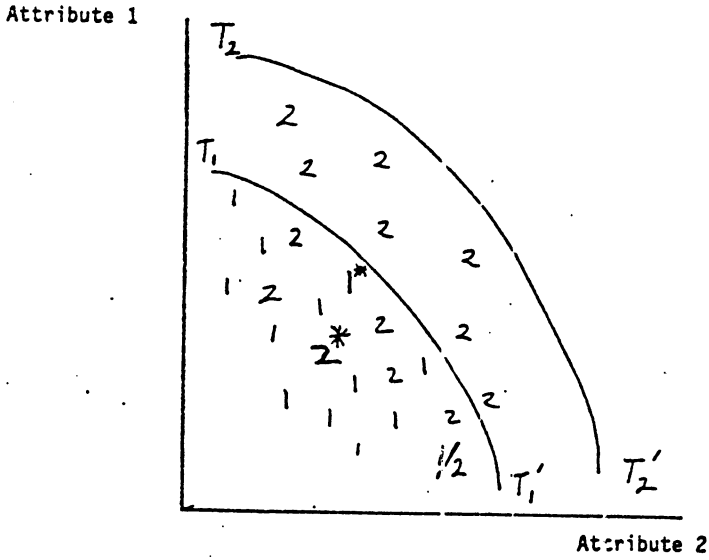
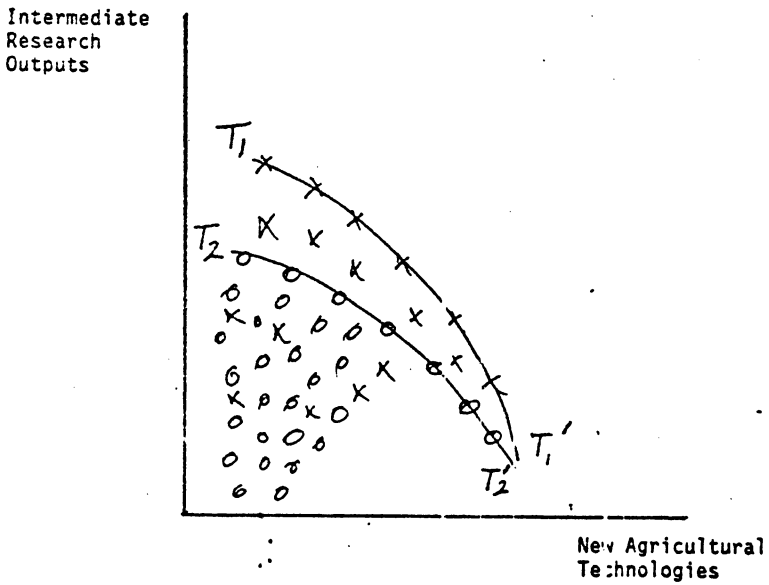


FIGURE 3



The perception that these two kinds of decline in research productivity are occurring is based on two aspects of output change. First, the belief that the quality of research -- that is, the degree to which EMBRAPA research is making significant contributions to knowledge about agricultural problems -- has declined over time; and second, a perception that the quantity of research as represented by publications and reports of various kinds has also declined. Finally, there is also a sense that new technologies are emerging at a slower rate. While all of these perceptions are speculative at this point, we will attempt to develop ways to explore the likelihood that the phenomena feared are occurring.

Note, however, that there may be some question as to whether the kinds of productivity decline illustrated in Figure 2 is in fact serious problems. Given that EMBRAPA is an applied research organization, the position of its researchers with respect to this frontier is of central importance only to the extent that it causes declines in the production of new technologies.

A more critical aspect of productivity decline is illustrated in Figure 3. This type of decline concerns stage 2 of the production process illustrated in Figure 1, i.e., with the transformation of intermediate research outputs into new technologies. The perception is that the rate of production of new technologies has declined over time. This may be because of obsolescence or decay of human capital, increases in the average level of difficulty of the problems to be solved, declines in resources available to be applied to research,

inefficient management of research activities, or some combination of the above.

The two frontiers in Figure 3, again denoted by T_1 , T_1' and T_2 , T_2' , are empirical production frontiers with axes representing, for example, different types of research products given some fixed level of inputs. The points making up these frontiers represent maximal observed levels of output in each time period. The points indicated by the "X" and "O" behind the frontier represent the output levels of non-maximal units in time periods 1 and 2, respectively.

The distribution of output levels in the two time periods has changed in three ways: the frontier for time period 2 has shifted downward; the output mix for most units has shifted toward the Y axis; and the variance of output levels has increased. Each of these changes may be symptomatic of important changes in the organization's productivity. The inward shift of the frontier may represent either a decline in productivity, or a shift in the underlying "true" production function. The shift toward the Y axis may reflect a change in the relative value (from the point of view of researchers) of, in this case, intermediate outputs vs. new technologies. The increase in variance may be a result of the cumulative effect of bad management, or the consequence of important exogenous constraints.

