SOCIAL SCIENCE PERSPECTIVES ON MANAGING AGRICULTURAL TECHNOLOGY

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LIST OF ACRONYMS

AICRPDA	All-India Coordinated Research Programme for Dry-land Agriculture
CAB	Commonwealth Agricultural Bureaux
CARE	Cooperative for American Relief Everywhere
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro lnternacional de Agricultura Tropical
CIDA	Canadian International Development Agency
CIP	Centro lnternacional de la Papa
CIMMYT	Centro lnternacional de Mejoramiento de Maiz y Trigo
DES	Directorate of Economics and Statistics (Ministry of Agriculture/ India)
DRI	Integrated Rural Development Program (Colombia)
EDI	Economic Development Institute
FAO	Food and Agriculture Organization
FMME	Fund for Multinational Management Education
FSSP	Farming Systems Support Project
IARC	International Agricultural Research Center
ICA	lnstituto Colombiano Agropecuario
ICAR	Indian Council of Agricultural Research
ICARDA	International Center for Agricultural Research in the Dry Areas
ICIPE	International Center for Insect Physiology and Ecology
ICRAF	International Council for Research in Agroforestry
ICRISAT	International **Crops** Research Institute for the Semi-Arid Tropics
ICTA	Institute de Ciencia y Technólogica Agrícola
IDRC	International Development Kesearch Center
IFARD	International Federation for Agricultural Research and Development
IFDC	International Fertilizer Development Center
IFPRI	International Food Policy Research Institute
IICA	lnstituto Interamericano de Ciencias Agrícolas
IICA	lnstituto lnteramericano de Cooperación para la Agricultura
IIMI	International lrrigation Management Institute
IITA	International Institute of Tropical Agriculture
ILCA	International Livestock Centre for Africa
ILRAD	International Laboratory for Research on Animal Diseases
INIAP	lnstituto Nacional de Investígaciones Agropecurias
IPM	Insect Populations Management
IRRI	International Rice Research Institute
ISAR	Institut des Sciences Agronomiques du Rwanda
ISNAR	International Service for National Agricultural Research

KLDP	Kenya Livestock Development Programme
NARC	National Agricultural Research Center
NFDP	National Potato Development Programme (Nepal)
ODI	Overseas Development Institute
PARC	Pakistan Agricultural Research Council
PCCMCA	Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos Alimenticios
PNAP	Programme Nationale de l'Amelioration de la Pomme de Terre
RCF	Rashtriya Chemicals and Fertilizers Ltd.
RF	Rockefeller Foundation
SACCAR	Southern Africa Committee **for** Coordination in Agricultural Research
TAC	Technical Advisory Committee (of the CGIAR)
UNESCO	United Nations Educational, Scientific, and Cultural Organization
USAID	United States Agency for International Development

FOREWORD

ROCKEFELLER FOUNDATION SOCIAL SCIENCE FELLOWSHIP PROGRAM IN AGRICULTURE

Joyce Lewinger Moock*

This volume presents a set of reflective commentaries on the ways in which social and economic perspectives can interact with and fortify the biologically based work of the International Agricultural Research Center (IARC) system. The authors are current fellows and alumni of the Rockefeller Foundation Social Science Fellowship Program in Agriculture.

Initiated in 1974, this fellowship program was a response to the lack of training mechanisms to prepare future generations of first-rate scholars to staff the social science component of the growing international agricultural research network. Our most recent account of the program's **41** alumni reveals that **39** are currently employed in international development work. Eighteen of them have joined the staff of an IARC, 13 hold positions with an American university, and 8 work for an international development assistance agency.

We were also delighted to learn from a recent external evaluation **of** the program that a majority of the Fellows assigned to the IARCs were felt to have made important contributions to the latter's technology application and training functions, and, in particular, to their efforts to strengthen links with national agricultural research systems. In general, the Fellows have earned widespread recognition **for** their ability to communicate effectively on technical subjects with biological scientists and engineers and, thus, to translate social perspectives into tangible technological outcomes.

In 1986, the Foundation added a biennial seminar series to the program to enhance professional interaction among the Fellows. The meetings, each co-sponsored by a different IARC, provide opportunities for the Fellows to reflect on their experiences and to discuss aspects of agricultural research that have benefited from socioeconomic analysis, while at the same time learning firsthand more about the work of the host center. In September 1988, 13 new Fellows joined program alumni at a second meeting, held in cooperation with the International Potato Center (CIP).

The Foundation wishes to acknowledge the efforts of IIMI staff in organizing the meeting in Pakistan, particularly those of Thomas Wickham, **James** Wolf, and David Groenfeldt. The Fellows were given a rare opportunity, through an intensive field trip in the company of local farmers and staff from the University of Faisalabad, to become better acquainted with irrigation management. **We** are also grateful to Amir Muhammed, Chairman of the Pakistan Agricultural Research Council (PARC), for stimulating the seminar discussion through his insights into the problems and potentials of the agricultural sector in his country.

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MANAGEMENT OF AGRICULTURAL TECHNOLOGY: THE VIEW FROM IIMI

Roberto Lenton*

While technology development continues to be dominant in the research programs of most IARCs, greater recognition is now given to management factors which constrain the full realization of various agricultural technologies. Social and management scientists, closely collaborating with technical scientists, have contributed toward understanding the management environment within which agricultural technology should he developed, and have recommended important changes in both technology selection and management practice.

A joint IIMI-Rockefeller Foundation workshop entitled "Social Science Perspectives on Managing Agricultural Technology" was held 24-27 September 1986 at IIMI's Pakistan office in Lahore. Participants included present or former Rockefeller Foundation Fellows currently affiliated with eight IARCs and one university, as well as IIMI staff from both the headquarters in Digana, Sri Lanka and the Pakistan office. Of the 15 papers in this volume, 12 were presented at the workshop and 3 were added later by authors who were unable to attend.

These papers deal with questions vital to social science and to the IARCs: What kinds of contributions can social and management scientists make to the more effective management of agricultural technologies? What is the suitability of various social science methodologies for crossdisciplinary applied research? How can social and management scientists play a more central role in shaping the broad parameters of IARC research agendas? What kinds of research can best contribute to the sustained adoption and productivity of particular agricultural technologies?

As one of the few IARCs with "management" in its name, IIMI was an appropriate host for the workshop. IIMI staff include irrigation and agricultural engineers, agricultural scientists, agricultural economists, and social and management scientists. The primary work of the institute is to develop and disseminate innovative management practices that can be implemented by our primary clients, national-level agencies which plan and operate or service irrigation systems. IIMI conducts interdisciplinary action research on existing irrigation systems in collaboration with government implementing agencies, research institutes, and universities. In addition to research, the institute's activities include professional development for officials attached to national agencies, and the communication and dissemination of irrigation management materials.

The issues discussed in the workshop are of direct concern to IIMI, and I believe will interest other national centers and IARCs, universities, government planning and

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implementing agencies, and members of the donor community. The purpose of the workshop was to raise issues for discussion among a small group of Rockefeller Fellows and IIMI staff who shared enough field experience to speak a common language but differed enough to provoke lively interchange about the uses of social science and about the role of the IARCs in agricultural development. This reflective, often critical, interchange is absolutely essential for those of us in the international research community as we seek to respond to the urgent hut changing needs of agricultural development.

The workshop was organized jointly by Joyce Moock of the Rockefeller Foundation and David Groenfeldt of IIMI. Assistance was provided by a number of IIMI staff, including Michael Jones, Hammond Murray-Rust, Edward Vander Velde, and James Wolf of the Pakistan office, and Mohan Abeysekera, Jenny Cramer, Ameeta Perera, and Douglas Merrey of the headquarters staff. These proceedings were prepared by IIMI with assistance from Robert Cowell, John Colmey, Champa Fernando, Francis O'Kelly, Radhini Selliah, Rekha Sirimanne, and Pamela Stanbury. Production staff included M.G.D.S. Priyantha, L.C. Perera, Norman Van Eyck, and T.M.K. Wijesinghe.

In addition, I would like to offer special thanks to Amir Muhammed, Chairman of PARC; to Aktar Bhatti, also of PARC, for taking an active role in the planning and substance of the workshop; and to Arshad Ali of the University of Agriculture, Faisalabad, for arranging a field trip to several nearby irrigation systems. I would also like to thank my predecessor, Thomas Wickham, for his encouragement and help in defining the workshop objectives and for his active participation in the workshop sessions. Finally, I would like to thank the Rockefeller Foundation not only for their financial support, but also for taking a lead role in drawing international attention to the importance of management issues in improving and sustaining agricultural development.

DEVELOPING AGRICULTURAL TECHNOLOGY IN PAKISTAN

Amir Muhammed*

I am pleased and gratified that the first substantial activity of IIMI in Pakistan is in the field of social science. I sincerely believe that breakthroughs in the field of agriculture in the developing countries during the coming decades will come from a sensible application of social sciences.

Pakistan, like most of the developing countries, depends heavily on agriculture. About 70 percent of the people live in villages and a great majority of the total labor force work directly in agriculture. The performance of the agriculture sector is also closely linked with the political and economic stability of the country. This situation is common in developing countries and therefore most governments very rightly give high priority to agricultural development. The IARCs, therefore, occupy a prominent position today, particularly in the developing world. Apart from the research emerging out of IRRI and CIMMYT in the shape of the Green Revolution, some of the results that come from other centers are also becoming known as their impact is being felt by poor and developing nations. Being a great admirer and an ardent believer of the IARC system, I believe that of all the investments being made in the field of agriculture, the best investment lies in the development of the IARCs.

Agriculture, one of mankind's oldest occupations, is a dynamic enterprise that is constantly changing with new and different needs arising on a regular basis. The complexities of agriculture have given rise to problems of management and to inefficiencies in production in developing nations, where agricultural research is often not well understood by its direct beneficiaries. Policy makers reflect this undervaluation in low financial allocations for national agricultural research. This is due to the neglect of research results which go largely unused or take a long time to reach producers. Some claim that the recommended technology is not adapted to local conditions, or is uneconomical; others blame the lack of good diffusion mechanisms. To the extent that some of the research results are not adequately utilized, the social payoff of the investment is less than it could generate. This discourages both the research establishment and its supporters.

Agricultural technologies are location-specific and sensitive to the agroecological, socioeconomic, and even political environments of the fanners who use them. The problems, risks, and limitations of directly transfemng research results are well documented throughout the developing world. There is also much evidence that adjusting technology to some extent is possible without a substantial capacity to do

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research. For the effective adaptation of technology it is necessary to be able to screen and interpret the possible alternatives, and this requires the capacity to do research. These experiences highlight the importance of and need for a national research infrastructure if a country wants to capture the potential benefits from the pool of existing knowledge and technological information. The implicit,belief that it is possible to do research without qualified scientists is one of the most common weaknesses of the research systems in developing countries.

The ultimate goal of agricultural research is to improve the condition of agricultural production. Its direct output, however, is knowledge incorporated into new production inputs as information on the use of specific components. For this knowledge to affect production it must reach fanners, and they must adopt it. The adoption decision is made by farmers, who assess the technological information resulting from research together with the set of other factors that affect the profitability of their enterprises, such as price support, agricultural services, input distribution, subsidies, credit, taxes, and marketing policies, and their own resource base, particularly land and labor.

Trained, capable, and motivated workers are therefore needed in sufficient numbers to facilitate technology transfer. Inputs should be available to enable farmers to adopt technology. Credit must be available so that the farmers can purchase technology inputs including equipment. A database is needed to organize, store, retrieve, and disseminate research information and technology packages. Lucrative markets need to be developed. A conscious effort should be made to design policies in support of agricultural development in all its phases: production, processing, and marketing. The promotion of a stronger channel of communication between the government and the private sector is essential in order to ensure mutual responsiveness.

The importance given to agriculture within the country is perhaps the primary determinant of the kind of support that research can expect to receive. The larger the relative economic and social size of the agricultural sector, the more attention it is likely to receive from policy makers and the more politically important the agricultural issues will become. However, in many developing countries agricultural research has lacked and still lacks the necessary support despite the importance of agriculture in economic and social terms. This lack of support is also surprising given the high rates of return that have been reported for investments in agricultural research — usually in the 40-60 percent per annum range and higher.

An objective analysis is required of the return on investment of research institutes in developing countries and IARCs. Research for the government is a long-term investment with a long-term visible payoff. When the competing demands for limited financial resources are many, then decision making for the government is rather difficult. It is up to us to prove that investment in research is worthwhile. We, as professionals, can compile studies and examples to use as convincing arguments about the consequences of a lack of investment in research. It would be unwise to start development projects without adequate investment in research. Agricultural research as an investment is even more attractive when it is realized that the population as a whole shares in the benefits of such efforts. Leaders of developing nations must realize that it pays in the long run to invest generously in agricultural research.

Monitoring and evaluation are essential in all research processes. The capacity to measure results against planned realistic objectives and introduce program adjustments as implementation proceeds is a key management function irrespective of the kind of activities the organization is involved in. The uncertain and long-term nature of research, however, makes this function especially important. To avoid waste and to simultaneously address national priorities and fanners' problems require the evaluation of the scientific quality of research as well as of the impact of research results on the production sectors. Besides being necessary for effective management, monitoring and evaluation are also required for producing relevant information for dissemination at the political level in response to the ever-present issue of accountability for publicly funded research systems.

We in Pakistan are going through an exciting phase of development of the national agricultural research system, and results are becoming visible at the grass-roots level. I hope IIMI's work in Pakistan makes an important contribution to improving agricultural productivity in the country.

Part Ⅰ

INTERPRETATIVE SUMMARY

NEW PERSPECTIVES ON MANAGING AGRICULTURAL TECHNOLOGY: AN OVERVIEW OF THE WORKSHOPS THEMES

David Groenfeldt*

Management has become a fashionable theme in international development. All sorts of development activities which were formerly considered mundane and straightforward — from building roads to supplying fertilizer — are now being reanalyzed according to management principles. Initially conceived to meet the needs of corporate powerbrokers and factory managers, the concepts and principles of management are finding important applications in Third World economic development, where the major contributor to the National Domestic Product, and to national sustenance, is agriculture.

The meaning of "management" depends on its context, and this observation alone suggests caution in using the term lightly. The best-understood uses of the word are situations where it is modified by a preceding adjective immediately narrowing its scope into something "manageable." Thus, when people speak of "financial management" or "personnel management" or even "corporate management" we have a fairly clear idea of what is being alluded to. The semantic roots of management convey the sense of handling something (from the Latin, *manus*), particularly a horse (from the Italian, ***maneggiare).*** In contemporary usage, management implies control over something, presumably to meet a set of objectives which may or may not be explicit.

Agricultural technology is the thing we are interested in managing, and this element of our topic is perhaps more familiar to both the authors and the readers of this volume. The establishment of the CGIAR and associated IARCs was directed towards creating better-performing crop varieties and more effective crop inputs (fertilizer, pest control, irrigation). The research, development, and subsequent adoption of these new agricultural technologies played a key role in bringing about the Green Revolution of the 1970s.

Although not generally conceived as a "management" activity, social science research within the IARCs bas focused on handling, or controlling, the agricultural technologies being developed, to enhance their benefits to the end users — the farmers. A better understanding of the social, political, and economic context of the farmers who are intended to use the improved rice, wheat, bean, or potato varieties has gradually become an accepted part of basic agricultural research at most of the IARCs. This type of end-user perspective, nurtured by the Rockefeller Foundation's program of supporting social scientists in the IARCs, is a critical component of managing agricultural technology.

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There are at least two other important ways in which social scientists are involved in the management of agricultural technology: 1) managing research within the IARCs, and 2) researching institutional policies and structures for using agricultural technology.

The papers in this volume touch on all of these meanings of managing agricultural technology. The field of reference is divided into four, somewhat overlapping, topics. The first topic, "Setting a Research Agenda" deals with research management. The second and third topics deal with the mainstream of social science involvement in the IARCs: helping to develop agricultural technologies that are appropriate for the socioeconomic context of the target area, and then adapting and fine-tuning the technologies to help in their adoption. The fourth and last topic deals with institutional arrangements for deriving maximum benefit from known technologies. This topic has been the most neglected of the four, and may offer the greatest potential for payoffs in higher agricultural production and more equitable access to development benefits.

SETTING A RESEARCH AGENDA

The mandate of each center prescribes certain boundaries for research, but within these there are strategic decisions to be made in how best to meet that mandate. In his paper, "On the Design of Commodity Research Programs in the International Centers," Lynam cites five primary objectives for the IARCs: 1) stable increases in food production, 2) improved small farmer incomes, 3) enhanced nutrition of low-income consumers, 4) environmental sustainability, and 5) more efficient resource use. The early successes of what Lynam calls the "Asian rice and wheat paradigm" were based on the introduction of agricultural technologies (new varieties, more fertilizer, more reliable irrigation) in relatively homogeneous environments — particularly in the case of irrigated rice — and on crops which, at the time, had almost infinite markets. The next generation of centers, such as CIAT, ICRISAT, ICARDA, and CIP faced a more diverse set of environmental and socioeconomic conditions within their target areas. Developing appropriate technologies required relatively more background research on existing farming practices, environmental and socioeconomic conditions, and, as in the case of CIAT's Cassava Program, on consumer preferences and marketing options.

Building a user's perspective into the technology generation process begins when research options are first considered. As Lynam notes, "By the time technology reaches the adaptive research stage, most of the design options have been fixed and the potential contribution of the social scientist is substantially narrowed." The essential ingredient in developing user-oriented technology is targeting (i.e., identifying which of the many potential users of the new technology are going to take top priority). The targeting process may require new methodologies for selecting beneficiaries, developing criteria for the technology, and developing strategies for delivering that technology. Refinements and revisions can be made during the course of research the process is iterative. The important point of

Lynam's paper, however, is that the first set of decisions about what kinds of information are likely to be important for generating a new technology (e.g., cassava production) have far-reaching consequences. "Management" in this context means strategic planning and forward thinking about the research elements required to meet a set of objectives defined around a target group of users.

DEVELOPING AGRICULTURAL TECHNOLOGY

The "end-user" perspective can, and should, guide all phases of technology generation, not only at the initial stage of setting the broad parameters of a research agenda, but also in designing specific research programs to develop the technology, and later on, in facilitating its adoption. Haugerud's research in Rwanda focused on farmers' preferences for potato characteristics as groundwork to a CIP program to introduce new varieties. She used both formal and informal surveys to capture a broad array of potentially relevant data on agricultural practices, storage, consumption, marketing, and inter- and intrahousehold division of labor. The selection criteria of farmers included, in addition to yield and disease resistance, a short growth cycle, short cooking time, short dormancy, good taste, and high starch content. Farmers also looked for a variety that could be intercropped, and most significantly, they looked for more than one variety. A diversified set of three to five potato varieties is the normal practice. This type of information is, or should be, a prerequisite to introducing a new or improved technology. As Haugerud notes, however, there are many other steps before the target group can benefit from the technological potential, and many of these intermediate steps are political and institutional in nature.

Social data (e.g., household division of labor) and socially derived data (e.g., farmers' agricultural knowledge) add an important dimension to assessing the potential benefits of new agricultural technologies, as Rubin shows in her paper on intercropping sugarcane. In addition to gathering information from farmers, Rubin interacted closely with research station agronomists and breeders, conveying the responses of farmers, and learning new questions to ask. This type of mediator role for the social scientist has become a classic one in development work (cf. Rhoades 1984). In Rubin's work, a mediating role was played at two levels: first, the agricultural experiment station where her study focused on a specific, field-oriented problem, and second, the two centers she was affiliated to (ICIPE and IFPRI), where feedback from her work contributed to an enhanced farmer perspective in the research agenda.

When an anthropologist is part of an on-farm interdisciplinary team, his/her role becomes one of eliciting and reporting farmers' explanations of their agricultural practices. The CIAT team of which Voss was a member in Rwanda included a plant breeder, a plant pathologist, an agronomist, and a nutritionist. These specialists were well-equipped to make detailed observations and records of how farmers cultivated, prepared, and consumed climbing beans. Voss surveyed farmers to learn what they perceive as the advantages and disadvantages of alternative bean varieties. The team's data were then applied to on-farm trials, and the task became that of monitoring cultivation results. In his role as anthropologist, Voss elicited the farmers' evaluation of the new varieties during and after the cultivation season. The preferred variety did not give the highest yield, but was easier to weed and performed much better than the comparative indigenous bean variety.

Analysis of constraints from the farmer's point of view, is part of the monitoring process in on-farm experiments. Voss found that the long stakes required for climbing beans were a severe obstacle to further production in an area where wood was at a premium. Another problem was the increased vegetative cycle of beans, which required a shift in the existing labor patterns. Identifying problems that farmers perceive, and then drawing on those same farmers to suggest solutions, or to react to potential solutions, is termed by Rhoades (1984) a "farmer-back-to-farmer" process. The farmer does not have to be a direct client in on-farm work rather, he becomes an on-farm collaborator along with the (other) interdisciplinary team members.

Farmers' initial responses, however, cannot always be taken at face value. A useful first assumption is that farmer responses are significant, and a task for the social scientist is to uncover what that significance is. When Dvořák first asked farmers why their planting date for sorghum is so late, they responded that it would be inauspicious to plant before a particular religious festival which may fall over a six-day period depending upon the moon. After studying the total agricultural system, including pest cycles, monsoon rain patterns, and competition for draft animals, Dvořák concluded that the farmers had a number of very good reasons to resist any advance of their traditional planting dates, as a new technology being tried by ICRISAT would require.

The role of social scientists in developing new agricultural technologies is not limited to on-farm research, as Scherr's work at ICRAF demonstrates. As part of a team of 10 scientists (4 of whom were social scientists), Scherr helped identify potential agroforestry technologies that would be broadly applicable within 4 ecological zones of Africa, and could meet specific priorities at the national level. The approach taken was to subdivide each ecological zone into research domains, for which particular types of agroforestry technology would be best suited. Scherr's task was to identify the social variables that might be significant in the suitability of particular technologies. While the project has involved fieldwork to assess constraints and potentials, the output is not a technology *per se*, but rather a methodology for developing specific technologies tailored to a particular set of local conditions.

A methodological advance of the 1970s and early 1980s was the application of a farming systems research (FSR) model as a means of identifying priority needs for new agricultural technology at the farm level. Although the model includes social variables, these are limited to the intrahousehold level (e.g., division of labor among family members). Grandin points out that the model does not take into account the larger community, which by definition operates at a suprahousehold level. Thus, production systems which involve communal property (e.g., communal grazing areas, shared land tenure rights, or community irrigation systems) cannot be adequately handled by the FSR model. Grandin suggests that by expanding the FSR model to include community-level variables, we can gain new insights into communal production systems (which are widespread among African pastoralists as well as Asian rice farmers). An expanded FSR model could help NARCs as well as IARCs expand their scope for technology generation and dissemination.

ADOPTING NEW AGRICULTURAL TECHNOLOGY

Development and adoption of agricultural technologies are overlapping processes. A newly developed variety is refined and modified to better reflect the demands of end-users (farmers) or intermediate users (national agriculture agencies and institutes). As the technology improves, presumably adoption will also increase. Social scientists play the role of marketing specialists in facilitating adoption: first, in determining what it is that consumers (farmers or agencies or both) want; second, in monitoring consumer response to a newly introduced technology; and third, in identifying constraints to technology adoption.

The importance of a comprehensive systems approach to the development and adoption process is elaborated in Reardon's paper. The viability of a new technology depends upon changing circumstances, which need to be predicted, or at least considered, before embarking upon a very costly program of technology generation and dissemination. Reardon breaks the adoption process into components of initial implementation, and "continued implementation, at which point one can speak of true adoption. However, adoption implies that the preexisting conditions of the overall system have changed, and there may be significant feed-back effects in other areas, as the situation works itself out. An important role for economists is to describe and monitor these interactions.

One way of facilitating adoption is a better understanding of why adoption is *nor* occurring. Gladwin uses a decision-tree model to show how farmers made decisions about adopting or not adopting a package of recommendations including fertilizer use and diversification from maize to vegetables and other crops. Once the logic was understood, new approaches, using somewhat different technologies, could be developed and introduced. The "adoptable" packages did not require farmers to grow less maize, but encouraged them to grow cash crops in addition to their maize subsistence crop. The pace of change was slower than originally envisaged, but much faster than would have been possible under the original plan. As farmers gamed experience with diversified crops, they created a demand for new services and for the technologies being provided. Gladwin notes that this model can also be used in understanding the constraints which institutions (e.g., government agencies) face in deciding to adopt or not adopt new practices.

Monitoring farmers' adoption of new technology provides feedback both to a specific program, and on a broader level, to the IARC's research agenda. Pachico's study of CIAT's Bean Program is, in a sense, a status report on the center's strategic decision to develop low-input bean varieties targeted to resource-poor farmers and marginal conditions. Overall, the response by farmers has been very positive, with yield increases of up to 100 percent from the new varieties alone. Farmers' willingness to adopt the varieties depends on their suitability to a given microregion, and the performance of local traditional varieties; in some cases farmers preferred lower-yielding local varieties that had a better taste and commanded a higher market price. There is a real challenge in managing a tightly targeted adoption process such as this one, and close monitoring of ongoing results for midterm refinements becomes particularly crucial.

The underlying assumption of CIAT's strategy to develop low-input varieties — that small-scale farmers will not use adequate amounts of fertilizer — is questioned by Guggenheim's study. Using national census data, Guggenheim documents that fertilizer is an essential element of small-scale farmer production strategies for certain crops. Yet, the way in which small-scale farmers use inputs is different from larger farmers; the key feature of small-scale farmer agriculture is diversification, both of crop type, and of cultivation practices. Fertilizer is applied to some crops and varieties and not to others; often the residual effects on the next crop are as important as the primary use. More importantly, fertilizer use appears to be increasing among small-scale farmers, particularly for cash crops. Guggenheim notes that there are many excellent reasons for encouraging low-input agricultural technologies, but the unwillingness of small-scale farmers to use inputs is not one of them. "Removing the 'zero-input' assumption," he suggests, "would allow for technologies more suited to small farmers' requirements and capabilities."

MANAGEMENT AS AGRICULTURAL TECHNOLOGY

There is potential for tremendous increases in agricultural production simply by making better use of existing technology through better management of those technologies. The constraints to realizing that potential are primarily human (e.g., lack of trained staff, inefficient agencies), but there may also be important physical and technical constraints to better management. In some cases, a physical constraint may be symptomatic of a human or institutional problem (e.g., a washed-out road that has not been repaired, or an irrigation canal that has fallen into disrepair). The management (*sensu stricto*) aspects of agricultural technology are becoming increasingly important as the new agricultural technologies produced by the IARCs are becoming well known, have been proven to be adoptable by farmers, and are generally available at the national level, if not always locally.

Rhoades gives three examples, taken from his experience at CIP, of management constraints to the long-term use of introduced agricultural technology. The types of "management technologies" that he describes may lie beyond the mandates of most centers: a seed distribution program, a potato processing plant, and a potato storage facility. In all three cases, inadequate management of the facilities for handling potato seeds, or harvested potatoes, has been an obstacle in realizing the full potential of the new potato varieties. As Rhoades notes in his paper, "generation and adoption are necessary stages but not sufficient for successful long-term use of a technology. However, most efforts in agricultural research and development are given to these earlier and easier steps without consideration of whether project beneficiaries have the managerial capabilities or resources to put the technologies to productive use beyond the stages of initial adoption."