2.2 Loss of Human Capital

EMBRAPA managers believe that the organization is losing qualified researchers to the external labor market at an increasing rate. This is viewed as a particularly serious problem because it is

assumed that the researchers most likely to leave the organization are those most highly qualified and with the most transferable skills.

The seriousness of this problem depends on the vantage point from which it is viewed. It may be efficient, from a social point of view, for highly qualified researchers within EMBRAPA to exit either to a private firm or elsewhere in the public sector. However, from an organizational point of view, this human capital flight is considered a loss, especially if it is not recognized by those evaluating EMBRAPA's social contributions as one legitimate output of EMBRAPA's research and training process.

The primary perceived cause of this problem is the severe budgetary constraints under which EMBRAPA is currently operating, combined with the increasing competition for highly trained manpower in the Brazilian labor market.

2.3 Human Capital Replacement

The third problem, perceived as a potential, rather than an immediate threat, is the question of "generating" new replacements for EMBRAPA's current staff of trained researchers. There is a several year lag, even for a previously trained professional, between initial employment and reaching full productivity. Furthermore, since much of EMBRAPA's research is carried out by teams, it is important that these teams be structured in ways which maintain continuity as senior members of the team leave the organization. EMBRAPA's current population of researchers has a highly skewed

distribution of ages concentrated heavily in the 40 to 50 age range. Most of these researchers were hired initially by EMBRAPA in the period 1975 through 1977, and will be reaching retirement age in the next 10 to 15 years. Thus, there is considerable concern that the organization pursue policies now to ensure that these senior researchers will be replaceable when they leave the organization.

3.1 CURRENT STATUS OF HUMAN CAPITAL STOCKS

The results presented in this section were obtained from an analysis of the active file of EMBRAPA's research and senior technical staff. (N.B. All of the analysis presented here focus on these two groups. Data available for non-technical employees is scanty, and furthermore, the perceived human capital problems focus on college-level trained manpower within the organization).

The analysis we present here should be viewed as extremely preliminary. The active file used in this work has not been recently updated, and some of the information it contains is of questionable reliability. Our objective was merely to obtain a sketch of the current status of human capital within the organization to use as a starting point for design of the complete analysis.

Charts 1A thru 1C provide a description of the distribution of advanced degrees among EMBRAPA researchers by years of experience, age, and occupational categories, respectively. Chart 1A amply demonstrates the skewed distribution of experience within EMBRAPA researchers. Approximately 70 percent of EMBRAPA's current employees are in the 10-15 years of experience bracket.

CHART 1A

**DISTRIBUTION OF ADVANCED DEGREES AMONG
EMBRAPA RESEARCHERS BY YRS EXPERIENCE**

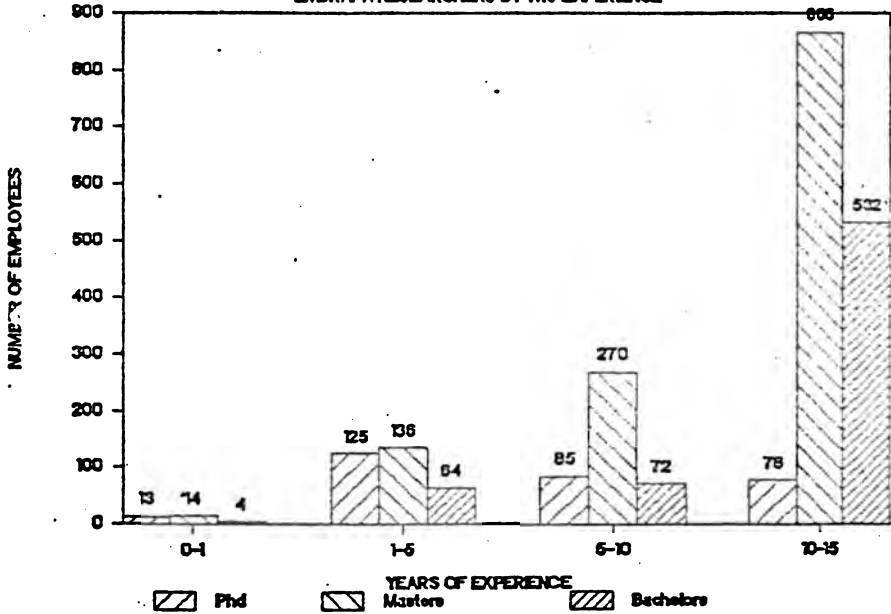


CHART 18

DISTRIBUTION OF ADVANCED DEGREES AMONG EMBRAPA RESEARCHERS BY AGE

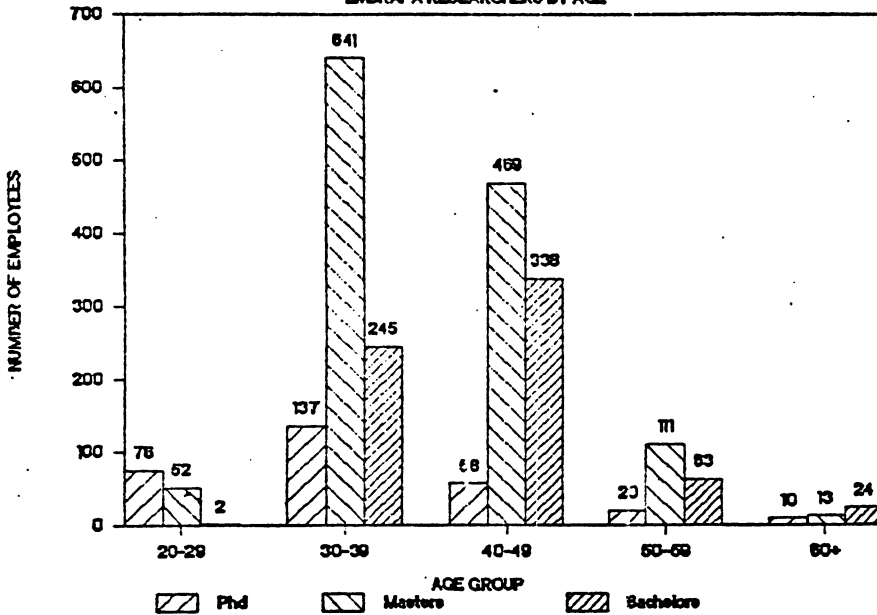


CHART 1C

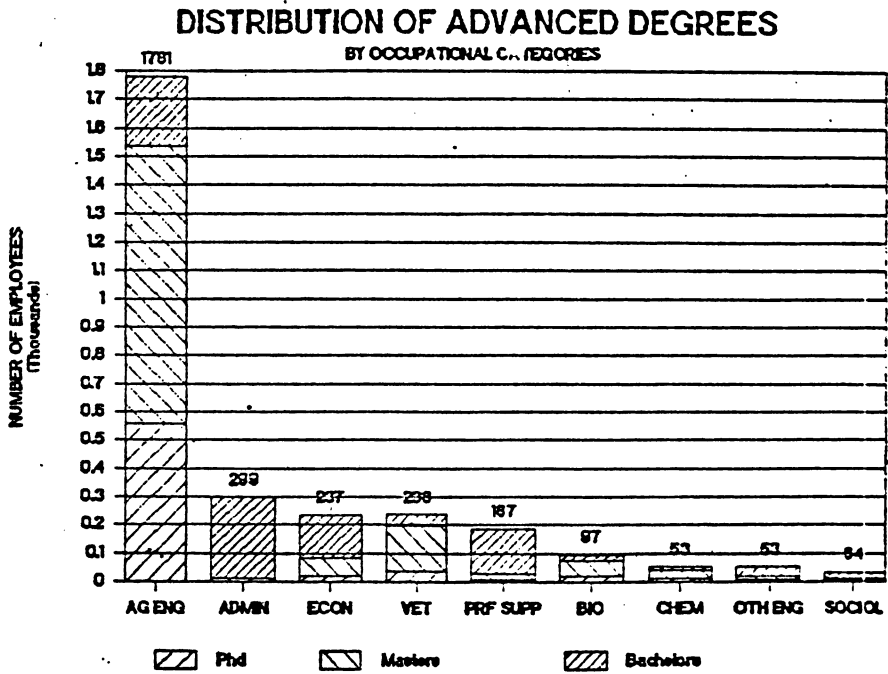


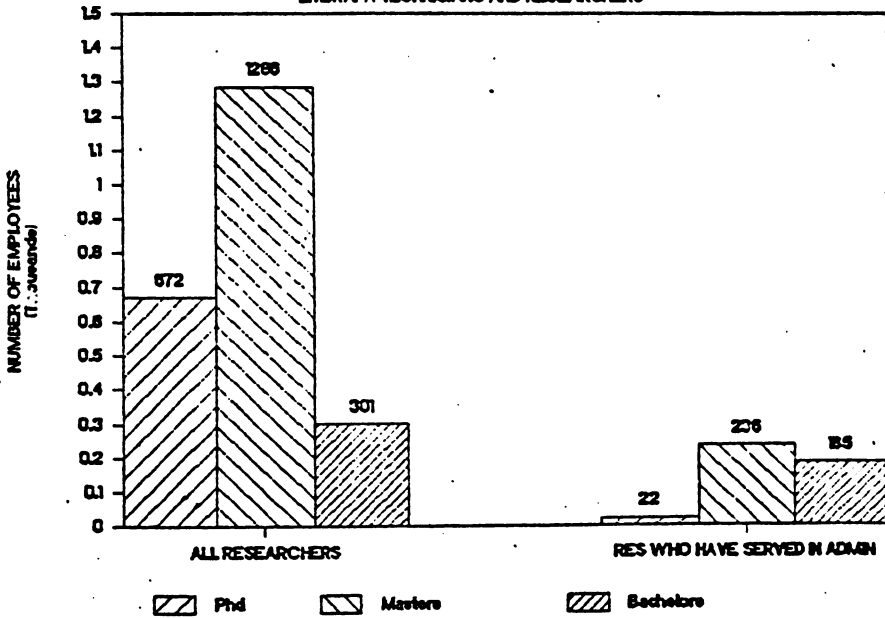
Chart 1B shows the roughly symmetric distribution of the current age structure within EMBRAPA with a substantial proportion of the entire research staff falling in the range of 35 to 50. (Note that more than 60 percent of EMBRAPA's research staff with Ph.D. degrees are in the age range 45 and older).

Chart 1C shows the current distribution of EMBRAPA's research staff across occupational categories. Note the distribution within each occupational category of advanced degrees. The vast majority of EMBRAPA's current staff are agricultural engineers. However, as the diversity of EMBRAPA's mission expands and the nature of the problems it must address changes, it is expected that a shift will occur in the direction of the other sciences and this figure will become less skewed in the future. One of the questions we wish to explore is the extent to which such a trend is evident in the recent years.

Chart 2 illustrates the distribution of advanced degrees among all researchers in comparison with those who have served in an administrative capacity for at least some period of their careers. The current approach for obtaining administrators and research leaders at EMBRAPA is through the use of temporary commissions under which a senior researcher is selected to serve in an administrative capacity. Other issues of interest are whether: (a) this approach is efficient in terms of its use of research talents; and (b), whether it is effective in producing competent administrators. We are

CHART 2

DISTRIBUTION OF ADVANCED DEGREES AMONG EMBRAPA TECHNICIANS AND RESEARCHERS



interested in examining the historical trends to determine: (a) what proportion of an average career for a researcher with an advanced degree is spent in serving an administrative capacity, and (b), whether there is a pattern of increasing focus among these researchers on administrative responsibilities.