The difference between good and bad management of agricultural technology is not necessarily clear-cut, however. Generally, there is some degree of choice involved in selecting from a number of management alternatives. Participatory approaches which involve beneficiaries may be preferred for reasons of social development even if productivity is reduced. In the case of Sri Lankan irrigation systems studied by an interdisciplinary IIMI team, tighter management is needed for more efficient water distribution. Groenfeldt suggests that devolving authority from government irrigation agencies to local farmer associations would improve overall performance (in terms of lower water use or higher crop production, or both) and could have important side benefits in giving fanners organizational skills and better access to other government support services. An alternative management solution that would strengthen the irrigation agency might result in the same or greater productivity increases, but without the extra social benefits to farmers. The decision to adopt a particular management alternative is thus rooted in overall development objectives.

The use of agricultural technology to attack poverty and redress economic inequity can be viewed as a management issue. At the level of technology generation and adoption, choices are made to target particular groups of farmers. The same kind of choices reappear in designing the "after sales service" that follows adoption. The DRI-CIAT Yuca Project was oriented to disadvantaged, small-scale farmers who did not have easy access to yuca processing facilities. Romanoff evaluated the project for CIAT to determine whether the target group was actually benefiting, and to identify management alternatives that could ensure those benefits.

CIAT presumably views the yuca processing plants as a type of agricultural technology, and refinements in their management are part of the adoption process by which they can be made to function better, and on a sustainable basis. As a management institute, IIMI's interest in irrigation management alternatives focuses on the management solution itself, and on the elements that can be replicated in other irrigation systems. A somewhat different application of management principles is presented by Raintree: the management of agroforestry information for use by the national agencies who are adopting the technology. The nature of agroforestry technology is heavily data-bound; information on land use systems and subsystems are the building blocks from which agroforestry recommendations can be made. Arguably, the most useful "after sales service" that ICRAF can provide is to facilitate access to the highly specific data needed on a routine basis by the national agencies. Raintree suggests that information management is a function that ICRAF is uniquely suited to fill, while the implementation of agroforestry research and development will be done increasingly by national agencies.

Management of agricultural technology, as broadly defined in this volume, runs through to all aspects of work within the international agricultural research system. In the past, most of the IARCs have chosen to emphasize technology production at the expense of working systematically with the intermediate users of the technology (national agencies) who stand between IARCs and the end-users (farmers). Times have changed. Heightened concern for the adoption and postadoption stages of agricultural technology suggests a new sense of accountability on the part of IARC scientists. For social scientists, this shift implies expansion from the traditional focus on farmers to include national implementing agencies and local government bodies that determine in large measure whether and how new agricultural technologies will be used. For all scientists, a management orientation implies close working relationships with the local and national organizations who are the "middle men" of IARC technologies, as well as developers of independent technologies. Taking time to understand, share, and learn from national scientists, planners, and administrators is an important part of developing better and more usable agricultural technologies.

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Part I1

SETTING A RESEARCH AGENDA

ON THE DESIGN OF COMMODITY RESEARCH PROGRAMS IN THE INTERNATIONAL CENTERS

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Thii paper is concerned with two overlapping management issues: 1) how commodity research programs are managed within the IARCs, and 2) how a user perspective can be integrated into agricultural research programs carried out on a continental scale. The first issue focuses on how objectives are defined, how these are translated into a research strategy, and how strategy in turn generates new technology. This discussion will be based primarily on work by the author and other social scientists at CIAT.

The second management issue is that of a user perspective: how IARCs manage the paradox of developing technology for a vast heterogeneous target area while simultaneuosly attempting to ensure that the technology will be adopted by the eventual client, the farmer. The issue is often subsumed in debates over the division of labor between IARCs and national research institutions, over the relative weight given by the IARC to basic US applied research, or over the potential for developing widely adapted technologies, especially crop varieties.

Underlying both issues is a basic conundrum facing the centers: they are justified as "basic" research institutions, but are evaluated by how effective they are in producing technologies that are actually adopted by farmers. Research on the dwarf wheat and rice varieties was able to bridge these two issues by focusing on a relatively homogeneous production system. Experience with other primarily rain-fed crops suggests that research must consider socioeconomic or edapho-climatic variability within the target area. A means of accommodating location-specific research thus becomes a critical issue in organizing commodity research programs.

SETTING THE STAGE: DEFINING AN IARC'S OBJECTIVES

An institutional framework for organizing international agricultural research for the tropics is a relatively recent phenomenon. The CGIAR was founded only in 1971, building on the work of the Ford and Rockefeller Foundations in the development of IRRI, CIMMYT, CIAT, and IITA. Mobilization of funds for the very rapid expansion of the system was justified by the success of the dwarf rice and wheat varieties in Asia in the early 1970s. Success naturally bred imitation and the design and strategy for the newer IARCs were swayed by the Asian rice and wheat models.

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The broad design of the international agricultural research system drew its conceptual analogues from economics. The role of the IARCs was defined in terms of an international division of labor (i.e., scientific manpower) in which the IARCs operated between research institutions in the developed countries, where the focus was on more basic research, and the national agricultural research systems in the developing countries, where the focus was often limited to adaptive research on crop technologies developed in the United States, Europe, and Japan (Evenson and Binswanger 1978). The IARC system would focus on those food commodities of major importance to developing countries. Finally, the division of labor would be based on the comparative advantage of the IARCs in certain key areas, especially germplasm improvement, where economies of scale existed. Operationally, the research of the IARCs would be organized along commodity lines, its direct clients would be national commodity research programs, and research would be strategic in nature and focus on those problems where technological solutions would have broad applicability and a relatively good prospect of success.

The spread of the dwarf rice and wheat varieties in Asia – the Green Revolution in the idiom of that particular decade to a large extent provided the overall objectives for the CGIAR system and the standards by which later crop research programs in the system would be measured. The impact of the dwarf varieties cut across several socioeconomic dimensions important to policy makers of the time. These included rapid increases in food production on a constrained land base, improvement of farmer income (especially those farmers with limited land resources), a reduction in food prices and food imports, and improvements of the nutrition of the lower-income strata. That improved varieties were sufficient to produce major benefits in all these areas was virtually unprecedented in modern tropical agriculture, and not surprisingly brought agricultural research into the political arena. Returns to investment in agricultural research were now to be measured in terms of the effect on overall policy goals rather than in terms of scientific outputs such as published articles or released varieties. This focus on development impact is clearly reflected in the goal statement of the CGIAR 'Through international agricultural research and research-related activities to contribute to increasing sustainable food production in developing countries in such a way that the nutritional levels and general economic well-being of low-income people is improved" (TAC Secretariat 1985).

The irony is that the Asian rice and wheat paradigm became dominant within the CGIAR system just as it was expanding into new commodities and new regions where that paradigm did not hold. The success of the dwarf rice and wheat varieties was based on several salient characteristics peculiar to the Asian context and to rice and wheat. First, the vast irrigated areas of Asia provided a relatively homogeneous soil and moisture environment, where edapho-climatic stresses are minimized. Breeding could focus on yield expression that was valid over a large target area. Second, rice dominates the food economy of tropical Asia, and there was still significant elasticity in demand for the commodity. For the poor consumer, it is the dominant expenditure in his budget, and for the fanner with irrigated land, it is the dominant income source. Lower production costs and lower output prices for such a commodity could impact on small-scale fanner incomes and poor consumer welfare at the same time. In the case of rice in Asia, there was a direct linear relationship between release of a new variety, adoption over a wide area, a significant production increase, adjustment in input and output markets, and impact on equity objectives.

However, with the establishment of the next phase of IARCs (e.g., ICRISAT, ICARDA, and CIP), the CGIAR was expanding into crops grown under essentially rain-fed conditions in ecosystems where there were major edaphic and climatic stresses. In addition, farm size was more heterogeneous, and the crops were characterized by either inelastic demand or severe postharvest constraints. Developing a research strategy under these more difficult conditions on a continental scale that also addressed socioeconomic objectives, necessarily incorporated issues of fanners' management of agricultural technology.

There is a basic tenet in economics that for every policy objective pursued, an instrumental variable under the decision maker's control is needed. The IARCs are now held responsible for a considerable number of objectives, but the number of instruments they have at their disposal is limited. Primary objectives include: 1) stable increases in food production; 2) improved small-scale farmer incomes; 3) enhanced nutrition of low-income consumers; 4) conservation of the natural resource base and control of environmental degradation; and 5) more efficient resource use, especially energy conservation. There are also pressures to include several additional objectives: 1) increased rural employment, especially for landless laborers; 2) improvements in the welfare of rural women; and 3) a more comprehensive approach to income generation in the agricultural sector (Schuh 1986).

An individual IARC defines its objectives in relation to its crop mandate, ecological mandate, and regional responsibility. The center may allocate specific objectives to different research programs, or it may require that each research program develop a strategy that meets all the objectives. For example, CIAT has developed a crop "portfolio" to meet its primary objectives within a Latin American setting (Chapter 1 of *CIAT in the 1980s)*; however, no single crop research program within the portfolio is responsible for meeting every objective. Other IARCs, such as ICRISAT and IITA divide their objectives between crop-specific research programs and fanning systems programs.

Thus, within an IARC, it is the responsibility of every research program to integrate the center's objectives, for which it has some probability of impact, into its research strategy. This is a complex undertaking because the strategy must be defined in several dimensions: the biological and economic characteristics of a crop, the agroeconomic characteristics of the target farm population and target area, and the overall pattern of food consumption and income distribution in the economies of the region. In many instances there will be trade-offs between objectives; for example, in Latin America the trade-offs between increasing the availability of rice at reduced prices to urban consumers versus increasing the incomes of small-scale rice growers in upland areas. Moreover, objectives may have to be set in priority order according to country. Technologies to increase the employment of landless labor in rice production in Java are not compatible with the need for more mechanized production of rice in parts of Thailand. Defining a research strategy in terms of clearly identified socioeconomic objectives requires a capacity for *ex-ante* evaluation of the stream of benefits arising from technological options (Pachico, Lynam, and Jones 1987).

TURNING STRATEGY INTO TECHNOLOGY
PUTTING THE HYV IN PERSPECTIVE

Successful applied research' (i.e., that which produces adoptable technology) usually depends on a clearly focused strategy, well- developed mechanisms for problem identification, and an appropriate organization of various scientific disciplines. The commodity research program, as the basic organizational unit in the CGIAR system, meets these requirements through a multidisciplinary research team focused on a single commodity. As the history of these programs would suggest, defining the appropriate disciplinary mix is an evolutionary process, essentially dependent on refining the problem. Identification of researchable problems occurs in three principal dimensions: 1) analysis of the different stages in the commodity system from production to consumption, in which technological intervention is warranted; 2) improved characterization of the target area and the target farm population leading to better definition of technology design parameters; and 3) the balance between a genetic or varietal solution to a problem versus an agronomic or management solution.

The Limits of a Pure Breeding Solution

Varietal improvement is the heart of virtually every crop research program in the CGIAR system. For many programs the multidisciplinary teams are organized around a central breeding effort, with entomologists, pathologists, physiologists, microbiologists, and even soil scientists contributing to parental evaluation and hybrid screening. Centralized crop breeding on a continental scale has been modeled on the dwarf wheat and rice experience. However, centralized breeding programs for the rain-fed crops began to decentralize in an attempt to cope with the heterogeneity of their target area. Crop research programs addressed the issue by subdividing the breeding program into ecological zones, by developing satellite breeding projects in each target region, and by sending out early lines for selection by national programs in diverse sites.

A more comprehensive approach to coping with diversity has been to balance a breeding program with complementary research on the management environment in which the improved variety will be placed. The potential for yield gains through breeding is a function of the kinds of stress to which the plant will be subjected, and therefore, the level of management and the edapho-climatic conditions under which the crop will he grown. Management practices can he used to overcome edapho-climatic, or biotic stress or both, or tolerance can be bred into the variety. However, as the number of resistances increases, the more difficult is the breeding task, and the more likely that the yield potential is sacrificed. The breeder must decide what selection pressures to apply, or conversely, what level of management practices to select under. Obviously, this decision is related to the agro-climatic conditions in the target area and to the level of management practices used by the target farmer population. To complicate matters, there is subregional variation in these two facts. The response to this situation is to stratify the breeding program, and to conduct research on improved management practices to complement the variety.

A wealth of social Science research in tropical agriculture has demonstrated that indigenous farming systems are well adapted, and often well buffered to the edapho-climatic, biotic, and economic conditions they face, except in those situations where rapid population growth or market penetration may have introduced ecological instability and "involution." Finding a strategy for increasing farm productivity while maintaining balance in the nutrient, soil, and pathogen subsystems is complex and often crop specific. Four general scenarios can be defined: 1) adoption of a high-yielding, improved variety prior to the adoption of new management practices; 2) incorporation of disease and insect resistance in locally adapted varieties; 3) adoption of management practices prior to the adoption of improved varieties; and 4) adoption of a technological package including new varieties and management practices. Each scenario is discussed in the following:

1. *The* varietyprecedes new management practices. For this scenario to operate, the new variety must give higher yields than the local variety under existing conditions, and in turn he responsive to changes in management (Byerlee and Harrington 1983), as in the now classic cases of rice and wheat. However, relatively high management levels were already being applied to indigenous varieties of rice and wheat prior to the introduction of new varieties. In rain-fed crops, this scenario seems to apply only in areas of relatively better rainfall and soil conditions, as Gerhart (1975), for example, found in the case of improved maize varieties in Kenya. Competition is usually high for better types of land, and normally only the more valuable and often nonstaple crops are grown in such areas. Outside these areas, crop varieties may have low-yielding potential but tend to be well buffered to local stresses.

2. Breeding *for* disease or insect resistance. Where diseases are a constraint, resistant varieties can precipitate major changes in the productivity of existing cropping systems. Field beans in Latin America are such an example, where the crop is subject to a broad disease complex which makes the crop very risky to grow. Varieties with multiple resistance have been adopted without changes in management practices, but because of the risk reduction, new varieties make increases in plant

density, and application of purchased inputs such as fertilizer, highly profitable (Pachico and Borbon 1986). Such a strategy, however, is not practical for a crop such as cassava in Latin America, which is much more in balance with its disease and insect complex (Lozano, Byrne, and Bellotti 1980).

3. Management practices *precede* improved varieties.' This scenario occurs where the variety must move into more marginal areas with more severe edapho-climatic stresses. Local varieties, especially in the center of origin, are usually well adapted to environmental stresses, even though they may be relatively low yielding. Cassava in Latin America and sorghum in Africa are prime examples. In such cases changes in management practices must relieve some of the principal constraints before a breeding effort has any chance of yield progress. Thus, tractor mechanization and early planting preceded the adoption of new barley varieties in a dry area of Mexico (Byerlee and Hesse 1982), and tied ridging, animal traction, and fertilization preceded new varieties in Burkina Faso (Sanders, Nagy, and Shapiro 1985). In such situations research on existing and potential management practices is essential to any progress in breeding.

4. A package approach. As Walker (1981) points out, "a package approach contradicts what has been confirmed in many studies about the dynamics of adoption, i.e., farmers adopt recommendations sequentially and usually proceed through stages of awareness, interest, evaluation, trial, and ultimately adoption." Byerlee and Hesse (1982) in their study of barley producers in Mexico, rigorously document this sequential process of adoption. The implication is that one of the three previous scenarios must hold and each technology component must therefore stand on its own at some point in an adoption sequence.

Targeting and Defining a Research Strategy

The interplay between breeding and management research highlights several basic issues in the design cf a crop breeding program at an IARC. Crop research programs that work on rain-fed crops, especially in more marginal areas such as the semiarid tropics, must rely on a relatively systematic characterization of their target area in order to assess strategy and priorities. Crops such as maize, cassava, and sorghum are grown across a wide range of edapho-climatic conditions in the developing world and yet have very strong genotypic interactions with such factors as temperature, soil nutrient status, rainfall distribution, and humidity. Defining relevant constraints is essential to stratifying the breeding program, identifying selection sites, and organizing testing networks (Sanders and Lynam 1982). The relative weight given to yield potential versus disease and pest resistance is partly defined from such a target area characterization.

Target area characterization must also include some analysis of the fanner population growing the crop. Farm size, cropping system, input use, input and output prices, competing crops, percentage marketed, yield distributions, etc., are all important in defining the management environment for the crop. Issues such as the importance of erosion in the crop system, the choice between soil amendments versus varietal tolerance to soil acidity or aluminium, and crop rotations or nutrient-efficient varieties versus fertilizer application are all answered from systematic, farm-level data collection.

Target area stratification is key to research priority assessment. A controversial issue is whether the research strategy should focus on high-potential production areas or commercial farmers or both (e.g., the case of CIAT rice research in Latin America), or whether the focus should be on more marginal agricultural regions or more small-scale and less commercial farmers or both (e.g., the case of the CIAT Cassava Program). This process, whereby global objectives are made operational, is what the recent CGIAR Impact Study (1985) calls targeting of technology.

A prime example of this process is the issue of producer equity. Although evidence now supports the scale neutrality of the dwarf rice and wheat varieties in the Asian irrigated sector, there is no basis for suggesting the scale neutrality of improved varieties of rain-fed crops in Latin America. Where mechanization or input use must precede varietal adoption, there is a clear potential for bias. More importantly, large- and small-scale farmers are not evenly distributed across agro-climatic variables, and thus do not face the same environmental constraints (Kaminsky 1980). As an example, breeding priorities for maize in the Andean region can be clearly targeted to large- and small-scale farmers on the basis of color, grain type, and agro-climatic zones. Pachico (1984) suggests the potential for targeting bean research to small-scale farmers in Latin America

Targeting implies that each crop research program should clearly specify its objectives and the means to achieve them. For example, a focus on one objective such as producer equity may be too costly in relation to another objective, such as the nutrition of poor urban consumers in which case a choice must be made. Whether the CGIAR system can meet all the goals it has set for itself depends on each commodity research program having a clearly articulated correspondence among research activities, technology design, and potential impact.[3]

Target area characterization is also key to assessing research on management practices, and especially in meeting the sustainability objective. Sustaining increases in crop yields due to improved varieties requires a strategy for disease and pest protection, soil-fertility management, erosion, and water control. Solutions are dependent on such factors as soil type, land gradient, land preparation methods and power source, input delivery systems, crop rotation interactions, etc. Targeting linked to research on innovative management practices is key to sustainable productivity increases, especially where input delivery systems are poorly developed. For example, increased productivity implies increased nutrient demand from the system, and where fertilizers are scarce, this implies crop rotations, improving or introducing mycorrhiza and rhyzobia, building organic matter content, and integrating livestock. Enhancing biological processes implies translating new knowledge into improved management practices. Developing that knowledge involves, in many cases, linking the laboratory to the farm. On-farm research with a distinct applied research focus as opposed to adaptive is essential.

Field-Level Research and **Feedback Mechanisms**

Target area characterization relies fundamentally on the development of a database system. The integration of the target area database into a crop research program provides a tool for focusing research and a mechanism for maintaining continuity in programs where turnover in scientific staff is relatively frequent. Thus, the database should not be seen as static. Rather, field-level research and feedback mechanisms create an interactive research process; the structure of the research and the data evolve in relation to a better understanding of the commodity, the target area. and research needs.

Feedback mechanisms at the IARCs are, in general, poorly developed, and those that do exist tend to focus on international varietal testing. Even here, the focus is on moving germplasm to national programs rather than two-way information feedback and hypothesis testing. International variety trials have tried to match varietal characteristics to the needs of individual national programs. Analysis of results of these trials across the target areas have been virtually nonexistent. This situation is symptomatic of the secondary status given to feedback mechanisms in IARC research programs. Similarly, on-farm research currently carried out at the IARCs focuses principally on adaptive research – fine-tuning the technology -- rather than systematic hypothesis testing in (or across) the target area. Ironically, the lack of consistent feedback mechanisms reinforces the "topdown" approach to technology development that on-farm research, with its "bottom-up" focus, was meant to reverse.

Feedback from the target area should be an integral part of the research process, especially for centers which must meet the needs of large and diverse target areas. Central to the development of effective feedback mechanisms are clarity in problem definition, a welldeveloped sampling frame, and field research capacity. Data feedback will, of course, depend on the questions being asked. For example, to answer the question of what the minimum number of breeding projects required to meet the needs of the target region is, entails specifying the methodology, data requirements, sampling frame (minimally across edapho-climatic variables), and well-defined field trials (including a critical mix of genotypes). Moreover, initial answers should be seen as approximations; the process is iterative with the first analysis leading to better stratification, improved trial design, and identification of further data needs.

Integrating a user perspective in technology design also relies on the same general process (i.e., specifying the research hypothesis, sampling, and field research). What is different is that the research often moves outside a singular focus on the production sphere. A user perspective, by definition, integrates consumer or fanner decision making in the evaluation of constraints, and in turn the definition of design requirements for new technology. The focus is on the commodity, but the research is set within a farming system or household context. The criticism of this research in the IARCs has been that it is highly location-specific. However, without being location-specific, targeting becomes virtually impossible. Moreover, most agronomic field trials are subject to similar criticisms of specificity. Target area characterization provides a framework for extrapolating results of fanning system or household research, or for that matter, agronomic research.

Field-level research is central to the effectiveness of the IARCs. On-farm research, however, needs to deal with the location specificity problem and move away from purely adaptive research. The organization of on-farm applied research is, in general, not compatible with an on-farm research program oriented to adaptive research. Choice of region and trial design follow different objectives. The objective in the former is hypothesis testing and feedback to the research program rather than refining a technology for extension (see Lynam, Sanders, and Mason 1986 for a discussion of this issue in relation to multiple cropping research). Experimental design focuses on understanding constraints within a systems framework (e.g., research on the soil subsystem may randomly sample farmer plots in a region for mycorrhiza or rhyzobia strains), while in turn relating these to yields of the crop under different management practices. Modeling helps analysis of subsystems with overall farmer decision making. Moreover, modeling provides an interactive link between hypothesis development and field-level verification.

STRATEGY AND TECHNOLOGY DEVELOPMENT IN THE CIAT CASSAVA PROGRAM

Cassava is generally a small-scale fanner crop in Latin America (Lynam and Pachico 1982), grown in marginal environments where the production of other staple or cash crops is problematic (Carter 1986a). The inherent labor intensity in producing the crop, the relatively high costs of mechanization, and the comparative advantage of small-scale processing could maintain the dominance of the small-scale producer in total production (Lynam and Pachico 1982). CIAT cassava research strategy has focused on maintaining the comparative advantage of the small-scale producer in cassava production as a means of raising small-scale farm incomes in relatively marginal agricultural zones (CIAT 1981). In a Latin American setting cassava is virtually unique in its potential to meet this objective (Lynam 1985).

Traditional cassava markets in Latin America are in decline. Rapid urbanization has shifted the locus of food consumption from rural to urban areas. Where cassava consumption is based on the fresh root, high costs of marketing have made cassava uncompetitive as a basic staple in urban areas (Janssen and Wheatley 1985). In Brazil, cassava flour (*farinha de mandioca*) has been a traditional staple, particularly for the poor. However, a negative income elasticity, compounded by very high consumer subsidies on wheat flour, has forestalled any growth in this market. With little elasticity in demand, new production technology would have a negative impact on small-scale farmer income, and in the case of fresh cassava, would have little impact on consumption as well, because marketing margins normally constitute over two-thirds of the consumer price. Thus, under present market conditions there is little effective demand for improved cassava production technology, and thus small potential returns to research investment — emphasizing again the limitations of an IARC's singular focus on varietal breeding.

Research on Postharvest Processing and Utilization

Determining research priorities in postharvest utilization began with an evaluation of market potential (Pachico, Janssen, and Lynam 1983) and an evaluation of CIAT's comparative advantage in this area *vis-à-vis* the private sector, especially in machinery design. Because research in this area focused on the development of new uses and markets for cassava, and in turn linked these to small-scale cassava producers, technology development was evaluated with regard to necessary changes in the whole commodity system, from production to final consumption.

The following example highlights some of the decision points and the interaction between subsystems. Composite flour programs have been advocated for tropical countries since at least the 1930s, but only one or two cases have been successfully implemented, and then only for a short period of time. CIAT's research identified the technical and economic facts determining success in this market. Traditional composite flour schemes were based on relatively large factories, where conversion rates were low, drying costs were high, and root supply was usually inadequate or costly. Even in small-scale plants, conversion rates remained low because of peeling of roots and inadequate particle size when put through a hammer mill. Also, how to organize the mixing and distribution of composite flour at the lowest cost was not clear: was the cassava flour to be mixed at the wheat mill, at an independent mixer, or at the bakery? Likewise, how were small-scale cassava producers to be integrated into the system?

The key to the system was'the finding that unpeeled, dry chips of a "grit" size could be milled in a normal wheat mill (i.e., roller mill), and peel and fiber could be separated from a flour of requisite particle size. Conversion rates and organization of mixing were solved. The parameters for village-level drying were defined - essentially washing and tray drying. Bakery evaluation found differences in bread quality depending on the cassava variety used, thus linking market development to production technology, A panel of bakers and consumers was drawn from a larger survey, and it was found that the bakers could make adjustments in their dough so that consumers found no differences between bread based on pure wheat flour and a 15 percent cassava flour mixture. The research defined the requirements for the entire system from production to consumption. A similar approach was used in the development of a technology for storage of fresh cassava for urban consumption and the technology for dried cassava for incorporation in balanced feeds.

Production Research

In Latin America, improved varieties are seen as a necessary, but by no means sufficient means of achieving a sustained increase in cassava production and productivity. In cassava's center of origin, improved varieties must compete with varieties well adapted to local environments and the quality requirements of regional markets. As Jennings and Cock (1977) have pointed out, yields are usually lower in the center of origin because of the greater number of biotic constraints; the corollary, of course, is that breeding progress is much more difficult. Additionally, there is virtually no input use in cassava production systems, principally because of marketing risk. The reason is that cassava is a long-season crop, making pest and pathogen control too costly, and it responds inconsistently to fertilizers.

A two-pronged research strategy followed from this situation. First, the breeding program was stratified by edapho-climatic zones. These zones were continuously refined by an evolving database which allowed an agro-climatic mapping of the target area (Carter 1986). Second, research on improved management practices was seen as critical to allowing yield progress in breeding. Because these practices did not rely on input use, changes in management of the crop were critical to productivity gains.

Research on management practices has two essential characteristics. It must address basic constraints on crop productivity and must introduce new knowledge not already incorporated in the farmers' cropping systems. Rates of input use, plant density, or time of planting are factors which the farmer himself uses when market changes make further intensification possible (such a process is evident in cassava production in Java). In this area the research must move from the pure empiricism of factorial trials to a more complete understanding of subsystem dynamics. Second, the research must follow from an understanding of principal constraints on farmers' cropping systems. Identifying those constraints derives from a more detailed characterization of the target area and target farm population (Carter 1987) and what may be termed investigative-on-farm research.

CIAT Cassava Program research focuses on a variety of management issues, including the following. First, cassava is vegetatively (and thus clonally) propagated from stem cuttings. Physiological determinants of stem viability, germination, and eventual yield are not well understood. Starch content seems to be a principal determinant, which leads to the issues of what the determinants of starch content in the stem are, and how these are optimally managed at the farm level. Second, cassava has a very poorly developed root system, and is fundamentally dependent on an effective mycorrhizal association **for** adequate yield. Understanding the interaction between mycorrhiza populations and soil and crop management is key to cassava's productivity and the efficacy of fertilizer application. Third, cassava requires about three months to close its canopy, leading to potential soil erosion, especially on poor soil in hilly regions. Developing cropping practices that reduce erosion losses are critical to sustainable yield. Because cassava is principally grown under marginal soil and rainfall conditions (inputs are not a solution to these constraints), management practices that build on soil improvement and more efficacious biological processes are key to sustained yield improvement.