One issue of considerable interest, having to do with the replacement rates for human capital, is the trends over time in the training of human capital after employment by EMBRAPA (the production of human capital) as compared with the "purchase" of human capital -- that is, the hiring of individuals who already hold advanced degrees. While the current files are not entirely appropriate for this sort of analysis, we did attempt to assess the trends in these two policies by examining the proportion of employees by year of employment who received training at EMBRAPA compared with those who held an advance degree when hired. The results of these analysis are shown in Figures 4 and 5, and Table 1. Figure 4 shows the mean proportion in each of the two categories in each year since EMBRAPA's founding. Table 1 displays the coefficients estimated using a logistic regression where the dependent variable was either the probability of having an advanced degree when hired, or the probability of having earned an advanced degree while employed by EMBRAPA.

These "pseudo time series" results suggest some interesting trends. Note that the cubic term for "month joined" is significant as a predictor of receiving an advance degree at EMBRAPA, while the "month squared" term is significant in the equation 1. Note also

that equation 2 explains considerably more of the variance in its dependent variable than does equation 1. The conclusion we draw (very tentatively) is that the rate of new training at EMBRAPA is declining at an increasing rate over time, while the rate of new employment with advance degrees is increasing at a decreasing rate. If these trends are borne out by the analysis of the historical data, the implication is that, if the demand for highly trained personnel remains constant, the current rate of replacement at EMBRAPA will be insufficient to meet future needs. Figure 5 graphically displays the predictions generated by the logistic regression results, and shows the difference in trend lines rather dramatically.

FIGURE 4

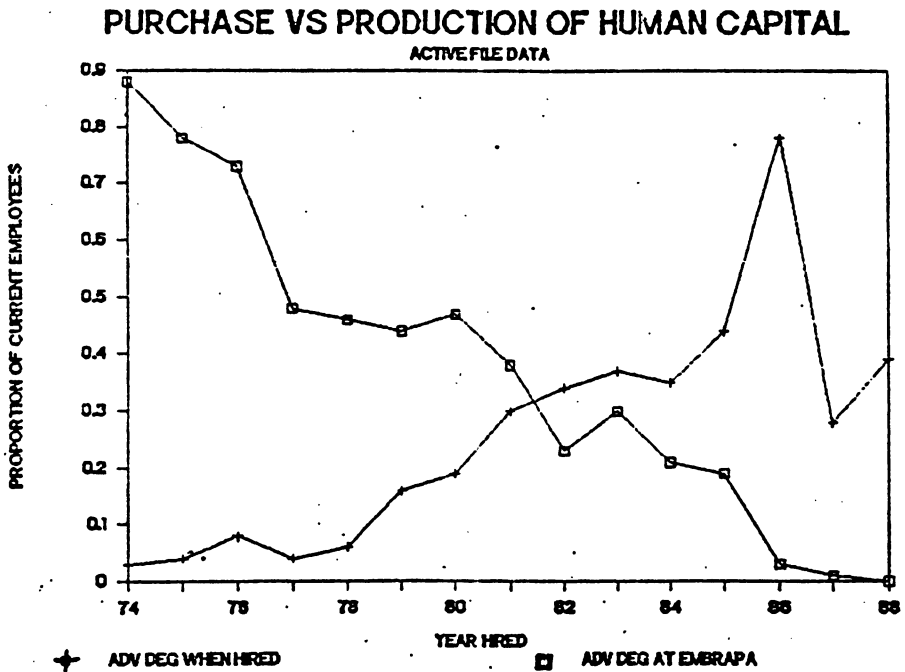


FIGURE 5

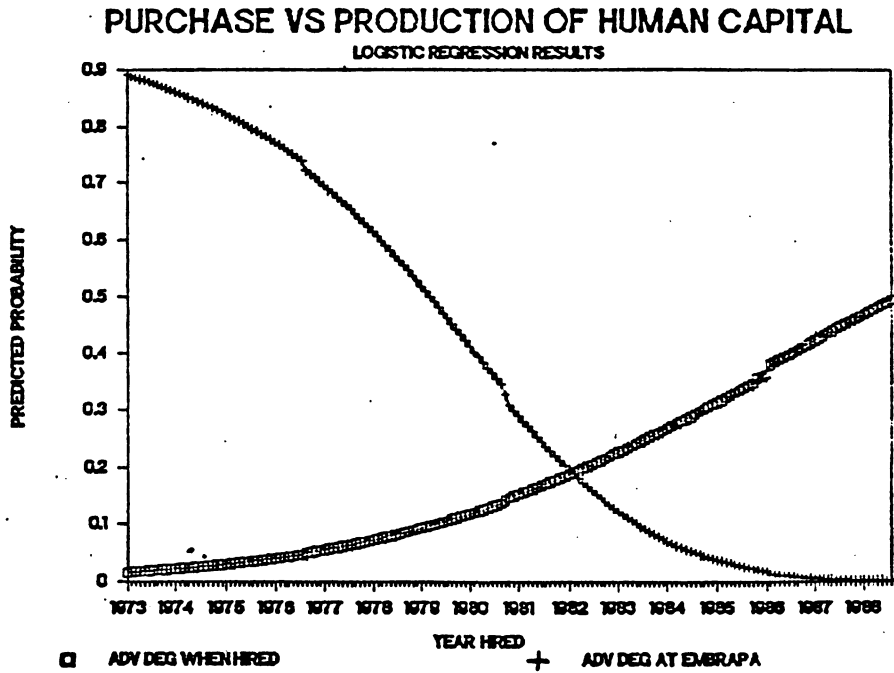


TABLE 1
LOGIT RESULTS

<u>VARIABLE</u> --	<u>EQUATION 1</u> <u>Adv. Deg. When Hired</u>	<u>EQUATION 2</u> <u>Adv. Deg. at EMBRAPA</u>
Intercept	-4.57** (39.4)	2.51** (31.4)
Month Joined	0.03** (10.3)	-0.03** (16.3)
Month Joined Squared	-3.68** (2.54)	-----
Month Joined Cubed	-----	-5.55** (13.5)
<hr/>		
R ²	0.304	0.684
N	3050	3050
<hr/>		

** Implies to ratio significant at the 5% level

4. HUMAN CAPITAL ANALYSES: PRELIMINARY STRATEGIES

4.1 Unit Level Productivity Analysis

The first stage of the substantive analysis to be undertaken is a unit-level analysis of both intermediate and final output productivity. This study will rely on the data used by Quirino, Hage, and Andrade (1985) in their analysis of human capital at EMBRAPA. Quirino, et. al., focused on the relationship between indicators of the quantity, quality, and diversity of human capital, and selected sets of output measures. While our objective will be somewhat similar, both the approach and the focus of our research will be different. Quirino, et. al., found a strong relationship between the diversity of human capital (as measured by the number of occupations within each unit) and the output of new technologies. They found a very slight relationship between the quality of human capital (as measured by education) and these final outputs. This research also showed strong links between the education of the researchers and the quantity of publications produced, and between education and a subjective measure of research quality. The 1985 study used path analysis and linear regression techniques to analyze these relationships. In order to apply these methods, it was necessary to aggregate some of the output measures to a level that might obscure some aspects of the relationships of interest.