Integrated Cassava Development Projects

Achieving impact in cassava production is much more complex than merely structuring a program of varietal testing and release in collaboration with national research programs. It was incumbent on the CIAT Cassava Program to develop a mechanism to generate and demonstrate an impact on defined objectives. The logic of achieving impact followed clearly from the same principles that defined the research strategy. Market development and introduction of processing technology had to precede the introduction of production technology. Because price incentives alone would not provide the impetus necessary for market development (Lynam, Janssen, and Romanoff 1986), institutional intervention was necessary. The concept of pilot projects which integrated development of new markets, introduction of processing technology, organization of farmers, and releasing of new production technology, was developed as the focus of collaborative activities with national organizations.

Pilot projects are now operating in Colombia, Mexico, Panama, Ecuador, and Paraguay, with plans for Peru and Brazil. The projects provide CIAT with on-farm research laboratories in which a range of issues can be studied, and learning-by-doing deepens the effectiveness of new technology. New research areas have been identified for refining processing technology. Evaluating farmer response to market stabilization is possible (Janssen 1986). Concepts for organizing farmers around the processing plants have been tested **so as** to optimize the distribution of benefits to farmers with minimum resources. Studies have been started to evaluate mechanisms for improving institutional coordination. Changes in production systems necessary to adapt to the changes in market requirements have been studied.. Finally, the projects have demonstrated impact and identified mechanisms by which to target benefits to small-scale farmers in marginal agro-climatic zones (see Lynam, Janssen, and Romanoff 1986 for more details on the impact of pilot projects).

CONCLUSIONS

Multiple objectives and accountability for impact have made the management of commodity research programs in the IARCs a complex task. There is ample room for argument over how problems should be framed, as well as the appropriate techniques available for evaluating alternatives. This haziness makes it very difficult to divine when research programs merely give lip service to meeting difficult socioeconomic objectives, and when they really have attempted to address the problem in a systematic way. In some quarters, the not unwarranted sentiment is still held that researchers should he free to follow their own intuition. However, this does little to satisfy the trustees of public funds concerned in allocating scarce research resources to resolve difficult technical problems in developing countries.

Principally, social scientists have held the research programs accountable for broader socioeconomic impact. Therefore, they should accept some responsibility for systematically setting out the alternatives open to commodity research programs. Social science research on the appropriate design of commodity research programs, on developing methodologies for evaluating the impact of different technology design options, and on targeting applied research, is limited or nonexistent. The dominant perception is that most social scientists in IARCs are principally concerned with testing and monitoring technology coming out of the research programs in the context of farmers' "circumstances." This view is expressed clearly in the TAC Priorities Document (1985:55): "Since social science research to integrate the users' perspective into the process of technology generation is highly location-specific and most relevant at the level of adaptive research, TAC foresees that it will be increasingly taken over by the national systems." This viewpoint, however, appears to dismiss the potential for incorporating a users' perspective much earlier into the technology generation process. By the time technology reaches the adaptive research stage, most of the design options have been fixed, and the potential contribution of the social scientist is substantially narrowed.

The means of integrating a users' perspective earlier in the technology generation process rests essentially on targeting. Targeting serves two functions. First, definition of target groups links research strategy to intended socioeconomic impact. Defining target groups such as landless laborers, small-scale farmers, or low-income urban consumers is only a first step at establishing a linkage between objectives and strategy. Second, targeting is a means of problem identification and of refining the characteristics of the technology. A users' perspective for fanners is set within a farming systems framework, which identifies principal management constraints within well-defined farming systems. A users' perspective for consumers is set within a household framework (i.e., utilization methods and nutritional implications, quality requirements, and household time allocation).

The key to the whole targeting process is developing a framework for sampling research sites on the one hand, and extrapolating location-specific research results to the target area on the other hand. Development of an interactive database for the target area is essential, in which crop production and, optimally, commodity consumption can be characterized across principal variables and at a workable level of spatial disaggregation. Nevertheless, the database is only as good as the state of research on the crop. Development and refinement of the database are iterative processes orienting, as well as building on, the research in the target area (Carter 1987).

Applied agricultural research as carried out in the IARCs cannot take place in a vacuum, independent of the clients who are the eventual recipients of the technology. Current concerns in the CGIAR system about sustainahility, landless labor, and the role of women, by their very nature require a blending of targeted, location-specific research, work on research methods, and identification of design options within the applied crop research program. Integration of a users' perspective at an early stage of the technology generation process is a key element in enabling the IARCs to meet their diverse objectives.

NOTES

[1]The TAC divides the research continuum accordingly: 1) basic research —designed to generate new understandings; 2) strategic research —designed to solve specific research problems; 3) applied research—designed to create new technology; and 4) adaptive research—designed to adjust technology to the specific needs of a particular set of environmental conditions (TAC Secretariat 1985).

[2]Lipton and Longhurst (1985) develop a reasonable position against this scenario. They cite yield data for the dwarf wheat and rice varieties, and hybrid sorghum under zero fertilizer application and under drought stress. There is indeed evidence in the agronomic literature that the dwarf characteristic and hybrid vigor infer a wider range of adaptability compared to varieties without these characteristics. However, these two characteristics are not employed in any of the other crop breeding programs in the IARCs— dwarf pigeon peas may be an exception— especially because CIMMYT has chosen not to develop hybrid maize. Moreover, they are useful up to a limit. Dwarf rice varieties have moved very quickly in Latin America, hut they have not moved into the unfavored, upland ecologies, which account for 38 percent of the area in rice in the continent, and where the interactions among drought, soil constraints, and disease susceptibility limit the potential of pure breeding solutions. Sorghum in Africa will probably jettison hybrids as an option and must deal with the crop in its center of origin as well.

[3]The IARCs are often caught in a disjunction between justifying potential of the center's work to donors and maintaining a research strategy that is neutral, *vis-à-vis* the range of needs of different national programs. The leap of logic necessary to bridge the two is not lost on the CGIAR's critics, as seen in this quote: [IRRI says that] "its role is merely to produce research outputs, place them in trays, like [sic]

in a cafeteria, and it is up to the users, the Philippine Government and its technocrats to make a choice. Yet, IRRI funding and brochures are all designed to convince people that it is doing splendid work, not only to alleviate hunger, but to bring prosperity to farmers" (Alvares 1986). This quote encapsulates a dilemma facing the IARCs; either they are passive research institutes, where the end objective or goal is just the production of germplasm, or they make concerted attempts to bridge technology design for development policies and objectives. Clarity is needed on this topic, where public relations have essentially blurred the issues. This paper, however, argues that one of the potential strengths of the IARCs is their capacity to set agricultural research priorities within a development framework.

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Part III
DEVELOPING AGRICULTURAL TECHNOLOGY

SOCIAL SCIENCE AND THE MANAGEMENT AND SELECTION OF AGRICULTURAL TECHNOLOGY IN RWANDA

Angelique Haugerud*

INTRODUCTION

Some of the familiar actors in international development work are the economist concerned with trade and exchange rate policies, or with "getting the prices right"; the anthropologist who affirms the need to pay attention to farmers' practices and constraints; the agronomist who conducts trials about seed density, plant spacing, and correct fertilizer doses; the plant breeder concerned with gene frequencies, chromosome segregation, and phenotypic stability; and (too often last) the farmer worried about how a particular rainy season will affect his or her crops and how the children's school fees will be paid.

In their daily concerns, these individuals appear to have little in common. But they are joint participants in the profusion of consultancies and contracts known as international development. Practitioners of positivist, empiricist science are the new missionaries who would convert developing countries to western bureaucratic and scientific norms and values. Most of the scientists and the institutions for which they work would agree, however, that African agricultural research and development are at an impasse.

The 1984-1985 Ethiopian famine brought the dimensions of crisis to world attention and stimulated new donor projects and relief efforts. But many of the underlying difficulties of food production, distribution, and marketing in Africa remain beyond the reach of much foreign assistance. The litany of problems is familiar — a deteriorating natural resource base, soaring birth rates, overvalued currencies, inadequate infrastructure, and declining per capita food production. In addition, and less amenable at present to donor intervention, are problems concerning the accountability, representativeness, and responsiveness of African political and administrative institutions.

The reasons for the impasse in African development are complex. They range from the structure of African states, to the material and social conditions of the continent's small farmers, and global economic forces (Berry 1983, Hart 1982, and Hyden 1980, 1983). This paper considers lessons that emerge from two years of research in an IARC and in a national agricultural research program supported technically by the IARC in eastern Africa.

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Social scientists who are expected to address technology management issues in agricultural research institutions do not always find any promising new technologies available for their attention. That was not the case in the project discussed here, which already had had notable local success with its improved cultivars. Social science research in collaboration with biological scientists, however, did contribute recommendations for more effective technology selection and management.

From 1984-1986, the author, an anthropologist, was affiliated with the CIP, whose headquarters are in Lima, Peru, near the Andean Center of origin of the potato *(Solanum tuberosum)*. Over the last decade, CIP has had several anthropologists and economists on its staff or as research affiliates (Brush 1986, Horton 1983, Monares 1984, Poats 1981, Rhoades 1984, Scott 1985, and Werge 1981). Until the research discussed here, however, CIP's social scientists had been based at the center's Lima headquarters rather than at its regional program offices in Latin America, Asia, and Africa. CIP, like other IARCs, provides technical support to national agricultural research programs in developing countries. One of these programs is in Rwanda in eastern Africa, where the author was based for two years while conducting research in Rwanda, Burundi, and Kenya. This paper focuses on Rwanda.

PNAP is part of that country's national institute of agronomic research. PNAP was established in 1979 by the Government of Rwanda, with technical and financial assistance from CIP (*see* Bicamumpaka and Haverkort 1983, and Nganga 1983). The program had attracted national and international attention before the research discussed here began. It was, for example, nominated for the 1985 UNESCO prize for scientific achievement; the ISNAR at the Hague uses it as a case study training document; the President of Rwanda awarded it a national prize for its role in helping to alleviate famine during the 1984 drought; it is widely praised by national officials and foreign aid donors as one of Rwanda's most successful agricultural projects; and it is used as a model for new projects in Rwanda and neighboring countries.

PNAP previously had neither local nor expatriate social scientists on its staff, though short-term CIP consultants had conducted some social science research and Poats (1981) had done an eight-month study on potato consumption in Rwanda. In spite of CIP requests to do so, Rwanda did not assign any of its own social scientists to PNAP.

How much flexibility and autonomy do anthropologists in the IARCs have in defining their research, and to what degree is basic as well as applied research acceptable? Answers to these questions vary from one institute to the next, as do definitions of basic and applied research. While one center may find land tenure research, for example, to be "academic" and unncecessary, another may view it as essential. Although it is now generally recognized that basic and applied research are mutually beneficial (Brush 1986), this recognition in the IARCs is perhaps more admissible in the biological rather than the social sciences. There is a perception on the part of the biological scientists who dominate the international centers that anthropologists "if not controlled, are commonly tempted into complex and complete studies of particular communities or situations" (Rhoades, Horton, and Booth 1984).

A too narrowly defined range of permissible research questions, however, can reduce the quality of any study. Social scientists are in the IARCs because it is increasingly recognized that they can help to define biological and technological research priorities relevant to fanners' circumstances, and can provide useful information on adoption and distribution constraints and on the impact of improved agricultural technologies. It is up to the social scientists themselves to define the relevant range of inquiry for their own research, taking into account the needs and objectives of the institutions with which they work. Part of their task can be to widen the scope of admissible social science inquiry, if they believe this would benefit the IARCs or the users of improved technologies.

The material accouterments of a professional in an IARC (housing, vehicles, and funds for research and travel) immediately remove one further from the conditions of fanners than is customary in traditional anthropological fieldwork. In addition, such a position can involve formal and overt identification with a government research program or project. Although such associations are often intentionally avoided by anthropologists in the field, they are not necessarily a disadvantage. In the case discussed here, association with a popular and successful national research program was a decided advantage in fieldwork with local farmers.

FIELD RESEARCH

One of the most effective ways to increase agricultural production in a country such as Rwanda is to breed, select, and release improved crop varieties that require no complementary purchased inputs. The cornerstone of the Rwandan national potato research program is the selection and release of new disease-resistant, higher-yielding potato cultivars that require no purchased inputs other than the seed itself (which in the eastern African highlands have a low rate of degeneration so that farmers need not repurchase seed for 5-10 years). During its first five years, the Rwanda program released six improved cultivars whose yields under local farm conditions (without fertilizers or chemicals) were two to five times the previous national average.

Given the program emphasis on selecting and releasing improved cultivars, the author's research first addressed how farmers assess and use potato varieties already cultivated in rural Rwanda. CIP has supported similar studies in Peru and Nepal (Brush, Carney, and Huaman 1980, and Rhoades 1985).

In Rwanda, formal and informal surveys were used to collect information on farmers' agricultural practices, and on what cultivar traits farmers in various environmental zones and wealth categories prefer and why. These data were used in the national breeding, germplasm screening, and seed production programs to help define research priorities, and criteria for trial management and varietal selection that reflect accurately farmers' circumstances.

With one crop (potatoes) as the starting point, surveys addressed farming systems issues concerning production, consumption, storage and marketing, and questions of household dynamics (e.g., differences within the household -- in responsibility for particular crops, in access to income and land, and in selection of seed; and exchanges between households of planting material, land, and labor). The intention was to collect an internally consistent and coherent body of data that would serve complementary theoretical and practical purposes. Field research also involved participation in the design, monitoring, and evaluation of on-farm trials to test and improve specific new techniques and practices.

This paper discusses three major research results and their programs' consequences: I) the utility of shortduration cultivars, 2) the importance and feasibility of intercropping and cultivar mixtures, and 3) problems of disseminating information and distributing program benefits equitably in all parts of the target area.

Short-Duration Cultivsn

Farm survey results contributed to a new program emphasis on selecting improved cultivars that have shorter growth cycles and shorter dormancies (time elapsed between physiological maturity of the tuber and adequate sprouting for planting the next season). Since land is a major constraint and rainfall is well distributed in the eastern African highlands, shortduration cultivars that permit multiple cropping are a particular advantage, even if the shorter cycles entail some sacrifice in yields. While one of the improved potato cultivars that **PNAP** first introduced in Rwanda does have a short growth cycle (about three months), most of the program's improved cultivars have later maturity (four to five months). It was not suggested that the later-maturing (and usually higher-yielding) cultivars be abandoned for an exclusive emphasis on short-duration cultivars, but rather that the latter be given greater emphasis in the germplasm screening and seed production programs.

Farm surveys of 186 farmers in all of Rwanda's major potato production zones suggested the need for such a shift in emphasis in the following ways. First, for example, among the four most frequently grown potato cultivars in Rwanda is a cultivar (*Gashara*) introduced a number of decades ago, which has degenerated and would have been abandoned long ago if yield and disease resistance were farmers' principal cultivar selection criteria. However, the surveys showed Gashara to be still among the most frequently grown cultivars, because farmers value its short growth cycle, short cooking time, short dormancy, good taste, and high starch content. None of the available new cultivars combines all of these preferred characteristics.

Second, the survey results indicated that only two percent of the 186 farmers interviewed prefer to use only long-cycle cultivars (which had been emphasized by PNAP). Over half of the farmers (52 percent) stated a preference for only short-cycle cultivars, 2 percent preferred medium-duration cultivars, and 44 percent preferred a combination of long-, medium-, and short-duration cultivars. Many farmers grow both long- and short-cycle cultivars in order to increase the number of months when fresh potatoes are available for sale and consumption, to reduce the risks of rainfall uncertainty, and to exploit different ecological zones. If a farmer grows a short-cycle cultivar which he knows he can harvest early, he is then more likely to be able to afford (if he has adequate land) to wait for the later harvest with a higher yield of a longer-cycle cultivar.

For Rwandan farmers, the acceptable range of days to maturity in potato cultivars is strikingly skewed toward the short end of the international breeder's theoretical range (which extends to over 150 days). Rwandan farmers' preference for a mixture of long- and shortduration cultivars translates into short and medium maturity (no more than 120 days) on a plant breeder's scale.

With regard to length of dormancy, most farmers surveyed again prefer either to maintain diversity in this trait by planting some cultivars with short and some with long dormancy (54 percent of those surveyed), or to plant only shortdormancy cultivars (43 percent). Short dormancy (to minimize the time between harvest and adequate sprouting of seed for replanting) is an advantage where rainfall distribution allows double and sometimes multiple cropping. Keeping cultivars with both long and short dormancy allows farmers greater flexibility in managing seed stocks and harvest and planting dates.

The type of cultivar PNAP had emphasized in its germplasm screening and seed production programs has large tubers, high yields (20-30 tons/hectare), relatively late maturity (110-I20 days), long dormancies (3-4 months), and good late blight resistance. Farmers who can benefit most from this type of potato cultivar have above-average land and capital assets. They can afford to keep plots of land occupied with longer-maturing cultivars, and they have adequate cash to purchase food while awaiting the potato harvest. A central recommendation of the farm surveys, however, was that PNAP's germplasm screening and seed production program begin to give less emphasis to (but not eliminate) the type of cultivar just described and more emphasis to those with early maturity or short dormancy or both. Given Rwanda's very small farms and high population density, many farmers can benefit from the latter type of cultivar. They cannot necessarily afford to keep scarce land occupied under longer maturing cultivars, and they do not have adequate cash to purchase food while waiting for the potato harvest.

While agriculture in developed countries is made vulnerable by increasing genetic uniformity in the form of cultivar specialization, the cultivar mixtures and intercropping already practiced by so many African farmers are an excellent first line of defense against crop biological and climatic hazards. Maintenance of such diversity is an important means of managing risk, environmental hazards, and resource limitations; and a means of meeting varied production goals (home consumption, sale in different types of markets). Many agricultural research institutions, however, give little attention to the possible benefits of cultivar field mixtures and intercropping.

In Rwanda, recorded observations of 360 potato fields in all of the country's major potato production zones demonstrated the prevalence of intercropping and field mixtures of potato cultivars. Surveys showed that most Rwandan farmers grow three to five different potato varieties at once and that most of their fields contain cultivar mixtures. They find advantageous the mixtures' variability in such traits as length of growth cycle and dormancy resistances, tolerances of rainfall excesses and deficits, dry matter content (which affects taste and storability), and marketability. Nearly half (47 percent) of the observed potato fields were intercropped. The most common crops associated with potatoes were maize, beans, sorghum, colocasia, and sweet potatoes. Government agricultural survey data show that over half of Rwanda's total cultivated area is intercropped, and that 48 percent of the area under potatoes is planted in crop mixtures (Government of Rwanda 1985:71). There is evidence that far from being a dying "traditional" practice, intercropping in Rwanda is increasing over time as population density increases (Janssens et al. 1985).

On the basis of these results, it was recommended that PNAP begin on-station research with cultivar mixtures to test their comparative performance under late blight and other environmental pressures. It was also suggested that given the scarcity of land, increasing population pressure, and likely increase in intercropping, it would be useful to conduct agronomic trials testing common crop associations to determine land equivalent ratios, possible positive effects of intercropping on disease and pest vulnerability, and the performance of different potato cultivars in crop associations. It was also recommended that germplasm selection criteria for some material should include short stolons and vertically extensive, rather than horizontally extensive leaf coverage (i.e., emphasizing height rather than breadth of foliage) in order to reduce competition of potatoes with associated field crops. PNAP then began new on-station trials to test the comparative performance of the program's improved cultivars when grown in crop and cultivar mixtures rather than in pure stands, On-station intercropping and cultivar mixture trials in Rwanda will measure the effects of genotype mixtures on disease and pest transmission and yields. Such trials help to correct publicly the idea that agricultural progress should necessarily involve the monocropping and cultivar specialization common in Western industrial economies.

Given the small size, limited resources, and youth of the Rwandan national potato research program, it has achieved a remarkable impact. Two of the improved cultivars that the program released in 1980, for example, were found in all of the country's major potato producing regions by 1985. In 40 percent of the potato fields observed in four production zones, the PNAP cultivar (*Sangema*) was the variety that occupied the largest field area. In nearly another quarter of the observed fields, a second PNAP (*Montsama*) occupied the largest field area. Such success becomes equivocal, however. as expansion of the area under the one or two most popular cultivars increases genetic uniformity and therefore vulnerability of the crop to pathogens (especially late blight). It is now important that cultivar diversity be encouraged and supported by the selection and effective distribution of a number of additional improved varieties that suit local circumstances.

Distribution and Impact

Farm surveys drew attention to two distribution and impact issues: 1) regional biases in germplasm screening and cultivar selection, and 2) limitations of farmers' access to improved seed. Although PNAP conducts multilocal cultivar trials throughout Rwanda, by the time would-be new varieties reach the multilocal trial stage, hundreds of genotypes (usually introduced from CIP's Lima or Nairobi programs) have been tested and eliminated during several seasons of screening in the northern volcanic soil zone where the national potato research program is based. Varieties selected according to this scheme often perform better on the highly fertile volcanic soils than they do elsewhere. A proposal is now under consideration to screen germplasm before the multilocal trials stage in the other two principal potato zones (lateritic and forest soils).

Although farm surveys showed that Montsama and Sangema (the first two improved cultivars released by PNAP) achieved a wide distribution, cultivars released later have yet to achieve a comparable impact. In part, this is because the time elapsed since their introduction simply had been shorter when the surveys were conducted in 1985 (no more than three years had passed since the later introductions, and it had been five years since the successful early releases). In addition, however, the present system of seed distribution makes access difficult to many farmers.

The national potato research program breeds and selects improved varieties, and produces a small stock of clean seed of the new cultivars which it distributes to a parastatal seed multiplication service and to a number of rural development projects, but not directly to farmers. These projects are responsible for multiplying the basic seed and distributing it to farmers. Because many farmers (89 percent of those surveyed) have not acquired improved seed through this system, proposals are being considered to widen farmers' access by involving private traders in seed sales, and by allowing the national potato research program to sell some of its seed in 5 or 10 kilogram units directly to fanners, rather than distributing all of its seed in multi-ton units to designated projects.

In short, producing suitable cultivars is only one step. Getting the technology right is sometimes more easily accomplished than is its effective distribution. The latter requires direct (and not necessarily welcome) involvement in political and administrative institutions.

DEVELOPMENT POLITICS AND ADMINISTRATION

While the effects of political and administrative structures on agrarian change and development receive considerable scholarly attention, they are often taboo subjects in project design and evaluation documents. **Some** development project personnel quietly attempt to overcome regional and ethnic biases in national agricultural research programs (by requiring, for example, that they be permitted to conduct agronomic trials in "representative"zones). But many others operate in a self-willed political vacuum. Ignoring politics does not necessarily preclude the achievement of technological improvements and production increases. But neither can it be assumed that improved technologies will find their own way to needy clients.

These considerations raise the issues of when, how, and by whom advocacy for clients underrepresented in national-level institutions is appropriate for international centers. Pleas for participatory research are not new, but the need remains to find ways of increasing the voice of less-privileged groups in defining agricultural research priorities and procedures.

For the most part, the IARCs respond to research priorities identified **for** them by state bureaucratic elites. One African country, for example, disfavors expansion of potato production into more marginal lower-altitude zones **as** counter to its policy of regional economic specialization and trade. Breeding potatoes adapted to marginal zones, however, is an important global priority of CIP. Potatoes can add an imporant new protein source ***(see*** Woolfe 1986) to some of Africa's more marginal zones that now depend heavily on low-protein staples such **as** sweet potato and manioc. In the country in question, CIP negotiated an arrangement to continue its development of new potato varieties adapted to zones outside of the cooler, well-watered highlands where the crop is traditionally grown.

Where national and international interests differ, foreign donors may become unwitting participants in regional or ethnic rivalries and conflicts. International insistence on an approach not locally favored also risks acquiring neocolonial overtones. The edifice that development "experts" have helped to establish in Africa is fragile. Projects have a tendency to revert to distribution of products and services through patronage once the expatriate buffer is absent. It is not surprising that some development project staff opt for the gains possible through the patronage networks that define their own institutions, rather than relying on the alien values and "civic public morality" (Hyden 1983, Ekeh 1975) of Western bureaucracies.

Formal economies in Africa are often the subordinate partner of the informal economy or "economy of affection" (Hyden 1981, **1983).** Similarly, the state and its civic public morality are counterpoised to the morality of patronage politics that is rooted in rural social and economic structures, and that sanctions the diversion of state resources into private hands. Reality of course involves more complex shadings than such dichotomies allow. But it is evident that formal economic and political structures in Africa are increasingly threatened by their opposite faces.

Individuals too are torn, as wealth accumulation and success in the formal economy and polity bring increased demands from kin and clients in the informal economy and polity. Individuals are not secure enough in their positions to risk cutting themselves off from the informal system, but the pressures of the latter inevitably undermine the formal system. For the moment, these counterpoised systems fuel both individual wealth accumulation, and redistribution of that wealth through the ties of kinship and clientage upon which its accumulation is based. Aid donors must find means to deal constructively with these sociopolitical and economic realities.

It is of course politically easier to focus on plants, genes, and soils, which is one reason why social scientists are not always welcome additions to agricultural research institutes, and why, when they do join them, they sometimes find it more politic to focus on getting the technology right than on the institutional issues involved in managing the technology.

Developing suitable technology is itself a long and difficult process. But it is the institutional questions (e.g., how sociopolitical relationships and particular local institutions structure individual access to resources such as improved seed, fertilizers, or chemicals) that largely determine a technology's impact. Social scientists can address such institutional issues; they can filter information about the conflicting interests of different economic, sociopolitical, ethnic, and regional groups; they can help to define research priorities relevant to local conditions; and they can help to develop and to test improved technologies. In so doing, they improve the appropriateness, distribution, and impact of new agricultural technologies.

BUILDING NATIONAL SOCIAL SCIENCE CAPACITY IN AGRICULTURAL RESEARCH

Both foreign and national anthropologists in African agricultural research institutes often encounter the view that social science research is inherently impractical, and that it should he a low priority for developing countries because they cannot afford the luxury of research for its own sake. Given a choice, many African agricultural programs prefer an agronomist, plant breeder, soil scientist, or plant pathologist to a social scientist. While social science research cannot be expected to assume a leading role in agricultural development, international donors and institutes nonetheless increasingly recognize the need to take explicit account of the circumstances and needs of the users of proposed new agricultural techniques, and of the local institutions responsible for their development, adaptation, and diffusion.

African agricultural institutions are sometimes unwilling to recognize the actual and potential contributions of social science, or to allow staff positions for their own national social scientists — whether locally or externally financed. At least one eastern African country turned down in **1984** a multilateral donor offer to fund a national social science position that would have been filled by locally selected candidates who would have worked with biological scientists in a national agricultural research institution. This unwillingness is linked not only to the view that biological scientists are more useful, hut also to the common perception that social science research is politically sensitive and risky.

In spite of these difficulties, one of the most important tasks of expatriate social scientists in national agricultural programs is to support the training and apprenticeship of local social scientists in agricultural research. At least as important **as** the results of particular research projects is the institutionalization **of** replicable approaches and methods for acquiring an understanding of farmers' circumstances and practices. This is especially Important given the enormous microdiversity of African farming systems and environments, and the location-specificity of particular research results.

SUMMARY AND CONCLUSIONS

This paper has considered the role of anthropological research in the IARCs and in national agricultural research institutions. It discussed some specific implications of such research for technology selection and management in Rwanda. Farm surveys in that country helped in identifying potato cultivar selection criteria suited to local needs and constraints, proposing specific new on-station experiments that reflect local farmers' practices and constraints, and assessing the impact of previously introduced, improved cultivars, and of the associated seed distribution program.