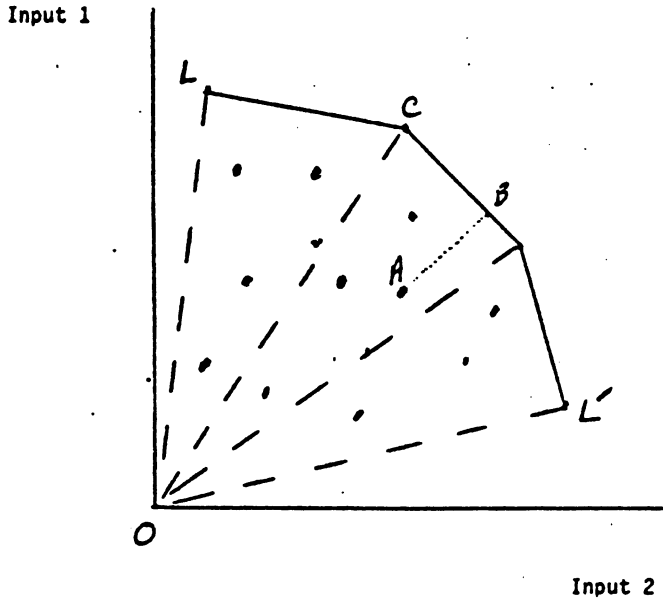
Our approach is to use these data to obtain an estimate of the frontier production functions for both intermediate and final outputs, as well as estimates of the relationships between

intermediate and final output. We shall use a multiple-input/multiple-output specification, and avoid the imposition of the distributional assumptions required to apply parametric techniques. The approach we intend to apply for this analysis is Data Envelopment Analysis. This approach, based on seminal work in 1957 by Farrell on measurement of technical efficiency (and developed further by Charnes, Cooper and Rhodes 1978) is, we believe, ideally suited for the analysis of unit-level productivity.

Figure 6 provides an illustration of the method of DEA in two dimensions, that is, in a case where one output is produced using two inputs. The curve L,L' represents the piece-wise linear production frontier. The distribution of points behind the frontier are inefficient, in the sense that they used more of at least one input to produce the same level of output as the research units on the frontier. Relative efficiency can be readily measured by comparing the Euclidean distance between each point and its respective frontier, and expressing it as a ratio of the distance to the origin. For example, the relative efficiency of point A is OA/OB . This measure obviously takes on values between 0 and 1 for points within the frontier, and is by definition equal to 1 for those firms which define the production frontier.

In addition, each linear facet of the production frontier defines a "technology cone" (cone LOC, or instance) which groups firms using similar input combinations to generate output.

FIGURE 6
DEA PRODUCTION SURFACE



4.2 Historical Trends

The second stage of the analysis will focus on the description of trends over the past seven years in some critical human capital indicators within EMBRAPA. The objective of this analysis is to determine the extent to which some of the perceived problems are in fact evident. Our approach here will be straightforward graphical description using a combined data set produced by the Human Resources Department at EMBRAPA. These data sets include: a) an active file of EMBRAPA employees, b) a historical file containing the records of those individuals who have left the organization, and c) a third file containing information about training of senior personnel while employed by EMBRAPA. These data are currently being prepared by DRH and are expected to be available in late 1988. The specific characteristics we will focus on in this section are: the changes in the age distribution of EMBRAPA; the patterns of exit from the organization; the changes in distribution of gender over time; the changes in distribution of senior technical personnel relative to research staff; changes in the distribution of advanced degrees; and finally, changes in the proportion of employees receiving degrees while on EMBRAPA payrolls. The primary purpose of this exercise is to explore aspects of human capital at EMBRAPA, clarify issues that should be addressed with more sophisticated techniques, and identify any hidden or unsuspected issues which should be addressed further.

4.3 Models of Organization Mobility

The next stage of the analysis to be carried out is a series of models of the transitions undertaken by employees at EMBRAPA which focus on patterns of promotions, training, and retention. The data to be used here will be the same as that used to describe the historical trends, that is, the merged file of the active, historical, and post graduate files being prepared by DRH. Our objective in this stage of analysis is two-fold: first, to develop (within the constraints of the data) explanatory model of these three phenomena; and second, to obtain more reliable estimates of transition probabilities for the succeeding stage of projecting future consequences of current trends. The purpose of the explanatory components is to obtain information that can be used to make policy recommendations if it proves desirable to alter some of the patterns existing in the historical data.