Although social scientists in agricultural research can help to develop suitable agricultural technologies and research priorities, their Contributions are **too** often sought after substantial investment in technology development has occurred. In addition, it is often difficult for them, and for the IARCs to address adequately the more sensitive, hut crucial, issues concerning sociopolitical and administrative structures that affect the management, distribution, and impact of the new technologies.

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INTERDISCIPLINARY RESEARCH ON INTERCROPPING SUGARCANE AND FOOD CROPS IN SOUTH NYANZA, KENYA

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Many parts of Africa are today facing a crisis in agricultural production. Growing populations and stagnating or declining levels of food production are forcing national governments to spend large amounts of scarce foreign exchange on food imports. Efforts by international and national agricultural research institutes have not been able to produce technological innovations in food production for most African ecological conditions that can be successfully adopted by the majority of Africa's food suppliers—small family farmers. New approaches in managing agricultural research are needed to integrate on-station work in genetic breeding of disease- and pest-resistant or higher-yielding varieties with better knowledge of farmers' actual production practices, and the labor, capital, and land constraints within which they work.

Agricultural research institutes in Kenya provide technical packages developed on-station, which are given to the Ministry of Agriculture for field testing through the national extension service. The information flow is largely one-way, with little data fed back to the station regarding farmers' responses to the new recommendations. Few agricultural research programs, with the exception of some CGIAR institutes, have involved noneconomic social scientists in their research.

This paper describes the initial efforts of a collaborative research project to develop a biologically and socially integrated research strategy for agricultural research in Kenya. Although the approach itself is not new, drawing as it does on the Farming Systems Research work and the basic principles of the "farmer-back-to-farmer" strategy described elsewhere by Rhoades (1984), it had not previously been applied by the participating institutes. This project was initiated in western Kenya early in 1986, and is being implemented by agronomists and anthropologists under the sponsorship of three institutions: ICIPE, IFPRI, and the Rockefeller Foundation. The project's primary objective is to identify food crops suitable for intercropping with sugarcane in three different types of cropping systems in western Kenya. More broadly, the project seeks to develop a methodology for interdisciplinary work to link the collection of sociocultural data on farming practices with the design and refinement of experimental field trials on intercropping.

The substantive portion of the project involves identifying food crops with potential for intercropping with sugarcane without decreasing cane yields, while simultaneously increasing household and regional levels of food supply. To' this end,

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the project entails coordinating on-farm field trials in intercropping (varying crop combinations, spacings, and arrangements of crops, as well as time of planting and level of labor inputs) with social surveys on existing intercropping practices, present use of labor inputs, varietal choices, and farmers' perceptions of pest problems.

Three project sites were selected representing different levels of agricultural technology and potential, and a range of agroecological zones. The Awendo sugar site which is described here represents medium agricultural potential and medium-level technology. The other two sites are in Kakamega and Kisumu where coffee and cotton are being tested with intercropping of food crops.

INTERCROPPING AND SMALL HOLDERS IN KENYA

In Kenya, the need to improve peasant production is particularly severe. The 800,000 small-scale farms, defined by the Central Bureau of Statistics as being under 20 hectares (ha), of which approximately 75 percent are under 3 ha, supply 55 percent of all marketed production, and 80 percent of all agricultural production in the country (Williams 1985:36-37). With the highest rate of population growth in Africa, now believed to be surpassing 4 percent, and only 13 percent of the nation's land suitable for agriculture, a heavy burden is placed on these small agricultural producers.

Agricultural production is the backbone of the Kenyan economy, producing not only food for domestic consumption, but also export crops (e.g., coffee, tea, tobacco, flowers, etc.) which supply the greater portion of Kenya's foreign exchange earnings. These export earnings are then used to purchase the additional food deficit not supplied by domestic production, as well as the fuel, machinery, and raw materials, which contribute to agricultural and industrial sectors. The national government must balance production of food and export crops in order to meet its food and cash requirements.

Research on the potential of intercropping is a response to these concerns about balancing food and cash crop production at household, regional, and national levels. If adequate food production is to be assured, then, those areas of the country suitable for food crops must be effectively used. Previous research at ICIPE on intercropping of cereals and legumes has shown that intercropping can have advantages over monocrop cultivation under some conditions. Depending on the crop mix, intercropping can inhibit weed growth and constrain insect pest populations.

ICIPE's research has been oriented towards the research station. Scientists carry out field trials either on the station grounds, or on farmers' plots with strict control over planting dates and varieties, field preparation, plant populations (arrangement and spacing), weeding, and harvesting. Research on socioeconomic aspects of pest management was initiated in 1984 with an exploratory study to understand farmers' perception of pest problems, and to identify socioeconomic factors which influence farmers' ability to adopt station recommendations for pest control (Connelly 1985).

A major constraint to improving small-scale farmer agriculture in South Nyanza is a shortage of farm labor (Goldman and Omollo 1983). Intercropping, as carried out on the ICIPE station tends to be labor intensive, requiring high plant populations with specific spacing and careful weeding. Yet, farmers cannot follow these recommended practices because of labor constraints.

The balance between food and cash crops is particularly important in areas devoted to cash crop agriculture. In South Nyanza, sugarcane is the major cash crop, followed by tobacco, trees, and maize. Food production remains a high priority, and sugarcane must compete with other nonconsumable cash crops as well as marketable food crops such as maize, beans, groundnuts, and vegetables. Farmers decide to grow varying proportions of these crops according to their assessment of household needs, and household availability of land, labor, and capital. Farmers with small holdings tend to maximize food production, and combine off-farm income earning efforts with small sales of food crops. Farmers with larger holdings and more financial security are better able to turn a portion of their land over to sugarcane, because they can afford to wait the two years until the cane matures. To obtain profitable yields, proper maintenance of the cane is vital. This includes frequent weeding in the first six months after planting, gap filling, and proper fertilizer application. Weeding is supplied either by family labor — often competing with the labor needs of other food crops — or by hired labor, necessitating regular cash outlays by the farmer. The advantage of sugarcane over other crops lies in its minimal labor needs after the first six months of growth, and the relatively large lump sum payment earned by selling cane to the factory at maturity.

Intercropping of sugarcane with food crops may bold some potential for alleviating the weeding constraints faced by farmers and the problem of securing an adequate food crop while concomitantly securing a cash income. The problem is to find a crop which farmers will want to plant, are willing to weed, and will not interfere with the yields of the cane. If the interplanted food crop would encourage weeding of the cane, this might as a by-product offset any potential decline in yield.

At present, few farmers intercrop their sugarcane partly because they are actively discouraged by the sugar factory and local government officials who fear low yields of cane if improper crops are chosen for intercropping. Their fears are partly justified in that those farmers who do intercrop tend to plant hybrid maize; the resulting yields of cane and maize tend to be poor. Some women plant maize in the cane fields in order to bolster food production, hut this can cause permanent damage to the cane, reducing tillering[1] and producing tall, spindly plants. The reduction in tillering results in lower yields per hectare and ultimately lower returns to the farmer.

Inadequate weeding, however, seems to be a much more important cause of low yields in South Nyanza than intercropping. Few families can supply sufficient family labor for weeding cane when it is in direct competition with the labor needed for weeding food crops. Women, the primary weeders, will regularly choose to direct their efforts towards food production. **To** them, weeding their husbands' cane has little personal benefit, as it does not produce food or usable income, and further reduces the time and energy available for food production and other household tasks. However, some women weed their neighbors' cane for payment. Weeding is an important source of income for some farm households.

Intercropping of cane with food crops might, therefore, encourage more families to weed their own sugarcane, and thus conserve cash, and provide additional food supplies. But several questions remain regarding the effect on cane yields of different food crops, the labor requirements for intercropping cane and food crops, the difference in yields between nonweeded cane and intercropped cane, and the overall acceptability of intercropping by farmers.

THE ON-FARM TRIALS

The first on-farm intercropping trials were started in the 1986 'long rains" planting season (February-August). Three sites were selected from land owned by farmers already included in another IFPRI survey on the nutritional effects of commercialization of agriculture in South Nyanza. Some of the same fields from the earlier IFPRI survey were used, which provided background information on farmers' agricultural practices and income/expenditure patterns from 1984 to the present. Arrangements were made to rent plots for the trials, and to use local labor for the farm work.

The process of setting up the field trials was itself instructive about the social context of farming in the Awendo area. The researchers found it difficult and expensive to hire equipment for field preparation. Most farmers use their own ox-plows to prepare their food crop fields, and factory tractor services are supplied to contracted sugar farmers for preparing their sugar fields. To ensure that the project data would be comparable with those derived from factory plots, it was necessary to follow the land preparation procedures recommended by the factory: tractor plowing and harrowing. However, as noncontracted farmers, the ICIPE/IFPRI project found it difficult to hire tractors because most had already accepted work subcontracting with the factory. The tractors available for private hire frequently missed appointments, broke down in the middle of their work, and gave poor service. In the end, the project had to hire factory tractors at extra cost to redo the field preparation. It became clear that obtaining local tractors for ordinary farm work is too expensive, time-consuming, and unreliable to be easily adopted by most small-scale farmers in the area, Consequently, although initial efforts to prepare the sites were begun in early March 1986, the plots were not ready for planting until mid-April, after the long rains had started, and several weeks after most farmers had planted their own food crops.

Of the three plots selected, only one (at Kokuro) could actually be planted, and cultivated during the long rains of 1986. A second plot became waterlogged at the start of the rains, and though planted, did not germinate. A third plot became inaccessible prior to planting when a small wooden bridge leading to it disintegrated with the season's first floods. Such problems are typical of those experienced by farmers in the project area. Many of the cane fields are black cotton soils which become easily waterlogged, and poor germination and lowered yields result. Similarly, inadequate road maintenance in the project area creates numerous problems in ensuring timely provision of inputs.

The successfully established field at Kokuro (trial plot 1) was one hectare in size, divided into six trial plots, planted as follows (Figure 1).

Figure 1. Distribution of plot in trial plot 1 at Kokuro.

Cane	Maize	Beans	Cane and beans	Cane and maize	Cane maize and beans

Because a crop of cane takes 18-24 months to mature in the Awendo area, the final results of intercropping on cane yields are not yet known. An indicator of yield is available, however, in the tiller count (Table 1) which suggests that the number of tillers per plant evens out between plots in the months after the harvest of the interplanted food crops. This trend implies that the effects of intercropping at the experimental spacing may be negligible over the entire growth term of the cane, if proper management is otherwise maintained.

Table 1. Tiller count, trial plot 1 (average number of tillers per plant).

Treatment	Cane-pure	Cane/beans	Cane/maize	Cane/maize/beans
10 Jun 1986	4.4	5.7	4.9	4.0
23 Jun	8.7	3.8	8.6	8.2
8 Jul	3.1	no data	3.3	3.0
5 Aug	3.6	3.2	3.8	4.1
18 Nov	3.5	2.6	2.9	3.9
18 Dec	3.2	3.3	3.0	3.2
18 Jan 1987	3.3	3.8	3.8	3.8

Cane height can be another indicator of poor growth. When in competition with other crops for light, the cane tends to grow taller and thinner at the expense of tiller production. Thus, one might expect taller cane stalks on intercropped plots than on pure cane fields. However, Table 2 shows that while at the first sampling this pattern held true, by the fourth sampling the pure cane field showed the tallest plants. Later sampling, however does show taller plants in the intercropped plots.

Table 2. Plant height of cane, trial plot I (average height of cane in centimeters [cm]).

Treatment	Cane-pure	Cane/beans	Cane/maize	Cane/maize/beans
10 Jun 1986	13.5	14.6	15.3	18.2
23 Jun	22.4	18.9	23.3	19.8
8 Jul	21.6	no data	23.4	23.2
5 Aug	31.3	28.4	30.4	28.3
18 Nov	70.1	68.6	12.3	79.9
18 Dec	81.3	94.2	w.2	104.2
18 Jan 1987	98.7	99.5	101.2	104.6

These preliminary results are inconclusive, and further analysis of cane circumference and yields will be needed before definitive statements can be made about the consequences of intercropping on sugarcane production. The lack of differences between the treatments of the tiller count, and the plant height may well be attributable to facts unrelated to intercropping. The late planting date, for example, might have worked to the disadvantage of the early growths of maize and beans while having little effect on the cane. , In Awendo, cane can be planted virtually year round, while maize and beans have more narrow planting periods. The experimental plot was planted several weeks later than is common in the project area, possibly affecting the competitiveness of the food crops.

FARMERS INTERCROPPING PRACTICES

An ethnographic survey already being conducted for an IFPRI study among a subsample of 75 households (from the nutrition survey mentioned above), provided an opportunity to piggy-back a series of questions on intercropping practices and other agricultural topics. Based on this information, an active sample of 55 households was selected (with the exclusion of nonfarmer and landless households), and interviewed about intercropping practices.

First, an inventory was conducted of all 367 plots farmed by the 55 households in the subsample. These included tree plots of bananas and eucalyptus which are not generally intercropped, as well as sugarcane and sweet potato plots which are also not often intercropped. Twenty-eight percent of the plots were intercropped.

The proportion of households intercropping at least I field, however, is higher (69 percent), reflecting the tendency for intercropping to be carried out in the major food plots of maize and sorghum.

Cereal/legume crop combinations were most popular, found in *16* percent of the cases. Among sample farmers who intercropped, cereal/cereal combinations were also found, but in much smaller numbers (18 percent). Other types of intercropping included legume/legume, vegetable/legume, and perennial/legume (six percent). Table 3 illustrates the types of intercropping patterns found.

Table 3. Intercropping combinations.

Type of intercropping	Plots intercropped
Major crop/ minor crop	
Maize/ beans	43
Maize/groundnuts	26
Maize/ sorghum	13
Maize/finger millet	5
Maize/ beans/ groundnuts	4
Kale/cowpea	4
Maize/ sorghum/groundnuts	3
Maize/beans/ sorghum	2
Groundnuts/ beans	1
Coffee/ groundnuts	I
Total	102

None of the farmers interviewed reported intercropping sugarcane with any food crop. Some intercropping of cane does take place in the project area, but it is discouraged by the sugar factory and local government by-laws. Most of this intercropping is with maize or beans, and only when the plant crop of cane is first planted. In all but one of the intercropped fields, the major crop was the earliest planted. The field was then left for two or three weeks, allowing this to germinate. After the first weeding, the minor crop was sown. The major crop is planted in lines, and these lines of germination are then used for placement of the minor crop. The second crop is generally not planted in straight lines, but is scattered somewhat randomly as the weeding takes place.

When asked why they intercropped, farmers gave three reasons: I) shortage of land or shortage of prepared land, *2)* lack of labor for weeding, and 3) following of traditional practice. Farmers did not mention a decrease in pest populations as a reason to intercrop, although ICIPE has determined this to be a significant consequence of proper intercropping. Farmers view intercropping as more important in interfering with weed growth, and therefore reducing the amount of labor needed for weeding food crops. Similarly those who mentioned shortage of prepared land as a reason for intercropping are implying a lack of labor to prepare land, rather than a lack of land itself.

The results of the survey highlighted several points important to farmers. First, labor constraints are seen as the most important problem in local agriculture. Second, farmers put priority on food crop production in choosing where to deploy land and labor. Third, insect pests are seen as less problematical in reducing yields than other, larger animal pests such as birds, pigs, and monkeys.

More significantly, the survey also exposed a number of differences between farmers' actual practices in intercropping and the procedures recommended by ICIPE: 1) Farmers use staggered rather than simultaneous planting when intercropping, in response to labor constraints. 2) Plant populations are low; farmers plant to achieve adequate yields for moderate or suboptimal conditions, such as low rainfall or poor soil nutrition, and they therefore plant their seeds at a relatively low density. ICIPE recommendations, in contrast, assume optimal conditions and space accordingly. 3) Farmers' plant arrangement is irregular. Again as a result of labor limitations, they tend not to plant the minor intercropped crop in straight lines, but to broadcast it between the lines of the major crop. 4) Fields are not weeded at one time, but in patches, as time and labor resources allow. 5) A number of the plants which were considered weeds by ICIPE workers were valued by the farmers as leafy vegetables, and were generally left in the fields. These findings were used as the basis for redesigning the second trial plot planted in the short rains of 1986-1987, and are described below.

COORDINATING ON-FARM TRIALS WITH SOCIAL SURVEY RESULTS

For the short rains of 1986-1987, several changes were made in the layout, timing, and crop choices to be tested on the second trial plot. Discussions between the agronomist and the anthropologist on the survey findings revealed that the first trial plot was not adequately testing some of the more useful questions surrounding the viability of intercropping of food crops with sugarcane, from the farmers' point of view.

First, a greater variety of crops was chosen for the intercropping trials on the second plot. Local varieties of groundnuts and cowpeas were chosen because of their prevalence in farmers' own intercropped plots. Cowpeas were added because of their general popularity as a local food source. The second trial plot was laid out with the following treatments: pure cane, cane/maize, cane/beans, cane/cowpea, cane/groundnuts, maize/beans, and cane/maize/beans.

Second, the question of labor and staggered planting was also incorporated into the new design. To follow the fanners' existing practice more closely, half of each treatment plot was planted first with the food crop, to be followed, after one month, with the cane. The other half of each plot was planted with both crops of the combination at the same time. Effects on tillering, plant height, and plant circumference were then compared between each half of each plot, as well as between treatments.

Third, the spacing of the cane (Cn)/maize (Mz)/beans (Bn) plot was changed. On trial plot 1, these crops were planted with spacing between each row of 45 cm as follows:

Cn	Cn	Cn	Cn	Cn	Cn	Cn	Cn
Mz	Bn	Mz	Bn	Mz	Bn	Mz	Bn
Cn	Cn	Cn	Cn	Cn	Cn	Cn	Cn
Mz	Bn	Mz	Bn	Mz	Bn	Mz	Bn

In trial plot 2, the spacing and arrangement were altered so that the maize and beans were planted alternately in one row between each cane line. The spacing between each row was 90 cm.

Fourth, a separate section of the trial plot was cleared, prepared, and left to the fanner to plant and cultivate in his usual way. This area will be monitored along with the trial plot in order to compare the different effects of husbandry on the two fields.

In addition to the above findings, more in-depth research on labor constraints, and perceptions of pest problems has been undertaken. Sampling on pest infestations, weed types, diseases, plant populations, and spacing are also being carried out on fanners' fields over the course of the next two seasons, with the assistance of the ICIPE technical staff. These results will be compared to the conditions found on the experimental plots, permitting comparison of the effectiveness of different management methods in controlling pests and improving yields.

Other changes in sampling techniques have also been raised. The inconclusiveness of the tiller count for example, might be due to the sampling method used. Trials done on cane plantations, generally take a tiller count for a 10 meter length row, rather than by plant, because of the difficulties of assessing the boundaries of one "plant."

CONCLUSIONS

The first season's results of the intercropping trials have been somewhat ambiguous with respect to questions of intercropping effects, but they have been extremely useful in initiating a dialogue between research station scientists and social scientists. The changes effected on trial plot 2 grew out of discussions on the differing priorities of the two approaches used in agronomy and anthropology. The social survey revealed that certain important variables — crop choice, labor availability, and time of planting — had been ignored in the design of the first trial, but could easily be incorporated into an on-farm experiment. Similarly, exposure to agronomic research techniques suggested other relevant questions to ask farmers in the interviews.

Other aspects of the project have already produced useful results. Working away from a well-organized station and its resources led to an appreciation by the station staff of the conditions under which ordinary farmers labor. It also resulted in improved planning of the second on-farm trial. Trial plot 2 was prepared prior to the onset of the short rains, and more in accord with the local cropping calendar. The experiments, carried out during the second season, are more clearly aligned with the issues that are of local importance.

Quite apart from the contributions to substantive research on intercropping which the collaborative project may uncover, the study is important in introducing a "farmer focus" into two institutions that have otherwise targeted user audiences. ICIPE's work is oriented towards supplying research institutions, national ministries, and planning programs with its data, rather than supplying groups working directly with farmers. Similarly, the recipients of IFPRI's policy related work tend to be national governments and international development agencies. The early efforts of the collaborative program have been instructive in highlighting some of the intellectual and practical changes that are required when farmers are contacted directly as participants and beneficiaries of the research program, There are indications that both institutions are becoming more receptive to incorporating farmer-oriented research strategies in their core programs. After an evaluation of the social science interface project at ICIPE's annual research meeting in April 1987, the governing hoard clearly stated its support of the project's objectives, and its confidence in the project's progress thus far.

The collaborative project has begun, in a small way, to contribute to clearer recognition of the reality that farmers and researchers view the world from different perspectives (Rhoades 198433). These differences must be understood and acknowledged in research efforts. By identifying variations between farmer practices and experimental assumptions, and clarifying the reasons behind them, the project has initiated the type of work which in the end will help to develop intercropping packages with a higher Likelihood of acceptance by resource poor farmers.

NOTES

'Tillers are shoots of cane which rise out of the bud in the cane set that is planted. High tiller rates generally signify good yields. Poor weeding and intercropping can interfere with tillering because weeds and the intercropped plants compete with the cane for nutrients and sunlight.

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INTEGRATING SOCIAL SCIENCE RESEARCH INTO THE DEVELOPMENT AND TESTING OF NEW AGRICULTURAL TECHNOLOGY: THE CASE OF CIAT'S GREAT LAKES BEAN PROJECT

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INTRODUCTION

This paper illustrates the effectiveness of integrating social science research into an interdisciplinary project, combining on-farm and on-station research, to enhance bean production in the Great Lakes region of central Africa. Emphasis is placed on the role of on-farm research in general, and social science research in particular, in setting research priorities and devising ways of testing and transferring technologies.

The Great Lakes region is at the heart of the central African highlands, on either side of one branch of the Rift Valley System. Running from north to south, the valley contains lakes Edward, Kivu, and Tanganyika. The altitude ranges between 900 and 4,500 meters above sea level and rainfall varies between less than 1,000 millimeters (mm) in the east and along the valley bottom, to more than 1,800 mm along the Nile-Zaire crest and in the area of the volcanoes. The Central Plateau region of Rwanda and Burundi receives between 1,000 and 1,400 mm of rain (Sirven 197425). There are two major cropping and rainy seasons, from mid-September to early January and from late February to early June; however, the intensity and duration of the rainy seasons vary considerably from year to year. The dry seasons are longer and more pronounced in the east.

The region supports the highest population density in Africa, over 350 people per square kilometer of agricultural land, with a projected density of over 500 by the end of the decade. Over 95 percent of the population is rural, with an average farm size of less than one hectare (ha) (Gahamanyi 1985:4). In the most densely populated areas such as the Central Plateau and the shores of Lake Kivu, over 50 percent of the farms are smaller than 0.5 ha. The eastern part of the region is lower and hotter with more intense dry seasons and generally has larger farms averaging about 3.5 ha. The Central Plateau is characterized by thousands of rolling hills separated by marshes which provide a dry season crop and is extremely variable in soil composition and fertility (Sirven 197441). In terms of cultivated land area, banana is the dominant crop, followed by beans, sweet potatoes, cassava, and sorghum.

In this region as a whole, all the major types of beans—bush, semiclimbing, and climbing—are grown. However, climbing bean production is concentrated in a few

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high rainfall areas and is little known in the rest of the region. Beans are typically grown as varietal mixtures and intercropped with a wide range of other crops, especially bananas, maize, sweet potatoes, peas, cassava, cocoyams, and at higher altitudes, potatoes. Because of heavy population pressure and a scarcity of fertile land, fallow periods have declined and bean production has expanded into marginal land, causing average yields to drop from 0.9 tons/ha to 0.7 tons/ha while total output has barely kept up with an annual population increase of 3.5 percent (CIAT 1984). Beans are the single most important source of protein in the region, contributing some 45 percent of protein needs. They also provide a significant proportion of caloric requirements, approximately 25 percent (CIAT 1984).

Considering that sparsely occupied land available for new settlement has now virtually been exhausted, further increases in food production will have to be achieved through intensified production on existing farmland. Such intensification provides a major challenge, because the reduction of fallow presumably accelerates the decline in soil fertility if farming systems are not adjusted to fit this new reality.

THE PROJECT

CIAT, with funding from the Swiss Development Corporation, has placed a team of five scientists in the Great Lakes region. These include a breeder/coordinator, a plant pathologist, an anthropologist, an agronomist, and a nutritionist. The major objective of the project is to develop technologies which can increase the productivity of common beans (*Phaseolus vulgaris*) in the region. The principal strategy for achieving this is to work together with national programs and projects on methodology, research, and extension strategy development (CIAT 1985:274).

The Role of Social Science Surveys in Helping to Set Research Priorities

In association with the project nutritionist, and in collaboration with the national programs, a combined bean production and consumption survey has been conducted in most of the major production zones of the region. The fundamental objective of the surveys is the description and diagnosis of farmers' production and consumption systems, including their knowledge, practices, constraints, and capabilities. This diagnosis is of significance for the other research carried out by the team in several important ways.

First, it aims to aid the selection process by identifying which varietal criteria or features farmers consider to be beneficial and those which they evaluate negatively. Such information greatly increases the Likelihood of producing varieties that will be acceptable to farmers and can considerably increase the efficiency of the selection process by the early elimination of varieties with undesirable characteristics. Second, it attempts to ascertain what farmers consider to be their main production constraints, and thus. has direct relevance to the design and conduct of agronomic research aimed at overcoming these problems. Solutions which address the perceived needs of'farmers are likely to have a faster rate of diffusion and a greater impact. Third, by analyzing how farmers obtain and experiment with new varieties, the diagnosis has direct impact on the design of the on-farm varietal trials and on future avenues of diffusion of those varieties that perform well.

The following examples illustrate the **use** of the survey research for each of these three areas. The examples are drawn from surveys carried out in Ruhengeri and Butare prefectures of Rwanda. In both cases the sample size was 120 farmers.

Varietal development. One of the most striking aspects of bean production in the region is the widespread use of varietal mixtures. Virtually all the farmers interviewed (96 percent) say they prefer to grow such mixtures. The usual reason stated is that mixtures are more likely to produce an adequate yield under uncontrollable climatic conditions. Such yield stability **is** of paramount importance to small subsistence farmers. It has also become clear that many farmers, especially women, select and maintain different mixtures for different agronomic conditions. Of the farmers interviewed in Ruhengeri, **37** percent planted 2 different mixtures, 51 percent planted **3** different mixtures, and only 9 percent planted a single mixture. The usual criteria for choosing different mixture types are soil quality and compatibility with bananas.

Among the farmers surveyed, **78** percent also indicated a strong preference for earlier-maturing varieties. Although many farmers recognize that later-maturing bean varieties can have higher yields, they consider that extra time in the field means greater risk. This has several implications for the varietal development program. a) Because new varieties are likely to he incorporated into existing mixtures (an aspect currently being investigated), the varietal development program's aim of increasing yields will require the successive incorporation of several improved varieties into these mixtures in order to have an appreciable effect. This program's work, thus, is essentially long-term with only incremental gains to he expected from the release of each new variety. The cumulative effect of several new varieties, especially if they also succeed in buffering the mixture against disease can, however, he considerable. For a more immediate impact, other possibilities must he investigated. h) Because farmers select different mixtures for poor soil, good soil, and banana association, varietal development needs to be targeted for these conditions. Thus, on-station and on-farm screening and evaluation should take place under similar conditions. c) Late-maturing varieties are likely to he less acceptable to farmers, even though they are higher yielding. On-station selection should therefore he oriented toward the highest yielding among the earlier-maturing varieties. On-farm research needs to establish the limits of acceptable vegetative duration for the most common cropping patterns.

Production consrrainrs. The project has been using farmer interviews and limiting factor trials to determine the major yield constraints. The two approaches are complementary in that the interviews reveal what farmers consider to be their major problems and the trials measure the extent to which these problems limit yields. Farmers consider their major bean production constraints to be excessive rainfall (and associated diseases),' lack of manure and compost, drought, insect attack, and lack of sufficient land. Many farmer practices already serve to control these problems. Drought stress, for example, is controlled by sowing under banana trees and by using early varieties. Intercropping helps to control the spread of diseases, as does the removal of old leaves from the bottom of the plant.

From an agronomic standpoint, the related problems of land shortage and insufficient manure and compost present major research challenges. For example, 78 percent of the farmers interviewed lacked manure for more than half of their fields. The limiting factor trials also show soil fertility to be the prime constraint. Only six percent of farmers considered their production of manure to be sufficient for their needs. Consequently, improved practices now under agronomic investigation include the use of green manures, nitrogen fixing plants, agroforestry systems, and better erosion control. There is also considerable room for improved management and better use of the organic matter that is available in most farms.

Given that half of Rwanda's farmers now have only 0.5 ha of land or less, and given a population growth rate of 3.5 percent, the already serious land shortage will soon reach critical proportions. Until the population/land ratio can be stabilized, the apparent solution is to intensify production systems further. Improving soil fertility through better management and other techniques is only part of the answer. Other potential means for increasing productivity include: a) greater use of climbing beans because they have a higher yield potential than bush beans; h) use of crop with the highest land equivalent ratios; c) development of higher-yielding and stable varieties; d) increased selection of materials that produce under marginal conditions; e) judicious use of agrochemicals, such as seed treatments and rock phosphate; and f) inclusion of more disease-resistant varieties into farmers' mixtures.

Faced with these options, the team decided that climbing beans had the greatest short- to medium-term potential for increasing productivity. However, the introduction of this technology raises some difficult farm management problems. Here the social scientist can play a major role, as will be discussed in the last section of this paper.

Farmers' Experimentation with New Varieties

The survey in Ruhengeri indicated a high degree of farmer experimentation with new varieties; 92 percent of farmers had tried new varieties. Of these, 78 percent tried them first in pure stands before incorporating them into a mixture. Almost all, (96 percent), of these farmers multiplied their own seed from new varieties that performed well. It also became clear in informal interviews that many farmers will try new varieties under different agronomic conditions before deciding into which mixtures they should be incorporated. In addition, it was apparent that all tasks connected with seed (i.e., seed selection, sowing, and storage) were done exclusively by women.

This information has several important implications for on-farm trials and varietal diffusion. First, on-farm varietal trials should be in pure stands and, ideally, under the same kinds of conditions the farmers would select for themselves (i.e., on good soil, on poorer soils, and in association with bananas). Second, the trials and subsequent diffusion should emphasize dialogue with women because they will ultimately make the choice. Because acceptable varieties will be multiplied by farmers themselves, small quantities can be diffused and still have a significant effect one or two seasons later. In order to understand better and optimize the effect of the diffusion process, more research is being done now on the channels and rate of diffusion among the farmers themselves.

On-Farm Varietal Trials and the Diffusion of New Varieties

The design of the project's on-farm variety trials closely follows the recommendation described. Besides allowing researchers to evaluate the varieties under farmer management, the trials provide an excellent forum for discussing preferred and nonpreferred varietal characteristics with farmers. The information thus obtained was more precise, more reliable, and more detailed than that gleaned from the surveys.

After many informal discussions with trial farmers, a simple farmer evaluation sheet was created, which allowed us to measure the acceptability of each variety. Table 1, comparing acceptability with yield, shows that yield by itself is not always a good indicator of acceptability. The highest-yielding variety, *Ikinimba*, scored rather low. The evaluation sheet allowed us to pinpoint the reasons for this low score: a sprawling plant type that caused weeding problems, difficulty of threshing, and less desirable black seed color turned out to be the main negative varietal characteristics. The variety, *Kiliumukwe*, which consistently had the highest acceptability rating, also significantly outyielded the farmers' mixture in some regions.

After five seasons of trials, carried out between 1984 and 1986, a follow-up survey was initiated. The objectives of this survey were to double-check our information on varietal acceptability, find out the conditions under which farmers were growing the varieties without researcher intervention, and start measuring the diffusibility and the rate of diffusion of each variety.

Results showed that initial confidence in accepting Kiliumukwe was justified (Table 2). A full 100 percent of the 45 farmers interviewed still grew the variety and gave it their highest rating. It also had by far the highest rate of diffusion; having reached more than twice as many other farmers as the next best variety.

Table 1. Farmer evaluation of on-farm variety trials, Central Plateau, 1986 (ranked according to yield).

Variety	No. of trials	Overall evaluation[a]	Average yield kg/ha
Ikinimba	41	67.4	1723
Local mixture	41	92.1	1472
ISAR mixture		81.3	1414
Kiliumukwe	41	99.4	1385
Rubona 5	41	82.5	1351
Kirundo	40	92.0	1328
A 197	18	87.5	1252
Umutikili	18	95.0	1114

[a]The evaluation is on the following basis:
100 = Excellent. 80 = Good. 60 = Fair. 20 = Very poor.

Table 2. Follow-up of on-farm varietal adaptation trials after two to five seasons, 1986.

Variety	Still grown	Other farmers given seed	Sown mixed(M) or pure(P)	Cultivation conditions (%) Fertile soil	Infertile soil	Under banana
Kiliumukwe	100%	51	P = 52% M = 48%	68	4	28
Rubona 5	70%	24	P = 52% M = 48%	48	17	35
Ikinimba	67%	24	P = 40% M = 60%	45	45	10
Kirundo	65%	16	P = 34% M = 66%	72	0	28
A 197	22%	0				
Climbing mixture	27%	5		60	0	40

Note: sample size = 45 farmers

As expected, the main recipients of the new variety were family members, neighbors, and friends, in that order. However, the follow-up survey did not examine how far the new variety had spread (i.e., its range). For this, a few cases would need to be followed to the limits of their diffusion, or a random sampling of the target area undertaken. Ikinimba turned out to have a much higher retention and diffusion rate than we had expected from its low initial evaluation. The reason became apparent by analyzing the conditions under which the farmers were growing each variety. In comparison with the other varieties, lkinimba has a much higher sowing rate on infertile soils. It seems that a variety can be forgiven some other failings if it performs well under marginal conditions. The follow-up also confirmed one result of our initial diagnostic survey: the great majority of farmers initially test a new variety in pure form. Furthermore, many of the farmers experiment with it under a number of conditions to see where its greatest advantage lies.

Results of thr on-farm varietal trials showed a considerable yield advantage of the new varieties in the eastern part of the country, but no significant effect on the densely populated Central Plateau. The probable explanation for this is that, in Central Plateau, farmer selection over the centuries has already improved local mixtures to such an extent that station varietal improvement programs have found it difficult to offer anything better to the farmers. The east, on the other hand, is a region of recent settlement with different agroclimatic conditions than those found in the points of origin of most of the migrants. Thus, the varieties the migrants brought with them may not be well adapted. Systematic screening and testing procedures have rapidly identified new varieties with up to a 30 percent yield advantage.

In seeking to have an impact on the populous Central Plateau region of Rwanda and Burundi, the team analyzed the known constraints and the available possibilities. The expansion of climbing beans was considered most promising for a short-term impact, because these have a much greater yield potential than bush beans. The problem lies in fitting an existing technology into different cropping systems. This requires some modifications of the system and some changes in farmer management practices. The task of the project anthropologist was to help analyze the problems and potentials for the introduction of the crop.

Production Potential of Climbing Beans in Central Plateau

A multitiered approach was chosen to address the constraints and potentials of climbing bean production. First, a small plot of climbing beans was included in the on-farm varietal trials and farmers were interviewed with regard to their reactions. Those few farmers already growing climbing beans were interviewed to find out what advantages and disadvantages they perceived in their production and consumption and whether or not their neighbors were adopting the practice. Second, a survey of 120 farmers was carried out in Gisenyi, where the great majority of farmers were very successfully growing climbing beans. We wanted to establish whether any aspects of their production techniques could be transferred to other parts of the region, and to see what solutions they had found to the production problems that most limited climbing bean production in Central Plateau. Third, the results of multiyear on-station trials that compared the yields of climbing beans with hush beans were reviewed to see if the findings were as promising as we believed.

The diagnostic surveys on Central Plateau showed that only five percent of farmers were actually growing climbing beans. Why not more? Were their experiences transferable to their neighbors or did they have some special advantage the others did not have?

Results uf on-station research. ISAR has spent many years comparing the yields of bush and climbing beans and the effectiveness of various kinds and lengths of staking material. Climbing beans show a yield advantage of up to 100 percent when they are adequately staked. Given such an advantage, why were more farmers close to the station not growing them?

Results of on-farm research. The on-farm trials carried out by the project agronomist included one plot of a climbing bean mixture among the new varieties of hush beans. On fertile soils the climbing beans had a considerable yield advantage over the bush beans, hut not quite to the level expected from the station results. Meanwhile, the overall results of the acceptability interviews were somewhat mixed. In general, the climbing bean mixture variety scored considerably lower than the most preferred hush variety. However, in many cases the climbers had been sown under unfavorable conditions. Most of those farmers who had trials on richer soil found them to he very acceptable.

Particular attention was given to climbing beans in the follow-up surveys. Although only 27 percent of the farmers were still growing climbing beans, nearly all of these stated they were happy with the results. The acceptability of the climbers appeared to be directly related to soil fertility. Diagnostic interviews with 24 farmers who already produced climbing beans supported this finding. Almost all the farmers noted that they were approximately doubling their yields by using climbing beans. There was also a clear trend in growing climbing beans by neighbors of farmers who had success with this variety.

Constraints. Among the production problems noted by the farmers, first and foremost was a general insufficiency of staking material. Many farmers said they would like to increase the area in climbers, hut were hindered by the lack of staking material. Large-scale farmers with woodlots were at a distinct advantage. Second, climbing beans required a more fertile soil. Production was generally limited to fields near the house which received sufficient compost. The third constraint was a longer vegetative cycle. This has at least two serious implications: it increases risk in the face of possible short rains, and it can interfere with the traditional crop rotational pattern between beans and sorghum. Staking requires considerable work and care. Further research is now being planned to measure the extra labor costs involved and the increase in productivity that is necessary to provide an adequate return on this labor.

Of course, the combination of high yields and labor intensity potentially makes the crop of greatest interest to poor families who generally have a shortage of land and a surplus of family labor. The introduction of climbing beans could thus have a positive impact on equity and on the quality of nutrition for smaller farmers. Pachico (1984) notes that climbing and semiclimbing beans have an inherent small-scale farmer bias because their production is labor intensive and not mechanizable. The smallest farmers in Rwanda often sell high protein value foods, such as beans, in order to meet their total calorie requirements by buying a larger amount of lower protein value sweet potatoes or cassava. Producing enough beans to meet the household's protein requirements on a smaller area by partially switching to climbing beans would liberate more land to tuber production, thus, reducing the necessity of selling beans to meet carbohydrate needs.

For this potential to be realized, however, the problem of added risk needs to be resolved, for it is the poorer farmers who are the least able to absorb loss. A final constraint, observed in the on-farm trials, was the susceptibility of the varieties being tested to bean common mosaic virus (BCMV), which badly affected some of the plots. Considerable emphasis in the on-station research is now being placed on screening and breeding for well-adapted, BCMV-resistant varieties.

Potential solutions. Given the primary importance of the lack of sufficient staking material, considerable emphasis was placed on analyzing how fanners in the climbing bean area of Gisenyi had solved this problem and the effectiveness of their solutions. Research was based on the rationale that the practices of other farmers in the region are Likely to be more adoptable by those in Central Plateau, than completely new external solutions.

More than 85 percent of Gisenyi farmers interviewed had sufficient staking material and did not find the extra work of staking inconvenient. The main source of stakes was the anti-erosion hedges of *Pennisetum* which are planted in bands about 20 meters apart along the contour lines. Some farmers in Central Plateau also grow Pennisetum, primarily for construction purposes. When interviewed they stated that their main problem with Pennisetum was its competitiveness with the yield of adjacent crops.

Based on this information, the Gisenyi survey sought to describe the techniques farmers used in managing their hedges to reduce the problem. These methods include regular cutting, thinning, and pruning of the hedge, as well as limiting the width of the Pennisetum band by cutting the roots on the field side of the hedge. Cutting takes place once a year, a few weeks before the beginning of the major bean season. This provides sufficient stakes immediately beside the field, thus cutting down enormously on the amount of time required to find and transport stakes. The ensuing hoe cultivation incorporates the leaves and other debris into the soil, as well as cutting the roots extending into the field. At the time of the first weeding, the hedge is thinned if necessary and any plants growing out into the field are cut back.

It is important that staking plants be multifunctional in order to optimize the land area they occupy. The farmers in Gisenyi liked the multipurpose nature of Pennisetum. Old stakes are an important fuel source for cooking; the hedge provides considerable protection from erosion; debris from the hedge increases soil fertility; and the leaves can he used for fodder. The Gisenyi research shows that an effective, manageable solution to the staking problem exists near at hand. The applicability and acceptability of this method and of more novel solutions involving the use of leguminous shrubs such as ***Leucaena***, ***Calliandra,*** and ***Sesbania,*** are currently being tested.

Interviews with farmers of Central Plateau, who are already growing climbing beans, also indicated a partial solution to the problems of drought stress, soil fertility, and of "fit" within the existing cropping systems. This solution is to associate the climbing beans with thinned banana stands near the house. Such stands are ubiquitous, because a house is not considered a home without sufficient beer-producing bananas. Indeed, suitability for growing bananas is one of the most important criteria in choosing a site for a house. The banana plots tend to be the most fertile, because they are near the house and they receive preferential composting. **As** it provides shade and wind break, a banana crop seems to reduce evapotranspiration considerably. Choosing a near-optimal density for the banana plants is essential.

CONCLUSION

To summarize the potential **of** climbing beans in Central Plateau, three basic questions are asked. The questions and their answers **are** restated below.

1. Can climbing beans significantly increase bean productivity on the plateau? On rich soil with sufficient humidity, the answer is undoubtedly yes. Their impact will, however, be limited by the availability of compost, manure, and staking material.

2. Would this yield increase be stable (i.e., not too risky for the smallest farmers)? Probably the association with bananas already goes some way toward this. But further means of increasing stability, such as using early-maturing BCMV-resistant varieties, need to be explored.

3. How can the problems of staking and soil fertility he solved? Trials are being conducted by the team agronomist and by several other projects to test the possibilities of leguminous shrubs grown as hedges, or integrated directly into field systems as sources of staking material, fodder, and as green manure to enhance soil fertility. Such improved agroforestry systems promise to alleviate the problems of system stability, soil fertility, and staking material in an integrated manner. Still, much more,work needs to be done on improving management, production, and the use of manure and compost.

In collaboration with the Project Agro-Pastoral and the extension service, the agronomist and the anthropologist have recently distributed climbing bean seed and have provided training, detailed instructions, and information brochures to over 110 collaborating farmers. These trials will be closely followed over the next two seasons in order to assess more accurately the real potential of increasing small-scale farmer productivity through the increased use of climbing beans.

Finally, it cannot be overemphasized that close interdisciplinary collaboration between biological and social scientists is indispensable for the formulation of survey topics and drawing the proper conclusions from the information gathered. The program's orientation and responses to information from farmers are the result of intense discussion among the team members and between team members and their colleagues in international institutes. On-farm survey work and experimentation with farmers on new varieties and new production methods also need to be seen as a continual feedback process where farmers and researchers learn from the experience. Thus, systems diagnosis is more appropriately viewed as an on-going process, rather than as an initial stage in farming systems research.

NOTES

'Rain and diseases are conceptually related to one another in the farmers' categorization of agricultural problems.

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A SOCIAL SCIENCE PERSPECTIVE ON EVALUATING AND DESIGNING COMPONENT RESEARCH: A CASE STUDY OF NITROGEN FERTILIZER AND POSTRAINY SEASON SORGHUM IN INDIA

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INTRODUCTION

This paper is a case study illustrating the role of a social science perspective in evaluating and improving an agricultural technology. The process includes establishing research priorities for IARCs and designing a technology development program in collaboration with NARCs. The topic of the research was the use of nitrogenous fertilizer on postrainy season sorghum in India.

Because nutrients are one of the fundamental components of crop growth, fertilizer has played a notable part in numerous modem agricultural success stories, and in IARC research programs designed to emulate such achievements. The persistently low use of fertilizer in low-productivity tropical agricultural systems is likewise notable. The IFDC has a mandate lo redress the imbalance of scientific and technical research on fertilizer in the tropics, and to identify constraints on fertilizer use. Research is frequently conducted in collaboration with national programs, or with other IARCs having crop or regional mandates. The research discussed in this paper involved collaboration between IFDC and ICRISAT to study fertilizer technologies applied to sorghum in the semiarid tropics.

The social science component of this research uncovered the choice of planting date as the key factor in the adoption of nitrogen fertilizer. Economic analyses were instrumental in evaluating constraints on advancing the planting date, and circumstances under which farmers would find fertilizer use attractive. An early planting date is a critical component of an improved technology package for postrainy season sorghum which includes fertilizer use. Nevertheless, farmers are reluctant to advance the planting date because of income loss and uncertainties associated with pest damage and waterlogging.

This paper begins with a discussion of the cropping system, the components of the improved package, and prevailing agricultural practices. The second section describes the process of systems analysis and constraint identification used in the research. The third section presents some implications of the project results for institute research planning.'

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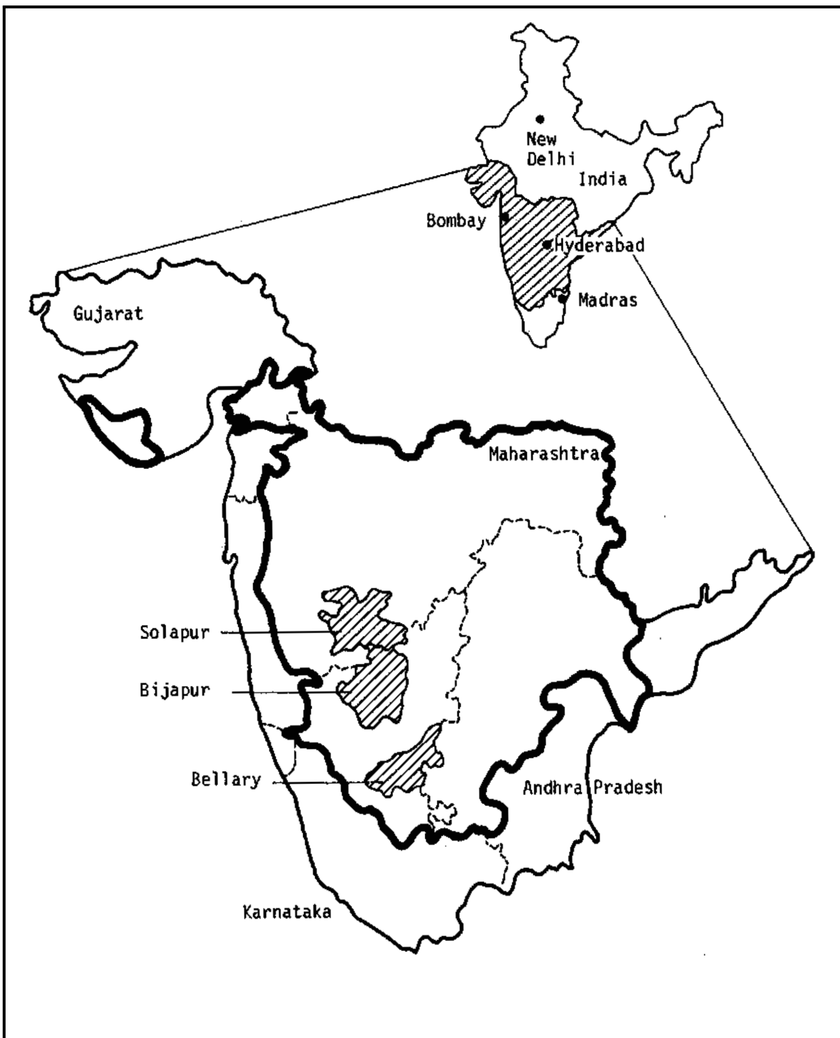
BACKGROUND

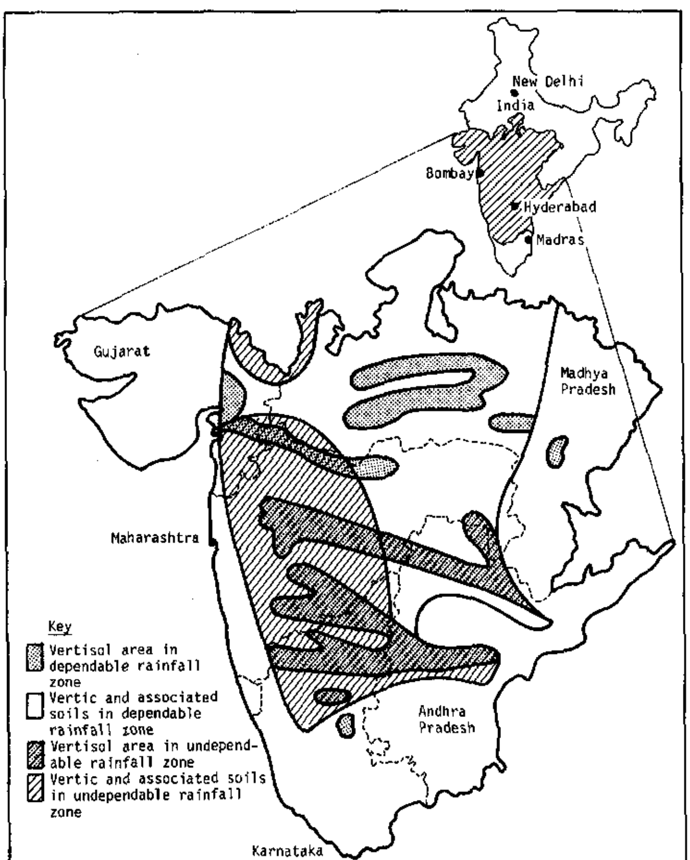
The setting is the semiarid tropics: a hostile environment for field crops with a low and erratic rainfall, nutrient-poor and heterogeneous soils, and limited irrigation. The crop is sorghum: a coarse cereal, low in value, and not generally preferred for consumption, but currently the major subsistence crop for 700 million people in Asia and Africa. Sorghum survives in the face of drought stress and neglect, but thrives when cared for, even when unimgated. From among the diverse agricultural systems of which sorghum is a part, this study focuses on postrainy season sorghum in India (see Figure 1).

Figure 1. Region of postrainy season (September-February) sorghum production in India (DES 1984.)



Of the 16.5 million hectares (ha) of sorghum in India, 6 million ha are planted in the postrainy season (DES 1980-1985). The environmental boundaries of post-rainy season sorghum area are relatively well delineated. The tract is characterized by vertisol and associated soils, the salient feature of which is their high clay content. These soils have a high water holding capacity, but are difficult to till when very dry or very wet. The distribution of rainfall is important and, defines two subregions. In one part of the region, rainfall is generally sufficient for double cropping. In the second part, total rainfall may be adequate for two crops, but the variability in distribution renders the probability of adequate moisture for rainy season cropping unacceptably low. Some (Binswanger, Virmani, and Kampen 1980, Virmani, Willey, and Reddy **1981)** have accordingly designated "dependable" rainfall areas as those in which the probability of rain is above 70 percent in more than half the weeks of the growing season. In "undependable" rainfall areas the rainfall probability is greater than 70 percent in less than half the weeks of the growing season (see Figure 2).

Figure 2. Rainfall patterns and soils of the postrainy season (September-February) sorghum region in India (Virmani et al. 1986).



The category of undependable rainfall roughly corresponds to annual rainfall of 500-750 millimeters (mm), and dependable rainfall to 750-1,250 mm. Because of the difficulty of cultivating clay soils prior to, or during the monsoon, the erratic distribution of monsoon rainfall, and the moisture storage capacity of the vertisol, fields are generally fallow during the rainy season, and planted only after the monsoon rains have ended. Because rainfall from October through February is very low, the crop experiences a receding moisture regime during its growth.

Average yields of postrainy season sorghum range from 400-700 kilograms (kg) of grain per hectare across districts and through years. Both the AICRPDA and ICRISAT find that yield potentials are much higher than current actual levels. Drawing from years of AICRPDA experiments, Venkateswarlu (1981) presented average postrainy season grain yields for three important research stations located in the undependable rainfall zone: for Bellary, 1,400 kg/ha; and for Bijapur and Solapur, 2,100 kg/ha. *M 35-1* has a yield potential as high as 3,300 kg/ha, and ***SPV 86,*** of 5,200 kg/ha in the postrainy season at Bellary (ICAR/AICRPDA 1983). Yields of over 2,600 kg/ha were obtained for sorghum following a rainy season fallow at ICRISAT (Virmani, Willey, and Reddy 1981). [See Figure 1 for district locations.]

As part of an effort to close the gap between experiment station and on-farm yields, recommendations for production practices that are crop and region specific have been developed and disseminated. The regional recommendations for postrainy season sorghum are summarized in Table 1. The improved practices include advancing the sowing date to take advantage of the last fortnight or two of monsoon rains; the use of the improved variety M 35-1, or a hybrid (SPV 86, or *CSH 8R)*; correct intra- and interrow spacing and plant population, and timely interculturing; and the application of nitrogenous, and in some regions, phosphatic, fertilizers. Factors responsible for the yield gap were ranked in order of importance at an AICRPDA-ICRISAT working group meeting in 1980. Their conclusions were that variety and fertilizer use were of primary importance in narrowing the gap between farmers' yields and potential yields (ICRISAT 1981).

Despite research and extension efforts, little has changed in the manner in which postrainy season sorghum is produced. District-level data on areas under high-yielding varieties (HYVs) indicate that postrainy season sorghum hybrids have not been adopted widely. The preferred cultivars belong to the land race *Maldandi* which has high quality, white, bold grain, is drought- and pest-resistant, and yields a high quantity and quality of fodder. The preference for local varieties of the postrainy season crop holds even in districts where rainy season hybrids have become quite popular.

Fertilizer use on postrainy season sorghum is negligible. From summaries of 1975/1976 district-level survey data prepared by Jha (1980), it is clear that postrainy season sorghum is the least likely of all major crops to have fertilizer applied, and when applied, receives a lower dose than other crops. More recent

Table 1. Improved agronomic practices for postrainy season (September-February) sorghum.

Region	Varieties/ hybrids	Seed rate (kg/ha)	Population (plants/ha)	Interrow spacing (cm)	Intrarow spacing (cm)	Fetilizer (kg N/ha)	(kg P_2O_5/ha)
Solapur	M 35-1 SPV 86 CSH 8R	8	150000	45	20	50	0
Bijapur	M 35-1	8-10	90-100000[a]	45-60	15	30[b]	25[b]
Bellery	SPV 86	7-8	130000[c]	64-75		30d	3od
	M 35-1	5-6	90-100000[c]	64-75		30d	3od

[a]If rains stop early, thin by blading every second or third row within 4045 days of sowing.