The methodologies to be employed here are a family of techniques classified under the heading of survival models (or duration models). These techniques provide an opportunity for analysis of events occurring over time, and also allow for correction of the problems of front and rear censoring, which will necessarily be embedded in these data.

4.4 Projections

The fourth and final stage of the central part of the analysis will focus on the projection of current trends into the future. Our objectives here are again two: first, to describe the

expected state of the organization at points in the near future; and second, to develop some basis for policy recommendations.

The approach to be taken will employ discrete-time Markov models. These models make use of matrices which map the probabilities of individual job changes over time. For example, a matrix A is the matrix of transition probabilities from states in time " t " to states in time " $t+1$ ". The columns of the matrix represents states in " $t+1$ " and the rows states in time " t ". The entry in cell " A_{ij} " is the probability that an individual in the state represented by row " i " in time period " t " will be in the state represented by column " j " in time period " $t+1$ ". The central specification problem in these models is that of defining the states. For our purposes, we expect that the states will be defined in terms of a set age groups, educational levels, and occupational grades. Thus, an entry in column 3, row 1 might be the probability that an individual with five years of service, a masters degree, and a grade of researcher II in year 1, will receive a PhD and be promoted to researcher III in year 2. Given a $(k \times k)$ matrix of transition probabilities, a $(k \times 1)$ vector, b_1 , of initial stocks, plus a $(1 \times k)$ vector, r , describing recruiting policies, the status of the organization in time period 2 will be simply $b_2 = (b_1 + r)^T A$. Similarly, the state of the organization in time period 3 (assuming a constant recruiting policy) is simply $b_2 + r$ multiplied again by the same transition matrix.

We shall be interested in determining what changes in transition probabilities and in recruiting policies are needed in

order to insure a workable distribution of characteristics within the organization in the future. We will also use the results of the Markov model in combination with the unit-level productivity analysis to attempt to extrapolate changes in productivity that can be expected to occur as a result of changes in human capital stocks.

5. OBSOLESCENCE AND DECAY

The final stage of analysis is at this point hypothetical. While the question of obsolescence and decay in human capital over time is an issue of considerable interest, the data currently available do not provide the time series information necessary to estimate the models of this phenomenon. There is a data set being constructed by Jairo Borges-Andrade consisting of 350 observations on individuals who were employed with EMBRAPA as researchers in 1983. In addition, there have been a series of studies conducted which examine the adoption of new technologies produced by EMBRAPA, and it is possible that these data may be used to provide some time series information on output of technology. Although the Borges-Andrade data set is a cross section, it might provide an opportunity to examine changes over the course of individuals' careers using vintage as a surrogate for time, that is, the years of experience of the individual as a substitute for a true time series on a single individual. Clearly, this approach leaves a great deal to be desired in terms of statistical consistency, but it may be possible to extract some hint of patterns of obsolescence and decay of human capital. The approach we adopt will depend to a great extent on the

nature of the data, which is yet unknown. Two possibilities include the use of DEA and a time series, that is, estimating a series of frontiers at different points in time to determine whether the frontiers are moving, and if so in what direction. The second possibility is the use of either a multiple equation regression, or similar techniques, for examining the relationship between human capital indicators and individual-level outputs and their changes over time.

6. MEASUREMENT ISSUES

As was clear in the previous discussions, there are number of gaps in the data needed to measure changes in individual- and unit-level productivity over time. Furthermore, there are number of deficiencies in the measures of outputs as well as inputs even in the cross-sectional data. Thus, one component of the analysis will be to clarify these deficiencies and suggest ways to address them. The specific measurement problems most likely to need attention are the measures of quality of research output (e.g., publications and reports), and measures of the differences in and the value of technologies produced. While it may not be necessary to identify a value function for the technologies, it would be useful to be able to differentiate more precisely than is currently possible.

Additional information is also needed on the organizational structures of the various research units. At this point, it appears that while there are substantial variations in the management styles

and organizational structures across units, little is known about the true (as opposed to formally stated) structures that are in place.

It would be useful to have information on the patterns of employment among employees who left EMBRAPA. Borges-Andrade is pursuing this in his proposed follow up on the 350 individuals in his sample, but it appears that the resulting sample size will be insufficient to do meaningful statistical analysis.

One of the main objectives of this analysis will be to more precisely identify the existing limits on data and measurement, and to suggest ways of systematically obtaining this information in the future. This component may also involve the development of some instruments for obtaining such data. One idea under consideration is the development of an exit survey to be given to employees leaving the organization. Another is to develop a brief questionnaire to be administered to researchers on a periodic basis to obtain information about recent publications, and if possible, to devise a method of determining the extent to which the researchers are current on a literature.