[b]If sowing alter late September, use 50 percenl recommended level of fertilizer. Top dress with 10-15 kg ha-1 if soil moisture is adequale.

[c]For failure of postsowing rains in October, thin to 65,000 or 85,000 plants/ha.

[d]Basal drilled.

Source: ICAR 1983: 19-23, 37-40, and 4648.

data from an IFDC/RCF study in Maharashtra in 1981/1982 confirmed the earlier data (IFDC/RCF 1984). Data collected for the ICRISAT Economics Program Village-Level Studies (VLS) for two representative villages in the undependable rainfall zone (Solapur District) revealed that fertilizer use on this crop has remained at zero from 1974/1975 through 1984/1985. However, as in the case of improved seed, farmers are using fertilizer on other crops, including sugarcane and rice.

The perceptions after the initial phase of developing and introducing the package may be summarized as follows: experiment station yields were several times that of actual yield levels, and an improved technology package developed, but there was no evidence of adoption of improved components. The next phase of the project dealt with identifying constraints on fertilizer adoption in postrainy season sorghum cropping.

IDENTIFICATION OF THE MANAGEMENT CONSTRAINT

One of the ICRISAT study villages, Shirapur, was the site of nitrogen fertilizer trials in the 1985/1986 season. The trials were simple dosage experiments, which replicated nitrogen treatments ranging from 8-50 kg N/ha on 100 square meter (m^2) subplots in farmers' fields. No other cultivation practice was altered, and farmers were responsible for all management decisions and expenses. There was no evident response to the fertilizer applied. Because the year of the experiment was a poor rainfall year, the results were compared to published experiments in which only fertilizer was applied, and rainfall was poor. Such data usually had to he culled from reports on high returns to fertilizer use on postrainy season sorghum, wherein response estimations were pooled across years, locations, and/or other treatments. After the culling, equally dismal results began to emerge. A meeting with national scientists conducting research on postrainy season sorghum confirmed the observations. This, in turn, led to careful consideration of the factors influencing, and, therefore, possibly limiting, the response of sorghum to applied nitrogenous fertilizer.

Maldandi is responsive to nitrogen and in many trials outperformed improved varieties and hybrids. In fact, HYVs appeared to be superior to traditional varieties in nitrogen response and yield only if the planting date was advanced by a month so that planting occurred three or four weeks before the end of the rainy season. Moreover, fertilizer response was significant only in 3 out of 10 years unless the planting date was advanced. It became clear that the advanced planting date was a critical element in the recommended improved management package. This management change is the key to the success of the varietal and fertilizer components of the package. Their advantages are lost if the planting date is not advanced, which explains why farmers have declined to adopt the hybrids and fertilizer. The question then became, "why have the farmers resisted advancing the planting date?"

When questioned about their choice of planting date in interviews conducted before the experiment began, farmers answered that they plant as soon as they can enter the fields after the festival of *Hastha* Nakshtra begins, the starting date of which varies from 27 September to 3 October. An earlier date was unacceptable — contrary to tradition and inauspicious. The interpretation of the on-farm trial and the comments of the farmers provoked an analysis of the economic consequences of changing the prevailing practice. A review of literature on sorghum physiology and entomology revealed that early planting would have substantial effects on costs of production and productivity. First, sorghum is susceptible to shoot fly (*Atherigona soccata*) infestation and damage at the seedling stage, 8-10 days after emergence. With early September planting, this growth stage coincides with high levels of shoot fly population. Second, during the September rains, fields are periodically waterlogged. Fawusi and Agboola (1980) demonstrated the sensitivity of sorghum germination to soil moisture content. When moisture content is 100 percent, germination is checked completely. Furthermore, the availability of bullocks for planting is a definite problem in the Solapur region, and renting bullocks is the single largest expense of production. Running the risk of loss of stand, and resowing would have limited appeal to these farmers. By looking at the system as a whole, it became apparent that the change in planting date is potentially very costly, and as such a very inelastic constraint.

IMPLICATIONS FOR IARC / NARC RESEARCH

The systems analysis not only explains the reluctance of farmers to adopt new varieties and hybrids, and to use fertilizer, but also has implications for IARC/NARC research on this cropping system. The specifics of a revised research program for postrainy season sorghum are presented below, and generalized to illustrate contributions of social science research. The discussion is divided into four parts: I) reinterpretation of existing data, 2) priorities for basic and applied research, 3) adapting technology to local conditions, and 4) assessing institute-level research priorities.

Reinterpretation of Existing Data

Discussions with farmers and first-hand participation in on-farm production situations help identify key agronomic factors in the farmers' environment. Economic analysis provides a means of comparing the attractive and problematic features of production components, and ranking constraints. Reinterpretation of existing experimental data and simple on-farm trials can be used to test hypotheses about acceptance of, or resistance to, new technologies. For example, the historical fertilizer trials data for postrainy season sorghum could be reexamined with particular attention given to soil moisture status at planting, planting date, and distribution of rainfall after planting, in order to determine the probabilities of conditions favorable to fertilizer response with a 'late" planting date.

Priorities fur Basic and Applied Research

In some cases, redefinition of research priorities at the IARC and additional experimentation are warranted. If an IARC goal is a biologically or economically superior sorghum cultivar for the advanced planting date in the postrainy season, shoot fly damage, and probable loss of stand because of waterlogging must be taken into account. Alternatively, the breeding research policy could be revised to reflect the confines of the 'late" planting date. Future fertilizer research should be based on the assumption of the "late" planting date, and methods of improving response under conditions of a receding moisture regime with highly erratic and very low rainfall. In all likelihood, this would mean greater emphasis on issues of timing and method of application.

Though the identification of relatively inelastic system constraints (partly technical, economic, and social) circumscribed the research scope for varietal and fertilizer system components, lines of inquiry for future research efforts still emerged. A decision to revise radically the fundamental approaches to basic research on systems components would rest with the disciplinary scientists.

Adapting Technology to Local Conditions

Variations in a key constraint within the system provide a natural framework for experiments across locations. Cases where a constraint has been lifted. or overcome within an otherwise traditional (or “unimproved”) production system may suggest lines of research for the broader system, and will provide information on farmer strategies for coping in difficult environments.

Shirapur farmers will, as a group, advance the planting date by 10 days when September rainfall is very poor. Apparently there is a threshold beyond which the risk of waterlogging becomes acceptable relative to the loss in yield that will be incurred because of low availability of water. (With a 10-day advance. the peak of the shoot fly period is still avoided). The farmers thus recognize the value of planting at the same time, and will do so according to their own criteria. Multilocational trials with different planting dates, fertilizer timing, and methods of placement would be useful. Identifying regions where shoot fly populations show a different seasonal dynamic, or where waterlogging is less likely, can lead to further study of cultural or social constraints to changing the traditional planting date.

Assessing Institute-Level Research Priorities

Trade-offs between research costs, and potential benefits of working with postrainy season sorghum can be more accurately assessed through a better understanding of system constraints. ICRISAT and IFDC must continually evaluate their research priorities. The more accurately defined are the system boundaries and their influence on productive potential, the more intelligently can the research institutions allocate their scarce research resources among systems.

CONCLUSIONS

This case study illustrates how a social science system perspective can contribute to the resolution of agricultural technology research problems. In this case, simple field trials and formal and informal interviews provided the only new information that was needed. Most of the analysis relied on reinterpreting a mass of technical data already available. Economic analysis was a crucial part of assessing the constraints from the farmers’ points of view. Important too were frequent discussions with natural scientists — entomologists, soil scientists, physiologists. breeders, climatologists, and agronomists and farmers, all of whom took an active interest in data interpretation and evaluation of alternative hypotheses. The result was a new program for sharply defined fertilizer research with a good probability of success in this agricultural system.

NOTES

[1] A detailed description of the cropping system, and an account of the analyses and results, including supporting data and references, may be found in Karen Ann Dvořák's (in preparation) ***Constraints on Use of Fertilizer on Postrainy Season Sorghum in Semiarid Tropical India.*** Economics Program Progress Report. Patancheru, AP 502 324, India: ICRISAT.

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CHOOSING PRIORITIES FOR AGROFORESTRY RESEARCH

Sara J. Scherr*

INTRODUCTION

Since the establishment of the IARCs two decades ago, their focus has expanded from narrow technical issues to increasing emphasis on the interaction between a particular technology and the socioeconomic environment which may constrain farm production. Along with this change in focus at the IARCs is recognition of the considerable heterogeneity in farmers' physical and socioeconomic environments. Moving away from site-specific research trials, research programs at some centers have begun to develop macroscale "research domain" classifications to permit more effective targeting of research efforts.

The first such efforts based differentiation of research domains on biophysical characteristics, using agroecological zone classifications (Brinkman 1986, ICRISAT 1986). A few centers have also begun to incorporate socioeconomic variables into the basic classification system, CIAT's cassava research domain classification being the most sophisticated (Carter 1986, Lynam 1989). Social scientists at several of the IARCs are currently attempting to determine which socioeconomic variables should be included in such classifications, and how they would be used (Goldman 1986, Grandin 1987).

ICRAF has been working since 1985 to develop a system of research domain classification/description for agroforestry. This paper reviews that process, the manner in which this information is incorporated into research design and planning, and the use of socioeconomic analysis in research domain classification, research planning, and research implementation.

EVOLUTION OF AGROFORESTRY RESEARCH PLANNING METHODOLOGY AT ICRAF

Agroforestry can be defined as the intentional growing of multipurpose trees and shrubs (MPTS) in combination with crops, animals, or other land uses. Despite their historical importance in farming systems throughout the world, agroforestry practices have only recently become the object of formal scientific research. The sheer number of potential agroforestry components, combinations, and spatial arrangements has made it very difficult to carry out systematic research planning. One of ICRAF's early concerns was to develop a methodology for determining the most promising and highest priority agroforestry research lines for a given site and to identify approaches for multidisciplinary and multiinstitutional research planning and implementation.

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The outcome was ICRAF's "agroforestry diagnosis and design" (D&D) methodology, spearheaded by an ecological anthropologist, John Raintree. Developed and tested for use on specific sites, the D&D was rapidly expanded for use at the community, watershed, and general land-use system level (Raintree, in press, Huxley and Wood 1984, Rocheleau and van den Hoek 1984, Hoekstra 1985, Raintree and Torres 1986).

The D&D farming systems approach is based on a "user perspective"; the choice and design of agroforestry interventions must directly reflect the particular needs and constraints facing farmers and other land users in a particular environment (Rocheleau, in press). To encompass other forms of land management, such as forestry and rangeland use, ICRAF refers to 'land-use systems," rather than "farming systems." Evaluation of **a** land-use system provides detailed specifications for the technologies to be generated through research.

The D&D process depends on a multidisciplinary team of specialists, with heavy input from target farmers. Joint rediagnosis of farmer conditions and redesign of agroforestry technologies is expected to continue throughout the period of research. Because little systematic information was known about agroforestry options, the early approach treated each land-use system as unique, requiring a unique set of agroforestry solutions to identified problems.

Biophysical Land-Use Evaluation for Agroforestry

While the D&D methodology was being developed for use with specific land-use (farming) systems, other research at ICRAF was being carried out on biophysical land-use evaluation for agroforestry. An environmental database for agroforestry was organized in 1983 to contain information on climate and soils, landforms, hydrology, vegetation, fauna, disease, and basic elements of geology and land use. The intention of building this database was to identify appropriate agroforestry systems, multipurpose trees and/or crops for association with MPTS appropriate for particular environmental conditions. It was expected that microlevel studies would sort out the technical options with respect to local land-use and socioeconomic characteristics (Young 1985). Work was subsequently done to merge the biophysical land-use evaluation approach with the more socioeconomically oriented D&D approach, and to outline a procedure for national agroforestry research planning (Raintree and Torres 1986, Raintree, in press).

The Agroforestry Regional Network for Africa (AFRENA)

lo 1985, ICRAF's mandate was reinterpreted to move beyond a methodology-generating role, to one of direct technical research in collaboration with national programs (ICRAF 1985). To avoid the potential loss of direction involved in carrying out a number of site-specific research projects, and to maximize its international impact, ICRAF decided to focus its research on target land-use systems rather than sites, and to concentrate field research in Africa. AFRENA was formed with programs involving several countries in each of four major ecological zones: 1) the upland plateau of southern Africa, **2)** the humid lowlands of West Africa, **3)** the humid and subhumid highlands of East Africa, and **4)** the semiarid region of the Sahel.

Each ecological zone program comprises: 1) country-specific projects generating and adapting specific technologies for a specific land-use system of high national priority, managed by national researchers; and **2)** zonal projects working on research topics considered to be of interest throughout the zone, managed by ICRAF researchers. Ultimate responsibility for determining the research agenda for country and zonal projects lies with national policy makers, while ICRAF acts as technical consultant (Torres 1985, 1986, Raintree and Torres 1986, SACCAR and ICRAF 1986).

Research planning for four countries in the unimodal upland plateau zone (southern Africa), and one in the humid lowlands zone (West Africa) was completed during 1986 and early 1987. The planning process for three cnuntries in the East African highlands began in 1987. Of the 10 professional scientists at ICRAF principally responsible for AFRENA research planning during this period, **4** were social scientists. specializing in ecological anthropology, farm management, agricultural development economics, and agricultural extension.

In order to select zonal and country priorities for AFRENA agroforestry research and also to help train national scientists. agroforestry potentials for all major land-use systems in the target ecological zone were evaluated. The tentative results from this macrolevel D&D were presented as a "provisional blueprint for agroforestry research" for each country and ecological zone.

The original D&D methodology had been conceived as a "sliding scale" applicable to any level of analysis, from a single farm to a broadly defined land-usc system stretching across a province. The logistics of data collection and evaluation in the "macro" approach, however, required modifications. The standard D&D applied to a single community or land-use system depends heavily on detailed visual interpretation of the landscape and direct farmer and community interviews. The "macro D & D process used in AFRENA depends more heavily on "windshield surveys," secondary data, and key informant interviews. To systematize the macro "diagnostic" process, a set of worksheets for land-use system description for agroforestry were developed (Scherr 1987). Because the AFRENA process is less detailed, the conclusions regarding agroforestry potentials are viewed as hypotheses. Once a target system for research is identified, a "micro D&D" is carried out to verify the "macro D&D" analysis and provide detailed specifications for research design.

As a response to the new needs of AFRENA for comparing agroforestry potentials in different land-use systems and the increase of information on agroforestry options, a new approach to evaluation of agroforestry potentials is evolving. This new approach matches specific land-use systems with relevant technologies, according to a definable set of criteria. Rather than depending on intuitive evaluation as in the original D&D, attempts are now being made to specify and quantify the ranges for particular land-use system characteristics which would suggest or preclude the use of certain technologies (i.e., to identify their research and recommendation domains).

PLANNING AND DESIGNING AGROFORESTRY RESEARCH

The process of differentiating land-use systems is more complicated for agroforestry than for single commodity-focused research. Because the diagnostic process seeks to find all potential roles for MPTS in the system, first, more information about the system as a whole, subsystem linkages, and distribution of production inputs and outputs is needed. Second, analysis must be done within an evolutionary perspective. Research involving trees has a longer time frame than that involving crops: trees become semipermanent fixtures in the landscape. In defining research priorities, one must be concerned not only with the current conditions of the system, but also with those which can be envisaged for the medium-term future. Third, because agroforestry is in many regions a relatively new approach to land management, the service, input, market, and extension infrastructure required to support agroforestry activities is often undeveloped. The level of such infrastructural support is a major consideration in the choice and design of suitable agroforestry technologies for research.

Classifying Agroforestry Research Domains

To classify distinct research domains, one must determine whether the proposed agroforestry systems would involve significant changes in tree/crop/soil interactions, arrangements, or basic management. At least five major facts determine the specifications for agroforestry technologies in a particular system: 1) biophysical conditions, 2) organization of the production system (land-use intensity, components, and management practices), 3) specific system constraints, 4) landscape organization, and 5) socioeconomic environment. Evaluation of all facts but the first requires a high input of socioeconomic analysis at both farm and regional levels.

Biophysical conditions. Biophysical conditions affect both the choice of MPTS species for use in agroforestry interventions, and the expected performance in terms of biomass production and tree/soil interactions. In using MPTS in particular regions, every attempt is made at "site-matching" to ensure that highquality germplasm suited to the environment is used. However, because systematic evaluation and breeding of MPTS began so recently, few species have anything like the certified gene pools available for crops and livestock studied at other IARCs. Selection of MPTS is still done more on the basis of species than on variety, and individual species and varieties tend to be adapted to fairly broad ecological ranges.

Organization of the production system. Characteristics of the production system (crops, livestock, and trees) determine the choice of **MPTS** for food, fodder, fuel, soil fertility, etc., and the design of agroforestry technologies. Important aspects include: a) land-use intensity, b) system components, and c) existing management practices.

a) Land-use intensity. Identical environmental conditions may call for quite different agroforestry interventions under different conditions of current **or** projected land-use intensity. **For** example, farmers in lowdensity population areas might he willing to increase production land by establishing permanent tree crop plantations in forests. Farmers in areas where fallow length is declining may need biologically improved tree/shrub fallows. Farmers in highly populated areas may he willing to intercrop with soil-improving trees **or** shrubs to increase yields per unit area (Raintree and Warner 1986).

b) System components. Specific components of the farming system may affect the choice or design of agroforestry technologies. For example, mixed farming systems can use hedgerow intercropping designed to include fodder MPTS, while agro-pastoral systems in which livestock are maintained away from the crop may require alternatives such **as** tree/shrub fodder hanks **or** fodder trees scattered in grazing lands. While alley-cropping can be used with most grains, rotational fallows may be preferred for tobacco or cotton, to help break the nematode cycle.

c) Existing management practices. Existing farm management and agroforestry practices affect the choice and design of new agroforestry technologies. Of particular importance are practices related to land preparation, rotation sequence, use of fallows, fertility improvement techniques, soil erosion control techniques, and feeding and penning of livestock.

Specific system constraints. Specific land-use constraints will call for certain types of MPTS products or farm services. **For** example, the species and management characteristics of MPTS to be included in a fodder hank would probably be different if the objective was year-round fodder production for dairy cows, rather than supplemental nutrition for oxen at plowing time. An alley-cropping system can include MPTS useful for harvesting fuelwood in a seriously fuel-short zone, **or** species for harvesting building poles where there is a lucrative market for them **or** both. Products which may be provided by MPTS include cash, food, timber, poles, stakes, fibers, crafts, fodder, fuel, medicines, chemicals, and resins. Possible service functions include soil fertility improvement, soil erosion control, weed control, water absorption/retention, on-farm drainage, watershed/floodplain management, fencing boundary markers, wind shelter, shade, and live staking for climbing plants.

Landscape organization. Organization of the landscape influences the choice and design of agroforestry technologies by determining where in the system trees can be established. This is partly determined by the local geographical pattern of production. Farming systems with dispersed homesteads may have a greater potential for multistrata homegardens than those with densely clustered villages. Distance to fields may affect the attractiveness of technologies requiring close supervision or high labor inputs. Rules of land use and tenure may limit rights to plant, protect, or harvest trees in particular places. Tree establishment in agricultural fields may he difficult where communal grazing of crop residues is customary. Boundary plantings of multipurpose trees may he highly contentious in areas about to undergo land adjudication.

Socioeconomic environmenr. The socioeconomic environment within which producers operate offers potentials and constraints for particular technologies in some regions. Key variables for agroforestry include availability of farm labor, land and capital, markets for farm and agroforestry inputs and outputs, transport, service, and extension infrastructure. Because of the fairly long time frame required for agroforestry research, it is necessary to evaluate conditions in terms of probable constraints at some period in the future. As a rule of thumb in the AFRENA exercises, a 15-to 20-year time frame is used. If there are no cattle in the system now, is it likely there will he in 20 years? If there is insufficient land-use intensity to justify alley-cropping now, will this persist in the future? If market opportunities are poor now, might they improve over the next decade? This may involve making heroic assumptions, but is more realistic than assuming that the current situation is permanent.

Stages of the AFRENA Research Planning Process

Once a broad target ecological zone has been chosen, the AFRENA research planning methodology attempts to collect systematic information on the facts discussed above for the targeting of research activities from a relatively large area (e.g., unimodal upland plateau or humid lowlands). There are six major stages in the planning process: 1) institutional arrangements lor research planning, 2) zonal description, 3) land-use system description, 4) evaluation of agroforestry potentials, 5) research prioritization, and 6) research design. More detailed descriptions of this methodology may he found in Raintree and Torres (1986), SACCAR and ICRAF (1986), and Scherr (1986a).

Institutional arrangements for research planning. The multidisciplinary and multiinstitutional input required for effective agroforestry research is achieved in AFRENA through national agroforestry committees, composed of policy makers in agricultural research and development institutions. They, in turn, appoint a multidisciplinary national agroforestry task force to carry out planning activities in each country.

Zonal description. Delineating the target ecological zone **is** accomplished by mapping major biophysical characteristics, especially elevation, rainfali, potential growing period, soils, etc. Major subzones are identified, such as the highly "acid soil" and "neutral soil" zones of the savannah woodland, the "mid-altitude" and "high-altitude" zones of the East African highlands, or "subhumid and "humid" zones of the West African lowlands. **A** summary description is made of the major zone characteristics, including socioeconomic characteristics such as rural credit, land tenure, and agricultural marketing infrastructure.

National and regional land-use policies and programs which may affect agroforestry in the target zone are then reviewed (Scherr 1986a, b). This review involves key policy documents, interviews with policy makers and researchers, and past, current, and proposed agroforestry policies and programs. Policy issues determined to have major impact on agroforestry research and development may be selected for subsequent in-depth study within the AFRENA research program. The zonal description concludes with identification and evaluation of institutions which could participate in agroforestry research. These include research stations, specialized research resources at universities and institutes, and other development institutions (e.g., extension services, cooperatives, and nongovernmental organizations).

Land-use system descriptiun. A preliminary identification of the broad land-use systems within the zone is made according to the five facts mentioned in the previous section. This is done jointly by scientists from ICRAF and the national agroforestry planning task force, based principally on secondary data and the personal knowledge of task force members.

The task force, accompanied by an ICRAF scientist to assist with the methodology, then visits all land-use systems of research interest to characterize the systems. Worksheets are filled in with detailed information concerning biophysical conditions, Organization of the production system, system constraints, landscape organization, and the socioeconomic environment. Information **is** collected from local secondary sources, visual evaluation of the landscape, interviews with key informants, and farm visits over two to three days.

Evaluation of agroforestry potentials. The next step of the AFRENA process **is** for a multidisciplinary group of agroforestry experts at ICRAF to review agroforestry potentials in the land-use systems. Using the land-use system worksheets, they evaluate the organization, problems, and constraints of each system. They then develop hypotheses regarding the probable future evolution of the system, a set of strategies for intensification of the system, and specific agroforestry technologies/interventions which seem appropriate to each system. This is where the criteria for classifying technology research domains are evaluated.

After completing the preliminary matching exercise, the team identifies any information missing from the worksheets which might be needed in order to propose specific technologies. A joint ICRAF/national task force reconnaissance mission (macro D&D) is then sent to visit the target land-use systems, and collect or verify needed information. The team goes to all the major land-use systems, spending two or three days in each system. The field activities involve visual evaluation of the landscape, interviews with key regional officials (provincial and district agricultural officers and development planning officers), and visits to a few farms to elicit farmer comments and suggestions. The outcome of this mission is a "blueprint" for agroforestry research. This document summarizes the results of land-use system description and evaluation, tentatively describes the specifications for these technologies, and proposes specific lines of agroforestry research for all land-use systems studied.

Table I presents a summary of this analytical approach for the small holder system of shifting cultivation plus permanent cocoa plantations on acid soils in the humid lowlands of southern Cameroon. Key characteristics of the system are summarized in the first column. Major problems found in the system (column 2) were declining food production and productivity due to reduced fallow length, low cocoa yields, labor scarcity, and crop damage from free-ranging small stock. Rapidly rising demand for food in urban centers was not being met by Local producers.

The development strategies (column 3) and recommended agroforestry interventions identified by the "matching" process were to: a) increase food production for home consumption and sale by improving soil fertility (improved fallows, hedgerow fallows, or semicontinuous alley-cropping, depending upon level of land-use intensity); b) intensify home compound food production (feed banks for small stock, live fencing for corrals and homegardens, multistrata homegardens); c) introduce labor-saving tools (improved tools for land-clearing, pruning, weeding, and harvest for management of agroforestty technologies); and d) increase and diversify cash income from the cocoa plot (mixed intercropping with MPTS for soil fertility and improved shade, mixed intercropping with MPTS for timber and other cash products). These agroforestry options were judged to have as much or greater promise for use in the strategies as identified nonagroforestry options.

Socioeconomic analysis played a major role in identifying land-use system problems, and selecting and setting priorities for appropriate agroforestry technologies. Key inputs included evaluating changes in population densities and settlement patterns, understanding the nature and timing of labor constraints for agricultural production, and projecting developments in markets and marketing infrastructure for food crops, cocoa, secondary tree products, small stock, and homegarden products, Regional farming systems researchers provided important input on local ethnobotanical knowledge and practices regarding trees, shrubs, and soil evaluation; and on customary tenure rights over cropping and fallow land in different zones.

Table 1. Land-use system evaluation and agroforestry potentials for the cocoa/food crops land-use system of southern Cameroon.[a]

Characteristics	Problems	Development strategies	Agroforestry prototypes
Rainfall: 1500-2000 mm	Declining food crops pdn/pdvty due to reduced fallow periods and low fertility	**Increase food production by improving soil fertility**	
Altitude 200-850 masl		- for producers with 2-5 year fallows	**Simple improved fallows** **Hedgerow fallows** (alley-cropping managed as fallow)
Soils: Orthic ferralsols (acid)	Underdeveloped home compound production		
Base production system: fallow-based (shifting cultivation) food crops *plus* permanent cocoa plantations	Crop damage from free-ranging small stock High soil acidity High weed problems (esp. *Eupatorium*)	- for producers with less than 2-year fallow **Intensify home compound production**	**Semicontinuous alley-cropping** **Feed banks for small stock** **Live fencing of homegardens** **Multistrata homegardens**
Principal food crops: Cocoyam Plantain Cassava Groundnut	High pest problems Low cocoa yields Limited diversification of cash income	**Diversify cocoa plantations**	**Diversify plantations with MPTS for fertility & products for home use & cash**
Principal cash crops: Cocoa Food crops Oil palm Coffee	Labor shortages due to nonfarm employment and high labor for cocoa, forest clearing, weeding	**Introduce labor-saving tools**	**Identify labor-saving tools for agroforestry**
Use of inorganic fertilizer: Minimal	Labor-saving technology unavailable		
Population density: Range from 3-6 in forest fallow zone to 25-100 near capital city	Food storage in humid conditions difficult Rising demand for urban food supplies unmet by local production		

[a]Adapted from: Cameroonian Agroforestry Task Force and ICRAF. 1986. Blueprint for agroforestry research in the humid lowlands of Cameroon.

Research priorities. After reviewing the "blueprint," the national agroforestry committee in each country decides which land-use system and which specific technologies should be given priority in national research efforts. These tentative country priority lists are brought to a zonal planning workshop where participants identify land-use systems, technologies, and specific MPTS needs which are important at a zonal level. Potential complementaries between the research needs of different countries are evaluated. Tentative conclusions are drawn about zonal, national, and institutional responsibility for generating specific technologies for specific land-use systems.

Research ***design.*** The next step **is** the "micro **D&D,"** carried out jointly by **ICRAF** and national task forces in representative sites of the target land-use system or systems for which research is being planned. In the "micro **D&D,"** the hypotheses from the "macro **D&D"** are checked on the ground with farmers to verify and quantify the analysis at the community and farm levels, to find out farmer reaction to the proposals, to identify divergences between farmer and policy priorities, to modify initial technology designs, and to collect detailed information required for research design.

The field exercise focuses on what is not already well understood about the system. **A** list of specific questions which need to be answered is developed by the team **for use** in farmer interviews. Two or three communities or suhdistricts are chosen for study, which are representative of important identified variations in the system, and different types of farm households are interviewed. Basic background information on these should he collected before the mission, including production, land distribution and tenure, population, and key markets.

A list of specifications is developed for each technology to be studied, specifying: a) what problems and potentials the technology is expected to address (e.g., improvement of soil fertility through applications of leafy mulch and harvesting two months worth of fnelwood from prunings of woody biomass); b) biophysical and functional characteristics of land to he used for the technology (e.g., scattered crop plots on Oxisols with pH **4.5** on 30-degree slopes); c) plant associations, geometry, and spacing (e.g, hedges of MPTS on grass strips, composed of three rows, with six meters between hedges); d) required characteristics **of** multipurpose trees or shrubs (e.g., acid-tolerant with cropping ability and light canopy); and e) management requirements and expected constraints (e.g., optimal pruning height and frequency subject to labor constraint during the planting season, and ease of establishment under weedy conditions). **A** tentative list of MPTS which might meet the specifications is then developed.

The "micro **D&D"** mission is followed by a research design workshop. The objective of this workshop is to finalize the list of above specifications and to establish the research sequence and component experiments required to develop the technology according to these specifications. **A** literature review is initiated, tentative experimental designs and assessment methodologies are proposed. **Also,** a provisional division of labor is established between different research groups and institutions in each country, and between national and zonal research teams. Research decisions are then summarized in a "proposal for agroforestry research," presenting the basic set of experiments, their objectives, experimental facts, research methods, and discussion of the experimental sequence in terms of technology specifications based on the land-use system evaluations. On-station, on-farm researcher-managed, and on-farm farmer-managed trials are envisaged. Most of the research plans are designed for a generally renewable, five-year research period.

Following the research design workshop, national scientists who are principally responsible for carrying out the research with the assistance of ICRAF scientists, will develop a more detailed set of research protocols. These should include experimental designs, survey questionnaires, and a detailed research plan identifying needed labor and material resources, a time schedule for taking assessments, and plans for data analysis and evaluation. Research implementation then begins. It is expected that the process of rediagnosis and design will, be refined throughout the research process, through continuous interaction between researchers and the target farmer population.

SOCIAL SCIENCE PERSPECTIVES IN ACROFORESTRY RESEARCH

The experience gained so far in agroforestry research planning and implementation raises interesting questions about the appropriate role of social science. This role may be more comprehensive than is commonly assumed by most technical or social scientists working in agroforestry. It includes specific responsibilities in land-use system diagnosis and technology "design," research planning, research implementation, and technology adoption and dissemination.

Agroforestry Diagnosis and Design

The role of social science observation and analysis in the diagnostic stage of agroforestry planning is well established in particular the role of holistic systems analysis, including the social, institutional, and economic constraints on farmer circumstances and options. The methodology for classifying research domains for agroforestry, and linking diagnosis with detailed technology design is still rough. Although there is general agreement on the criteria on which classification is based, the actual classification depends very much on the subjective judgement of a group of experienced agroforesters. There is as yet no system whereby this experience has been quantified or organized for use by nonexperts, or even for consistent use by experts.

However, the current demand for such evaluation is strong, not only for research, hut also for identifying priority technologies for agroforestry development activities. A new project has recently been established at ICRAF to develop a "matching" system, ultimately with a user-friendly computer program which could be accessed directly by researchers involved in land-use system data collection and evaluation (see paper by John Raintree in this volume). Systematic evaluation and quantification of relevant socioeconomic facts could he linked with the environmental database and other work on climatological influences on agroforestry, for classifying biophysical facts. It should also he possible to link a technology "matching" system with ICRAF's multipurpose tree and shrub database, lor rapid identification of promising MPTS components which meet particular specifications. In order to carry this out, it will be necessary to review each technology individually, and to standardize specification options for technology functions, landscape niches, outputs, **MPTS** components, and technology management under different biophysical and socioeconomic circumstances.

Planning Agroforestry Research for Technology Generation

Currently one of the weakest phases of the process of agroforestry technology development is the leap from diagnosis and design to the actual program of research (development of the "proposal for agroforestry research" in **AFRENA).** One may have a clear idea of needed specifications for a technology, but a poor idea of which research questions need to be answered first, how much certainty is required before prototype technologies can be designed and tested, or how soon to begin research at the farm level. This may in turn lead to confusion about appropriate experimental designs, survey instruments, and sequence of research activities which will most effectively, at minimum cost, and in the shortest period of time, answer the priority research questions. There is a particular need for systematic principles and guidelines for research planning to assist researchers who have limited personal experience in carrying out agroforestry research.

While this is a field in which the input of technical experts in agroforestry research is essential, it **is** also one for which scientists are rarely well trained. Foresters have usually not been trained to evaluate trees for characteristics of relevance to their use in agroforestry technologies. Agronomists have usually not been trained to engineer agricultural technologies based simultaneously on little-studied components, arrangements, and land husbandry practices, nor in methods for studying and evaluating multicomponent systems. Nor are most scientists trained to work jointly with members of other disciplines in technology generation.

Social scientists, provided they are familiar with the basic principles and substance of technical agroforestry research, can play a very useful role in research planning teams by helping to fill these gaps. Their orientation is more holistic, and their tendency by training is to focus on the technology to be developed and the final user, rather than on the details of biophysical interactions. The latter can sometimes so engross the technical scientist as to distract him or her from the ultimate aims of the research. The social scientist will keep asking the bothersome questions: "How will this research benefit the farmer?" and "How can we make this research more useful to the farmer?" The trained eye of a social scientist can help identify leverage points in the farmers' conditions which would suggest research priorities. The social scientist on the team can also act as facilitator and interpreter between the different disciplines in the group, as an "honest broker" with no bias toward a particular line of research.

Research Implementation and Prototype Development

Social scientists can **also** play a valuable role in research implementation, particularly in periodic evaluation of research findings to suggest relevant new trials, and collaborate with technical scientists in planning prototype designs and implementing prototype trials. They can help to reassemble components of a technology to fit the original diagnosis and specifications. In addition, social scientists will almost certainly play a leading role in planning, design, and implementation of on-farm research activities involving farmer participation. These may run the gamut of activities: organization of farmers for participation in research; training of technical scientists in communication **skills;** carrying out exploratory prototype trials: participating in ethnobotanical surveys to identify indigenous MPTS species and management systems; evaluating labor use or the social, economic, or land-use impacts of new or modified agroforestry technologies or all.

Adoption and Dissemination of Agroforestry Technologies

The ultimate objective of agroforestry research for technology generation is the adoption and widespread dissemination of technologies which will effectively address identified land-use system constraints and potentials. While dissemination and extension issues *per se* are commonly outside the scope of the IARCs, they must be kept in mind during the process of research planning and implementation. The common failure of agricultural research to produce extension recommendations, much less to widespread sustainable farmer adoption, is well known. It is **also** clear that the technical characteristics and input requirements of agricultural technologies can affect the ease of dissemination.

Therefore, whenever technical choices are made during the design process for agroforestry technologies. it is essential to reflect on their implications for future dissemination. Will this system require special education in nursery techniques? Will this MPTS species require facilities for seed storage? Will this arrangement affect the management of ox-plowing? Where the requirements for dissemination are not likely to he met, a different approach might be tried. Where special needs for dissemination are identified, it makes sense to approach extension agencies about them and encourage pilot extension trials as soon as possible. This role is another one which could be usefully played by well-informed social scientists.

Social Science or Social Scientists?

A comment that frequently arises in discussion concerning the role of social scientists in agroforestry research (and agricultural research in general) **is** that their major contribution is one of perspective, of sensitivity and commitment to the farmer as the priority client for research. This suggests that a technical scientist with this same level of sensitivity and commitment could replace the social scientist on research teams. For certain roles, this suggestion may be valid. Commitment to the farmer as client is a psychological and ideological attribute, rather than one provided by professional [raining. An agronomist or forester with basic social science training and/or substantial personal experience with problems of rural development and interaction with farmers at the field level might be an adequate substitute for the trained social scientist. In a fundamentally multidisciplinary field such as agroforestrj, the value of an individual to the whole research process is enhanced significantly by a multidisciplinary background in training and experience. It is not what one calls oneself that counts, but what one knows, and a technical scientist *so* trained can know a lot about social science analysis.

There is, however, an indispensable role for the social scientist as a disciplinary specialist in agroforestry research planning and implementation. "Perspective"and "sensitivity" are often not enough in the field for a rapid appraisal of farmer problems, in the research station for evaluating the implications of research results for technology design, or on the farmers' fields for attempts at testing technology trials. A "sensitive" agronomist may he aware of farmer problems in adopting fertilizer. and may even be capable of spending several hours calculating the cost/benefit ratio. But the professionally trained agricultural economist can at once determine the implications of figures on cost and return, and at the same time be able to judge the probability of changes in cost/return figures that might lead to future adoption. This comes from intensive exposure to case material on similar problems under many different conditions, and training in effective analytical techniques.

Similarly, a "sensitive"forester may be aware of the importance of local beliefs in tree planting and try to find out about them. But the professional anthropologist has been trained in effective, reliable, and efficient methods for eliciting this type of information. The professionally trained economist or anthropologist, as well as other social scientists in their disciplines, are comfortable with and trained to understand and evaluate *complex* social situations, and predict their implications for research activities.

The overall importance of social science evaluation in agroforestry research has serious implications for staffing of agroforestry research at both national research institutions and the IARCs. The AFRENA experience *so* far suggests that with the frequent exception of those with farming systems training, few agricultural scientists have the background necessary to collect, much less analyze, the basic socioeconomic information required for selecting and designing agroforestry technologies. It is essential to train more technical scientists in basic social science skills required for agroforestry research, as well as to recruit more social scientists to national research institutions for agroforestry research planning and implementation. It is to he hoped that as more agroforestry research is applied, and particularly to farmers' fields. social scientists will be able to support the research process effectively through both disciplinary research focused on agroforestry problems, and direct input into technical research programs.

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ADDING COMMUNITY-LEVEL VARIABLES TO FSR: A RESEARCH PRIORITY

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INTRODUCTION

Farming systems research (FSR) has gained increasing recognition as a cost-effective approach to small-holder agricultural development. Tenets of FSR include paying close attention to farmers' goals and circumstances, and working together with farmers on their fields in order to test new technologies and adapt existing technologies to farm circumstances. Although FSR stresses the need to understand farmers' circumstances, in practice little attention has been paid to the wider cultural and social organizational context in which farming takes place (Shaner, Philipp, and Schmehl 1982). Yet, in developing countries small-holder agricultural production **is** embedded in a social organizational framework without which it cannot be fully understood. Many small-holder producers are poorly incorporated into market economies; they live in an uncertain world in which social relationships rather than markets, corporations, or the state, provide their sources of production and their security both present and future.

FSR evolved from a western-oriented farm management tradition which emphasized the farm family as the unit of production and consumption and used a narrow family-firm model based on economic-maximizing. It incorporates a spurious distinction between "economic" and "sociocultural" behavior based on the assumption of neoclassical economics that Western man, in acting "economically" **was** not acting "culturally." The development of FSR was spearheaded by agricultural economists in a number of IARCs (e.g., CIMMYT, ICTA, ICRAF, IRRI) in conjunction with natural scientists of various disciplines; there has been little systematic sociological input.' As a result, in FSR, sociocultural factors have been defined as constraints not amenable to change; the focus has been on those circumstances and management practices directly under the control **of** the individual farmer. This perspective has fostered a research approach which appears socially and politically neutral, and which has undoubtedly fostered the acceptability of FSR.

However, because small-holder production **is** imbedded in culture and social organization, there are serious limitations to the current FSR emphasis on the family farm. By ignoring suprahousehold social processes, FSR has limited applicability to certain types of production systems and problems. It **is also** hampered in understanding requirements for extension and technology transfer.

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This paper argues that social organization and social processes must be taken into account in order for the IARCs and FSR to realize their full potential to contribute to the development of appropriate and adoptable technologies. This will require redefinition of the role of social scientists in agricultural development research.

A distinction must be made between several types of FSR-related research: **1)** research which is done by IARCs in order to develop and test FSR methods, particularly those appropriate for use by national programs; **2)** FSR which IARCs use to identify their own technological research priorities and to conduct adaptive research; and **3)** FSR which is carried out by national programs. The primary focus in this paper will be on the first type. It assumes that IARCs have a crucial role to play in the continuing development of FSR, and that this will necessitate strategic social science research.'

NONECONOMIC SOCIAL SCIENTISTS IN IARC FARMING SYSTEMS PROGRAMS

In most IARCs, noneconomic social scientists **(NSSs)** are in a marginal position in relation to the natural scientists (and occasionally economists) who dominate these organizations. A number of recent publications (Rhoades 1984, Cernea and Guggenheim 1985, Tripp 1985) and workshops (IRRI 1981. CIMMYT 1984) have addressed the issue of the possible contribution of **NSSs** to FSR or IARCs or both. **As** a result of such efforts there appears to be increasing acceptance within IARCs of the usefulness of **NSSs** in limited service capacities, but still little acceptance of the need for IARCs to include strategic social science research in core activities.

The **Present Situation**

Currently, there are two primary service functions that **NSSs** fill in IARCs often within an FSR-type program. The first, the role of culture broker, has perhaps been the most important one to date. Many biological scientists appreciate that as a result of their training and disciplinary perspective, anthropologists possess unique skills for understanding farmers' goals and practices. Thus, in initial descriptive stages of farming systems research programs, IARCs may now request anthropologists' assistance to describe complex indigenous cropping patterns and farmers' varietal choices, management practices, short- and long-term goals of production, the division of labor and product, indigenous technical knowledge, etc. Within this framework, it is the natural scientists and to a lesser extent the economists who determine the variables to he described by the anthropologists. The extent to which the **NSSs** can enlarge on their narrow mandate to include broader sociological concerns depends on a number of facts, including the workload of the team and the willingness of the team leader and other scientists to consider the relevance of sociological phenomena to their research.

The second major function of the **NSSs,** related to the first, is **as** technicians with expertise on data-elicitation among Third World small holders. Such data-elicitation can include the design and administration of formal surveys, enumerator, training, etc., as well **as** informal participant observation. A number of **NSSs** have contributed to the development of methods for rapid appraisal for their organizations, and have also contributed to training of other staff.

In both functions. **NSSs** act largely in a service capacity to biological scientists who are perceived as doing the "real work" (i.e., technology development), and to the economic scientists who are thought to do the "real evaluation" (i.e., neo-classical cost-benefit analysis). It is assumed that farm-level economic analysis can be divorced from sociocultural phenomena. Yet **as** Cancian (1972191) noted: "Economic man always operates within a cultural framework that is logically prior to his existence as economic man; and this cultural framework defines the values in terms of which he economizes." Society provides the institutional and organizational context in which producers must operate.

When it is incontrovertible that social issues affect technology development and adoption possibilities, IARCs usually maintain that such issues are outside their domain, that they more appropriately belong to "extension."As Haguerud observed (1986), IARCs do not usually consider strategic social science research as their concern. Participants at the IRRI workshop noted that "social scientists have not explained the relationship between social organization or ideology and agricultural technology in a form understandable to biological scientists"(IRRI 1981). Although the **NSSs** were not held entirely to blame, it was felt that "the burden was on anthropologists to better articulate their positions to correct the misconceptions held by those unfamiliar with anthropology or sociology." The message seems clear: **NSSs** must assume an advocacy role and strive to work their way to more powerful positions in the IARC hierarchy. Euphemisms about "constructive controversy" not withstanding, acceptance of the substantive concerns of **NSSs** will require concerted effort. FSR programs, which emphasize research relevant to farmers' circumstances, are the logical point of entry for social science concerns in IARCs.

The Future: The Need for Sociological Variables in FSR

There is an urgent need to expand the limited role of **NSSs** in farming systems research in IARCs. Although the service function of **NSSs** is vital, the non-economic social sciences have far more substantive contributions to make to an understanding of Third World small-holder agriculture than their current role in IARCs usually permits.

There are a number of different types of activities and products of sociological research which FSR requires. For simplicity they can be grouped into three: 1) basic knowledge of the system and its dynamics, **2)** formal field methodologies, and

3) action-oriented methods. The first includes models and theories about how small-holder communities are structured (social organization) and how this structure affects adoptability of particular technologies, equity concerns (including policy requirements), and possibilities for community organization and action (Doherty 1979a, 1979b, Sandford 1983, Cohen and Uphoff 1980, Hunter 1982). The second stresses methods usable by both NSSs and other scientists for site-specific understanding of these issues (Chambers 1985), and the third emphasizes methods for action-oriented research and development (i.e., putting knowledge into action to help producers meet their needs, e.g., Rocheleau 1986). This paper focuses on the first two of these, but with the understanding that their eventual goal is to inform the third type of activity.

Three broad levels of social organization which require attention are intra-household, household, and suprahousehold. In recent years, it was: largely anthropologists who demonstrated the need to look at intrahousehold dynamics, and particularly at the role of women in agricultural production. This was in clear contrast to incipient FSR methods which treated the family farm as a unit. Although there are still numerous obstacles to the full implementation of this perspective, it is becoming increasingly accepted within FSR circles that the division of labor, of responsibilities, and of products within a household varies from society to society, and that for agricultural technology to be appropriately designed, it is necessary to take these intrahousehold divisions into account.

It is now time for NSSs to encourage the investigation of suprahousehold relationships and institutions which have been largely ignored in FSR. Such processes include some which bind producers together and others which split the community. Small-holder producers operate within a web of social relationships through which they obtain both production inputs and security. In many areas. essential means of production cannot be obtained through the market place. but only through social channels. Society defines rules, responsibilities, and expectations for behavior among people, as well as organizational structures through which action occurs. Although, to outsiders a community of small holders might appear homogeneous, it will surely he differentiated on wealth lines and is likely to have factions based on age, gender, education, and kinship and/or political affiliation.

In most small-holder communities, traditional organizations and institutions have changed radically in adaptation to external economic and political influence. but continue to exist in some form, Frequently these institutions are ignored in farming-systems research as well as in extension and development. As Sandford (1983) has noted with regard to pastoral development, governments often perceive traditional institutions as potentially hostile, retrogressive and/or incapable of managing modern development, and hence, do not use them as conduits to rural populations. This perception is often indirectly reinforced by the failure of academic social scientists to deal with dynamic, evolving aspects of traditional institutions and practices.

THE USES OF SUPRAHOUSEHOLD SOCIAL VARIABLES IN FSR

Although FSR scientists are not unaware of the importance of community-level processes and institutions on access to resources, production goals, and management practices, they have not systematically taken these parameters into account. Rather the focus has been on inputs and decisions under the control of the individual households. This household-level focus has allowed for some of the rapid gains of farming-systems research, both in terms of technology generation and in terms of its acceptance by national organizations and political systems which are comfortable with the emphasis on within-farm boundaries.

The current FSR approach, however, has serious limitations on both the types of production systems and the types of problems it can address. Production systems based on communal access to resources, for example, are not easily within the scope of the current FSR approach, yet such systems cover much of sub-Saharan Africa. Even where individual control of resources is high, certain problems (e.g., pest control. watershed management) require suprahousehold cooperation.

Systems with Communal Access to Resources

Pastoral systems with communal grazing. In most African pastoral systems, while animals are individually owned, grazing resources and watering points are often held communally. Until recently all of Kenya's pastoral systems, covering **80** percent of its land area, were characterized by communal access to grazing and most water resources. In the late 1960s under KLDP a new form of territorial organization and control was introduced, with the Kaputiei subtribe of the Maasai as the pilot area. The new form, called group ranches, involved a radical change in the definition of property rights in Maasailand (Grandin 1980, 1985a).

Communal lands were divided into numerous group ranches with officially registered members who hold a group title deed and who were intended to limit stock numbers and to have exclusive use of the ranch resources. This major tenure change was deemed essential by planners in order to stem range degradation and to provide sufficient incentive for investment in infrastructural development. Group ranches were seen as a compromise between the planners' preference for individuated tenure and production requirements in a semiarid zone.

Maasai participation in formulating the concept of group ranches was very limited: virtually no attention was paid to existing mechanisms of resource control. Maasai welcomed the group ranches for two reasons: a) they were able to retain control over most of the land they had occupied since independence, and b) they were promised infrastructural development (primarily water and dips). Under the new policy. group ranch committees were to be democratically elected: they were given a wide range of functions, many of which overlapped with those of traditional bodies.

The required means of decision making (elected committees and majority rule rather than consensus) were alien to the Maasai and served to delay the formation of effective decision-making bodies and exacerbated tensions within the Maasai community (cf. Doherty 1979a and 1979b for a case study). Difficulties in moving toward a new mode of organization have been exacerbated by the absence of strong support and communication from government agencies charged with supervision of group ranches. Group ranches exemplify Sandford's (1983:240) comment that "establishing new organizations of pastoralists takes far longer than is usually foreseen. . . . Established with new constitutions, new tasks, new procedures, new ways of selecting their leaders, they have no successful model of behavior to copy."

Access to water resources and responsibilities for their maintenance also changed under group ranches. Prior to the group ranches, man-made water facilities were either developed and owned by the government (with users paying a fee) or were developed by an individual producer (who was traditionally obligated to allow others to use it). Natural water points were under the jurisdiction of neighborhood elders whose primary concern was controlling access. Group "ownership" of a water resource was a completely new concept to the Maasai, and serious problems arose of both ownership and maintenance. In 10 years, the 15 Kaputiei group ranches (with about 1,800 households) received loans of over Ksh. 9 million (approximately US$ 1.3 million), for infrastructural development, short-term working capital. and money to buy fattening steers.

While according to the legislation, the group ranch was owned "in undivided shares," infrastructural debt was to be proportional to grazing quotas. Rich people felt overburdened by having to pay more than their "fair share" and poorer producers feared that the rich, by paying proportionately more would begin claiming exclusive ownership and control. In addition, many water points serviced only part of a ranch; people who normally lived in other areas were unwilling to pay for the building and maintenance of services which they would not use. A further problem occurred because a number of water points were sited in grazing areas traditionally reserved for dry season use, which were deemed by planners to be underexploited. The establishment of permanent water in dry season grazing areas, at the same time that social control mechanisms were being undermined, destroyed the old system of grazing organization. When rich and influential people moved into these areas at will, committees were helpless to prevent it, as new sanctions had not been provided and traditional sanctions were not within their dominion.

The outcome of this situation was that committees let water facilities fall into disrepair and eventual disuse, A survey carried out by the author in 1980 (Grandin 1980) revealed that the majority of waterpoints and half of the dips installed with KLDP funds were nonfunctional (Table 1). This performance was much poorer than nonproject facilities, most of which were far older. This waterpoint situation has occurred despite the fact that many households live so far from water that their animals are watered every other day and that the promise of waterpoints and dips was one of the main reasons group ranches were initially accepted.

Table 1. Status of Kaputiei waterpoints and dips in 1980.

Funds	Waterpoints		Dips	
	No	% functioning	No	% functioning
Project	13	39	16	50
Nonproject	13	92	7	70

This example denionstrates a situation where the technologies are available, and to a large extent meet fell needs yet they have not been delivered in a manner which enabled sustained use. The problem is clearly one of the management of infrastructural development and maintenance, itself a sociological rather than a technological issue. While the Maasai situation represents an extreme case — of major land tenure and local organizational change as part of a large-scale development program the organizational problems manifested are not unique.

Mixed land tenure agropastoral systems. Major portions of Africa retain a tenure system in which crop land is allocated to individual households (e.g., by the chief or lineage head). but grazing land is held communally. As FSR methods were designed to work within farm boundaries, in such areas they can only focus on the individually allocated land, even where livestock and communal grazing play an essential role in overall agricultural production. Swaziland is a case in point (Getz and Grandin 1986). The Government of the Kingdom of Swaziland requested international assistance in its efforts to raise the productivity of the traditional agricultural sector. Sixty percent of Swaziland, called the Swazi National Land (SNL), is devoted to small-holder mixed farming with maize self-sufficiency as a primary goal. On the average in SNL villages, 13 percent of the land is allocated fairly permanently to homesteads for crop production; the remaining 87 percent is retained as grazing land with communal access. Communal grazing lands are most heavily used during the cropping season; after harvest livestock graze largely on crop residues, access to which is primarily communal.

Livestock, particularly cattle, play an essential role in the overall agricultural production system in the SNL. The cattle population is roughly in parity with the human population; cattle are kept by over 60 percent of the homesteads with a mean of 19 animals per herd. In many areas cattle are the sole source of traction and their manure is an important input to continuous cultivation. Cattle represent the primary source of investment for small holders, providing better returns than institutional investments. Studies by Sibisi (1981) indicate that capital accumulation through livestock keeping is the primary way migrant laborers accumulate sufficient assets to become full-time farmers. More than 50 percent of on-farm cash income is generated by livestock sales. Milk from cattle, and meat from cattle and goats make important contributions to the local diet.

Despite the essential role of livestock in small-holder production, when a major FSR program was established in Swaziland, livestock were ***a priori*** excluded from consideration. Donor commitment to a livestock component was weak, apparently from an unwillingness to deal with the social issues involved in communal resource use. The research program focused instead on maize, horticulture, and irrigation: The "cropping systems" program has limited its activities to the enterprises and land completely under the control of individual farmers, thereby excluding from consideration important mechanisms of improving agricultural productivity and the welfare of **SNL** farmers because of the desire to focus on within-farm boundaries.

Irrigation systems. Large-scale irrigation represents another type of system in which access to an essential productive resource—in this case water—is communal. Goodell **(1984)** notes that, in Southeast Asia from 20-100 or more farmers have their fields in a "turnout area" (the smallest independent unit for water control). Field neighbors are not necessarily from the same village, which further complicates organizational challenges. "In the case of the new rice technology, several of its main components have built-in requirements for farmers' organization configurations" (Goodell **1984:23).** Irrigation requirements feature-predominantly among these. Even small-scale irrigation often requires joint control of water sources (Doherty, Miranda, and Jacob **1981).** Interventions for such systems must be based on an understanding of their underlying social organization **so** that technologies developed do not outstrip organizational and infrastructural capabilities.

Systems with Individual Access to Major Resources

Even in societies where individual control of major resources **is** predominant, some essential needs (e.g., water, fuel wood) are met from off-farm sources. A within-farm focus arbitrarily excludes these from consideration and action. Rocheleau (1985:16) presents a case study from Kenya where farmers secured individual titles more than a decade ago. There remained a "discretionary common use of private land" as well as of public lands which provided fuel, fodder, grazing, timber, fencing materials, and other forest products, especially to poorer households. She notes (1985:16) that "roadside, woodland, and gully sites provide grass, shrubs, and high-protein pods to supplement on-farm fodder. Changes in animal management for fodder tree protection would necessarily involve the community-at-large."