7. POLICY RECOMMENDATIONS

The development of policy recommendations to address the organizational measurement problems identified in the analysis will to an even greater extent than the analysis itself necessitate close collaboration with EMBRAPA managers and researchers. It is anticipated that the policy recommendations may include not only recommended changes in internal practices and policies, but also some

suggestions as to the potential gains to be achieved by relaxing some of the current budget constraints. For this purpose, a cost-benefit analysis of some of the possible alternative features may be required. Thus, we may wish to explore the potential for developing rough estimates of the cost of training, renting, and purchasing human capital. This would require data on the cost of training (which we do not presently have), and also some data on the costs of consultants. We do have the information sufficient to generate an estimate of the cost of hiring a employee at each educational level.

COLLABORATORS

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Programa II. Geração e Transferência de Tecnologia

O Programa de Geração e Transferência de Tecnologia é a resposta do IICA a dois aspectos fundamentais: (i) o reconhecimento, por parte dos países e da comunidade técnico-financeira internacional, da importância da tecnologia para o desenvolvimento produtivo do setor agropecuário; (ii) a convicção generalizada de que, para aproveitar plenamente o potencial da ciência e da tecnologia, é necessário que existam infra-estruturas institucionais capazes de desenvolver as respostas tecnológicas adequadas às condições específicas de cada país, bem como um lineamento de políticas que promova e possibilite que tais infra-estruturas sejam incorporadas aos processos produtivos.

Nesse contexto, o Programa II visa a promover e apoiar as ações dos Estados membros destinadas a aprimorar a configuração de suas políticas tecnológicas, fortalecer a organização e administração de seus sistemas de geração e transferência de tecnologia e facilitar a transferência tecnológica internacional. Desse modo será possível fazer melhor aproveitamento de todos os recursos disponíveis e uma contribuição mais eficiente e efetiva para a solução dos problemas tecnológicos da produção agropecuária, num âmbito de igualdade na distribuição dos benefícios e de conservação dos recursos naturais.

INSTITUTO INTERAMERICANO DE COOPERAÇÃO PARA A AGRICULTURA

O Instituto Interamericano de Cooperação para a Agricultura (IICA) é o organismo especializado em agricultura do Sistema Interamericano. Suas origens datam de 7 outubro de 1942, quando o Conselho Diretor da União Pan-Americana aprovou a criação do Instituto Interamericano de Ciências Agrícolas.

Fundado como uma instituição de pesquisa agrônômica e de ensino, de pós-graduação para os trópicos, o IICA, respondendo às mudanças e novas necessidades do Hemisfério, converteu-se progressivamente em um organismo de cooperação técnica e fortalecimento institucional no campo da agropecuária. Essas transformações foram reconhecidas oficialmente com a ratificação, em 8 de dezembro de 1980, de uma nova convenção, que estabeleceu como fins do IICA estimular, promover e apoiar os laços de cooperação entre seus 31 Estados membros para a obtenção do desenvolvimento agrícola e do bem-estar rural.

Com um mandato amplo e flexível e com uma estrutura que permite a participação direta dos Estados membros na Junta Interamericana de Agricultura e em seu Comitê Executivo, o IICA conta com ampla presença geográfica em todos os países membros para responder a suas necessidades de cooperação técnica.

As contribuições dos Estados membros e as relações que o IICA mantém com 12 Países Observadores, e com vários organismos internacionais, lhe permitem canalizar importantes recursos humanos e financeiros em prol do desenvolvimento agrícola do Hemisfério.

O Plano de Médio Prazo 1987-1991, documento normativo que assinala as prioridades do Instituto, enfatiza ações voltadas para a reativação do setor agropecuário como elemento central do crescimento econômico. Em vista disso, o Instituto atribui especial importância ao apoio e promoção de ações tendentes à modernização tecnológica do campo e ao fortalecimento dos processos de integração regional e sub-regional.

Para alcançar tais objetivos o IICA concentra suas atividades em cinco áreas fundamentais, a saber: Análise e Planejamento da Política Agrária; Geração e Transferência de Tecnologia; Organização e Administração para o Desenvolvimento Rural; Comercialização e Agroindústria, e Saúde Animal e Sanidade Vegetal.

Essas áreas de ação expressam, simultaneamente, as necessidades e prioridades determinadas pelos próprios Estados membros e o âmbito de trabalho em que o IICA concentra seus esforços e sua capacidade técnica, tanto sob o ponto de vista de seus recursos humanos e financeiros, como de sua relação com outros organismos internacionais.



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