Constraints and Solutions Involving Suprahousehold Cooperation

Even where resource control is vested largely at the household level, the exclusion of a community-level focus in FSR limits the types of constraints and solutions that can be researched. Some problems have greater effect on tne community (current and future) than on any individual farmer. With other problems, one producer cannot cost-effectively control the situation on his farm or with his animals, unless neighboring producers take similar action. Integrated Pest Management **(IPM)** is one of the best researched examples of an intervention requiring joint action by farmers. Clearly the potential success of such an intervention depends **not** only **on** its cost/benefits to any one farmer, but also on its requirements for social organization and modes of group action --either those extant or those developed as a component of the technology.

Effective control of contagious diseases may also require joint producer action. In much of eastern and southern Africa, tick-borne diseases present serious problems to livestock keepers. Many national governments currently have insufficient resources to provide free acaracidal treatment for tick control; different solutions to the problem have been adopted. For example, the Government of Kenya has largely retained centralized control of dips and has introduceo a user's fee. However, centralized control is costly and inflexible, and acaricides are not always available from central stores. Many poorer producers no longer dip livestock, leaving their animals as loci of tick-borne infection. In Swaziland, the control of dips was devolved onto users who were given responsibility for both dip maintenance and the purchase of acaricide. There was no clear policy on how charges should be determined (e.g., by a fixed fee per user **or** a fee proportional to livestock dipped), nor was assistance given to incipient dip associations to resolve this issue. Thus, although dipping is mandatory by national law, many dips are not functioning, and in others use **is** restricted to only some producers.

Where interventions involve skills new to the community (e.g., grafting trees, diagnosing animal diseases, determining drug dosages, establishing nurseries, constructing small ponds), community-level cooperation and control can ensure that several members of the community are trained and continue to provide the necessary service in an equitable fashion. Certain scaledependent interventions require suprahousehold cooperation purely on economic grounds. The cost of certain technologies (e.g., mechanization, waterpoint development, dipping facilities) **is** likely to be prohibitive even for wealthy producers. To be widely adopted, such technologies will require suprahousehold cooperation. ILCA's design of an ox-drawn scoop for community pond construction has proved highly successful in the Ethiopian Highlands largely because of the pre-existence of peasant associations through which the intervention could be channeled (Anderson, n.d.).

A number of authors have noted that the greatest successes **of** the Green Revolution (e.g., crop varieties, fertilizer use) have been with scale-neutral technologies; yet even an apparently scale-neutral technology may require resources to support it which are not scale neutral (e.g., credit). The cost of obtaining an input is part of the real cost to the farmer, and might render unattractive an otherwise cost-effective technology. Additionally, a group of producers may face less risk due to untimely delivery of inputs than an individual farmer. The importance of the community in this regard **is** often inversely correlated to population density, and becomes critical in agropastoral and pastoral communities.

Effective suprahousehold cooperation can open a broad new range of technologies that includes those which require joint action or, which are scaledependent, while facilitating the adoption of scale-neutral ones. Such technologies cannot be effectively developed by FSR scientists purely through research on individual fields without paying attention to community-level variables, particularly as they affect possibilities for joint action. If the organizational structure required by the intervention is incompatible with the existing structure or beyond its capabilities, failure may result.

Social Soundness and Equity Implications of Technologies

When community-level information is excluded, the analysis of social soundness and equity implications of technologies becomes problematic for FSR scientists. FSR usually involves a within-community target grouping exercise. This is often based on a simple, single variable (e.g., size of farm or with/without own draft oxen) which is insufficient for social soundness analysis. Only by having a "community profile" will the researchers be sure of the position of the "target group" of farmers and be able to predict likely effects of an intervention on the target group and other members of the community. Such "social screening" of possible interventions should be an ongoing facet of FSR. This will require several types of community-level information, including social structures, local organizations, informal groupings of farmers, plus intracommunity characteristics such as wealth, education, political affiliation, and ethnic group. Although government policy ultimately dictates where resources are channeled, the FSR team can provide government officials with the information necessary to carry out their policies, and monitor their effects as well as suggest improvements.

As an expediency, FSR teams often work with pre-existing farmers' organizations without being aware of what segments of the community are included or excluded from participation. This situation continues despite increasing evidence that resource-poor farmers, female farmers, and minority group members are usually excluded from such groups. Recent community-level research in Kenya showed that membership in farmer groups is dominated by middle-wealth rank farmers: the rich do not need the assistance offered and the poor are unable to benefit. An initial proposal to rely exclusively on these groups in order to assess needs and define priorities for farmer training courses was fortunately abandoned as a result of this research.

Sensitivity to factions in a community can be crucial to the success of FSR, particularly when these factions are coincident with farm variation. Even when factions do not appear related to farming (e.g., religious or political affiliation), they can have important repercussions for on-farm trial collaboration, cross-farmer assistance, and group action. In extreme cases, factionalism could lead to sabotage, particularly if one group believes its interests are being ignored or abrogated. Awareness of community factions and heterogeneity will enable the FSR team to prevent the monopolization of their efforts by a single group, and facilitate their responsiveness to the whole community.

In the absence of a community profile, there is likely to be unconscious biased selection, particularly **of** cooperators, which in turn might bias results and recommendations in an unknown way (cf. Hansen 1984 for a case study). **Poor** farmers' fields that are fallowed less frequently or receive less manure **or** fertilizer might respond very differently than fields of richer farmers. It is understandable that FSR teams want to work with volunteer cooperators who often represent the better-educated, more progressive elements of a community. To a certain extent, and particularly in the initial stages of research, such an approach might be justified. However, it is important that the FSR practitioners understand how representative their farmers and their fields are.

ADDING A COMMUNITY-LEVEL PERSPECTIVE IN FSR

The IARCs have an important role to play in documenting the value of a community-level perspective in agricultural research and development, **as** well as in developing and testing data-gathering techniques within the capability (present and future) of national programs. IARCs should actively encourage their **NSSs** to look beyond the farm boundary, at the web of individual ties and organizational structures that bind small holders together and divide them into competing factions. On the basis of such research by professional NSSs working in a wide variety of societies, important variables can be defined and cost-effective ways of describing them in specific production systems can he devised. Typologies of community types and behavior types (Doherty, Miranda, and Kampen 1981), "rule-based or decision-based cooperative behavior" can serve as useful guidelines for nonsociologists trying to understand local social processes. As Cernea (1985:19) has noted, sociologists need to develop "new sociological knowledge, methodologies for social action, and operational skills" which will contribute to "putting people first" in the development process. The development of such knowledge will require strategic research on the part of NSSs in IARCs.

National-level FSR activities can begin to incorporate sociological considerations even with current knowledge levels. Every FSR program should have a sufficient understanding of the social, cultural, political, and economic heterogeneity within a community in order to assess the overall position of their "target" farmers within that community. In addition, national-level FSR programs working in areas with communal access to essential resources or working on problems which do not respect farm boundaries should be encouraged to increase their attention to community-level variables and suprahousehold social processes.

There are several ways to initiate an emphasis on the suprahousehold level with relatively little additional input. First, in many areas there is a wealth of anthropological literature which can be consulted (Hansen **1984).** If resources permit, a professional social scientist could be hired **for** a short time to prepare an annotated bibliography, or a review of relevant materials. Second, FSR teams can use "key informant workshops" to explore aspects of local social organization. Social science students, consultant NSSs (e.g., from extension education) can serve as resource people. This approach was successfully used by the national FSR team in Zimbabwe to learn about local wealth heterogeneity, intrahousehold aspects of production and cross-household animal tenancy arrangements (Grandin 1985b). Other topics might include the level at which access to resources is controlled and mechanisms for control. Community heterogeneity can be discussed in broad terms, asking "How are farmers different from each other in terms of wealth?" Key informants can readily tell the FSR team about social organization including the basic social structure (what kinds of people live together, help each other, etc.) and groups active in the area. Third, a key informant technique can be used for assessing wealth rank within a community (Grandin 1980, 1983, 1988). This approach can be applied in any community, as the wealth of a farmer almost invariably affects his access to resources, type of production activities, education level, degree of group participation, and overall influence in the community. The same technique would he easy to employ to determine group participation, ethnic group or clan membership, or other characteristics of farmers which would affect possibilities for community cooperation. Subsequent informal and formal surveys should then include information on the factions felt to be important for the proposed direction of research.

If the result of key informant workshops and interviews suggests the household is not a stable or independent unit, then as Behnke and Kerven (1985) suggest, the dwelling place might be used as the unit of sampling; or if the household is used, its links to other households (both local and urban) can be traced in the on-farm trial phase when researchers have more time to interact with farmers (Tripp 1985).

Finally, reflecting the need for action-oriented research, national FSR teams can begin to observe group interaction and bolster community cooperation as they carry out their duties, by emphasizing group interviews and demonstrations. When possible, discussions with farmers and selection of cooperators should be channeled through suitable local organizations, or if none are available, be used as an opportunity to develop a local self-help organization within the community based on existing groupings and organizational modes. Thus, not only the individual farmer, but the entire community may benefit from FSR.

SUMMARY

FSR currently focuses its efforts within farm boundaries, thus limiting technology generation to inputs under the complete control of the producers. The initial focus on the farm-family has matured to include a subhousehold focus with particular emphasis on the sexual division of labor and product. The focus, however, remains within the farm. The applicability of FSR is limited by its lack of attention to community-level issues, particularly as they affect communal resource control and organization for community-based development. The IARCs which have been in the forefront of developing FSR, particularly those working in Africa, have an important opportunity to develop and test methods which will assist national programs to incorporate community-level variables and hence expand their scope for technology generation and dissemination.

NOTES

[1]A notable exception is ICRAF whose FSR program is headed by an anthropologist (cf. ICRAF 1983).

[2]The Second Review of the CGIAR (1981) distinguishes between basic, strategic, applied, and adaptive research. While basic research is "designed to generate new understanding," strategic research is "designed for the solution of specific research problems."

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Part IV
ADOPTING NEW AGRICULTURAL TECHNOLOGY

THE ROLE OF HOUSEHOLD AND MARKET-LEVEL ECONOMIC RESEARCH IN IMPROVING THE DESIGN AND MANAGEMENT OF TECHNOLOGY

Thomas Reardon*

The purpose of this paper is to discuss the role of economic analysis of farm households and rural markets in improving the design and management of agricultural technologies.

IARCs and NARCs have traditionally assigned economists the role of performing static cost benefit analyses of new technology impacts. A relatively new, broader role is increasingly promoted for economists. This role is twofold: 1) to assess the dynamic effects of new technologies and their management systems on rural households, and 2) to examine the interaction of these effects at the household level within the wider economic context of the regional market and the national economy. These assessments should serve technology designers (such as IARCs and NARCs), managers (such as government agencies charged with system maintenance and input delivery), and agricultural policy makers as inputs in elaborating systems. and policies that promote "sustainable" agricultural development. This implies maintenance over time of economic profitability and ecological norms.

This also means encouraging the use of the "new farm household economics" as well as macroeconomic modeling. The former analyzes the farm household as a producer and consumer simultaneously (Singh. Squire, and Strauss 1986). The latter analyzes aggregate responses of rural households, building on the foundations of microeconomic behavior supplied by farm household economics (Baum and Shertz 1983, Taylor 1979).

If technology designers and managers do not take into account the dynamic and aggregate. direct and indirect economic effects (e.g., labor markets, general equilibrium effects. etc.) of a given technology on rural households' real income, they risk seeing the technology become unprofitable over time, and thus, not "sustainable." The investment in research and the ongoing cost of managing the technology system could come to exceed welfare gains in the user group, as well as in the overall population.

Below, the proposed broader analytical role oi economic analysis is presented in detail. Then, a heuristic sketch is suggested, depicting a "circuit of analysis" moving from the identification of the need for a technology change, to the initial design of a technology and its management system, through assessment of its impacts at the rural household and market (macroeconomic) levels, and finally to the eventual revamping of design and system.

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A BROADER ROLE FOR ECONOMIC ANALYSIS

The specifics of the broader role for economists in IARCs and NARCs can be broken down into the following functions:

1. Help identify the need for a technological innovation or change, or change in a management: delivery system.

2. Examine how variables such as input availability, infrastructure, and market outlets, condition farmers' willingness to adopt new technologies, continue to use them, and manage them effectively.

3. Assess the impacts of changes in technology design and management systems on output and costs at the farm level.

4. Analyze the farm household economy as an integrated system of production, consumption, purchase, and sale choices in response to income and price levels.

5. Examine how output and cost effects (at the farm level) of the change, influence, income, and nutrition levels, as well as supply and consumption decisions of farm households.

6. In turn. examine how farm household supply and demand decisions, taken in the aggregate, influence price levels in the overall market economy. and impact on actual income levels of rural and urban households alike.

7. Assess how the above effects influence long-run demand and supply outlook for crops affected by the change. Explore what orientations these suggest for agricultural research strategies.

8. Interact with the technology design and off-farm management institutions, as well as policy makers, to concretely relate the results of the above analyses to needed modifications in technology design, management and delivery of support services, and the agricultural policy environment.

CIRCUIT OF ANALYSIS: PROBLEM DEFINITION, INITIAL DESIGN, IMPACT ASSESSMENT, SYSTEM REDESIGN

The functions specified in the preceding section can he arranged in a heuristic "circuit of analysis" which begins with the identification of the problem, or the need for a change in the technology or management system, proceeds to the design of a new technology or a management system or both, then continues with an assessment of its impacts at the farm household and market (macroeconomic) levels, and ends with modification of the design or management system or both to ensure "sustainability."

This "circuit of analysis" is of course very much related to and draws upon the field of project analysis and the use of project cycles (Squire and Van der Tak 1975). The latter, however, focuses on the impacts of projects (primarily on specific investment activities), while I am referring to a system of ongoing analysis as input into institutionalized technology design and management processes. Moreover, I am stressing the need to bring to bear the fruit of the microeconomic analysis (inherent in integrated farm household modeling) on economy-wide analysis of market impacts of changes.

At first glance, these market-wide impacts can be classified as "externalities" in project analysis, but they generally affect groups outside the domain of direct influence of the change. For example, a large irrigation scheme will affect regional levels of food availability, and thus affect rural households as producers and consumers, as well as urban consumers. The impacts on the real income of these groups will in turn affect demand conditions for food and nonfood items, and so on.

I will first discuss some concepts/definitions, then present the "circuit of analysis," providing illustrations from the context of irrigation management.

Some Concepts and Definitions

To facilitate discussion of the "circuit" in the interdisciplinary context of this workshop, I will begin by defining "technology" and its change, "profitability." and technology "design" and "management."

The production function. The "production function" describes the use and transformation of a set of inputs into an output. The function is the set (levels) of inputs of various kinds that yields a mean level of output (with some positive variance). The inputs could themselves be outputs from other production processes. The production function shows the following characteristics of a given production process: a) given a certain level of output, what changes in the levels of other inputs must accompany a change in the amount of a given input ***(substitutability);*** h) how much of a change in output would be occasioned by a given percentage change in the levels of all the inputs ***(returns to scale);*** c) how much cost, in terms of inputs, is associated with producing a given level of output ***(efficiency);*** and d) how intensive the process is, as in terms of labor use versus machine use ***(factor intensity)*** (Yotopoulos and Nugent 1976).

Technology and its change. Technology is the sum of the characteristics depicted by the production function: substitutability, returns to scale, efficiency, and factor intensity. That is. it describes the possible sets of inputs, the relationships among them and between them, and the possible range of outputs thus produced. Technological change is modification of these characteristics.

Technology design. This is the specification of the set of characteristics of the production function. The outcome is a set of combinations of inputs which yields (on average, but with some variability) a given level of output. This set gives rise to upper and lower limits on the use of any given input. The breadth of this range indicates the flexibility of input use in the technology, and is a factor in the flexibility of system management.

Profitability. This is used in the sense of financial return to the farm **used** for a given technology or management system or both.

Technology management. This is a multifaceted set of operations, institutions, facilities, and regulations that have as their purposes: a) the facilitation of adoption of a particular technology by farmers; b) the implementation (delivery, operation, and maintenance) of the system, once adopted, and c) the modification of the system and economic context (infrastructure, price policy, etc.) over time, in order to maintain profitability and maximize returns to society, or a part thereof.

Various actors participate in management: farmers, IARCs, government agencies, agricultural extension, and policy makers. Moreover, management takes place at a variety of levels: farm, agency, market, regional, and national.

Note that in this definition, there are some slightly unconventional elements. I have separated initial planning and design from "management," because the two are often undertaken by different institutions or actors. Second, I include modification of design, delivery, and maintenance systems as part of management, in order to stress the maintenance of the profitability and social benefit of a given technology in a changing physical and economic environment. Third, I explicitly include the economic context in the management scenario (i.e., policy makers who create the price policy, infrastructure, and market regulation context are seen as an integral part of the technology management).

Thus defined, if properly undertaken, management becomes an input in the productive process. It serves to facilitate, orchestrate, and modify the process for maximum profitability for producers and social benefit for producers, users, and the rest of the economy. In short, management is an input into particular production processes, as well as an orchestration of the input demand and outputs of the full set of on- and off-farm processes.

Illustration of Concepts: An Irrigation System

The above concepts can be illustrated by examining an irrigation technology which is losing its profitability. Imagine three segments of the technology's production function: 1) the "agency segment": the irrigation agency captures, conveys, and delivers "agency water," from the watershed to the turnout at the farm. This is an output of that particular segment, but an input to the "on-farm" segment of the production function: **2)** the "on-farm segment" (which is assumed to be substantial): the farm uses water from the agency system as an ***input*** in a **process** which has as its *output* the delivery of water to crops using inputs such as ditches and sluice gates; and **3)** the "crop production process," which uses the irrigation water, plus other inputs to produce the crop output.

The irrigation technology could become unprofitable for a number of reasons that are tied to economic conditions. Wages or material costs might rise as a result of increased demand. Alternatively, the increase in the supply of the crop generated by this new technology could drive down rice prices.

Management takes place at each of the three levels of the above system. The ***farmer*** controls the irrigation process which provides water on a timely and sufficient basis. Farm-level management requires overseeing labor application, the maintenance of farm-level sluice gates, etc. Moreover, farmers need to interact with the irrigation agency to ensure that their needs are satisfied (e.g., agency canal water flow rate and timing).

The ***agency*** uses infrastructure (dams, canals), institutional and organizational arrangements (rules, incentives), information (extension), and implementation tools (taxes, policing) to manage the quality and quantity of the canal water.

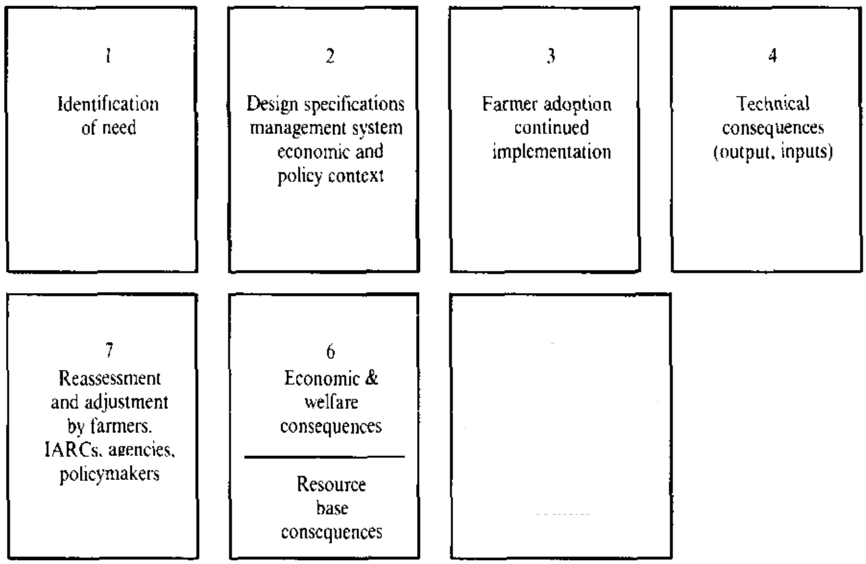
Policy makers participate in management as well. They need to ensure that the changes in input and output flows, associated with the adoption of the new irrigation schemes, will be efficiently met by increased market outlets, roads, storage facilities, and complementary input access. Moreover, they need to adjust price, tax, and income redistribution policies to compensate any counterproductive consequences of irrigation on price levels, and relative incomes.

"Circuit of Analysis" with Irrigation Illustration

The "circuit of analysis" is presented in Figure 1, with discussion proceeding from block to block around the circuit. An illustration pertaining to irrigation is given for each.

1. Identification of ***need.*** Block 1 (Figure I) represents an ongoing research capacity to identify the need to meet objectives at the farm household **or** economy-wide level, which technology or management system change or both would facilitate. This implies, of course, ongoing research programs which not only assess the impacts of specific initiatives taken, hut identify the potential areas of need in which they should be undertaken.

Figure 1. Circuit of analysis.



2. *Design specifications / management system / economic and policy context.* The design of a technology may be developed by IARCs, government agencies, universities, private companies, or other groups. In the case of irrigation, design would include the specification of materials used in canal construction, canal size and layout, the type of regulation technology (gates, pumps, etc.), and techniques for labor use.

A management system is formulated to deliver the necessary set of inputs to the on-farm system, and to provide the informational, regulatory, and infrastructural bases for the farmer to operate the system. For irrigation, this would involve: a) infrastructure and input delivery (such as construction of dams and public canals); b) setting up operating regulations and organisms to oversee these; c) specifying *user fees* (taxes, input prices, etc.), and the degree of farmer participation in operation and maintenance; d) extension; and e) setting up a maintenance system (Svendsen 1986 and Easter 1986).

The economic and policy context guides the managers. For example, various ministries are responsible for price policy, and market development and regulation. These concerns are usually out of the purview of the irrigation agency. While we call the irrigation agency a "manager," the policy makers (e.g., the Ministry of Economy) are also de facto managers in this context, *vis-ak-vis* the irrigation agency and the price policy context.

Each manager reacts to a different set of signals in assessing the need to alter his own behavior. For instance, the irrigation agency may react to physical degradation of public canals, or farmers' refusal to pay user fees or participate in maintenance. On the other hand, the Ministry of Economy may react to price declines caused by bumper crops arising from the scheme. However, the crop price changes do not necessarily affect the incentive or accountability structure of the irrigation agency.

3. ***Farmer adoption / continued implementation.*** In deciding whether to adopt a given technology system, farmers are faced with: a) the initial design, delivery system, and set of user fees and regulations; b) their own perceptions of infrastructural support and input availability; c) their own judgement of risk involved: and d) their guess **as** to the range of probable effects of technology adoption on yields, output, and net revenue. Moreover, very importantly, the farm household compares the net return that would come from the new technology applied within a given sector (e.g., crop production) versus the potential returns on the use of its time and resources via activities in other sectors, such as off-farm activities. It is possible that farm households would not adopt profitable technologies, because they are not ***as profitable*** as alternate uses of their resources in competing sectors.

Social scientists can aid research institutions or implementation agencies or both in specifying design and off-farm management systems, assessing the probability of adoption, and monitoring its rate (see Rhoades 1984). There is an abundance of literature on the analysis of technology adoption, and I will not treat the subject here (Feder, Just, and Zilberman 1985).

4. ***Technical consequences (output, inputs).*** Once a new technology **is** installed and adopted, there will be changes in: a) yield; b) total output; c) variability of yield and output; d) average cost and net revenue; e) labor allocation and requirement; f) commodity characteristics (e.g., nutritional value); g) farmer interaction with the government: and h) farmers' information, infrastructure, market outlet, and marketed input needs. Of these changes, (a) to (d) pertain to conventionally perceived effects of technology and management system change; (e) relates to the interaction of the technology with the farm household economy (such as labor demand and supply); (f) relates to direct nutritional and marketability effects; (g) and (h) relate to changes in farmers' interaction with the economic context, off-iarm managers, and policy makers. Hence, we can group these eight effects into four categories for subsequent discussion: a) output and efficiency, b) household economy, c) embodied value, and d) external interaction.

5. ***Farm household economy / market price formation / economic andpolicy context.*** In farm household economic analysis, the focus is on the farm household as a producer and a consumer, as well as a buyer and seller of food (and nonfood crops, animals, services, etc.). Moreover, in most lessdeveloped countries' **(LDC)** contexts the rural household **is** "semisubsistence"—consuming a portion of what it produces.

Each farm household makes decisions about production, consumption, sales, and purchases based on knowledge of farmgate and consumer prices, its total income (crop sales, other revenue, plus the imputed value of home consumption), as well as other facts such as family diet needs, rainfall, and cultural demands. Decisions concerning crop output mix, and perhaps the overall level of consumption itself, depend on aggregate output, as well as purchase and sales decisions (Singh, Squire, and Strauss 1986).

The profitability of production (determined by technology and management, along with prices) is a key determinant of income. Technology itself will be chosen so as to at least maintain, and perhaps even maximize expected profit. Thus, the technology choice, via its "output and efficiency" effects, will change household income, which will in turn affect its supply and demand choices.

The adoption of technology affects output and costs, and potentially, income. Income changes affect demand and supply decisions. The aggregation of these changes over all the user households influences the price level in ways conditioned by market infrastructure, government price fixing arrangements, etc.

For example, the introduction of rice irrigation might cause a glut at the local level. If transport is available, the rice may be shipped from the region to support the market price. Eventually, increased rice export outlets may he needed to dispose of the excess. If the government supports the price, infrastructure must he present to store the crop, or consumer subsidies must be instituted to raise demand or both. In short, infrastructure, trade, price and subsidy, and market regulation policies (as well as merchant, farmer, and consumer behavior) determine the ways in which supply and demand changes will be translated into price changes.

If a crop price falls, and output and demand rise, following the adoption of a new technology, it is not clear what the fate of the farmer will be. Output increases may outweigh price falls, but then again they may not. The outcome depends on: a) the farmers' responsiveness to income changes in terms of production, consumption, sales, and purchases; h) the market's "reaction" in terms of changes in price levels to changes in demand and supply from farm households; and c) the reaction of the farmers in terms of sales and consumption behavior to the changes in incentives, or prices from the market, and to the implied real income or welfare changes.

One role of the economist is to assess the above three types of responses (in addition to illuminating reasons for the original adoption decision). Thus, the economist studies ways in which technology affects output and efficiency, income, supply and demand choices, market price formation, and household real income, all of which start a new round of demand and supply decisions. Eventually, the profitability of the technology and its management system affect real income, on- and off-farm. In this way, the outcomes of the economic analyses are crucial inputs into the assessment by managers of changes which may be needed in their systems.

6. ***Economic and welfare consequences / resource base consequences.*** Referring again to Figure 1, the price, income, and consumption effects generated directly from block **4** (technology's output/input effects), and indirectly through the interactive processes in block **5**, can affect farm ***real income,*** and nutrition levels. Moreover, commodity characteristics or "embodied value" (in block **4**), such as timing **of** harvest, nutritional quality of crop, ease of digestion, and storability, affect income timing, and nutritional adequacy. (For a discussion of technology effects on nutrition, see Pinstrup-Andersen et al. 1984.)

Technology change can also affect the resource base. For example, new practices can affect the fertility or water retentiveness **of** the soil. While these direct environmental effects may be well known, often unknown but potentially serious side-effects can also occur through interactions within the household economy. For example, intensification of monocropping or multiple cropping or both may change the fallow system (Ruthenberg 1986). Another example would be drawing labor away from traditional soil conservation activities to participate in new labor intensive technology processes.

The economist's perspective does not imply reducing complex technical, cultural, and economic interactive processes to simple calculations of profitability, and supply and demand. Within the circuit presented in Figure 1, I have related economic analysis to farmer attitudes, nutritional problems, complex intrahousehold interactions and labor allocation, and a variety of nonmarket operations.

7. ***Reassessment and adjustment.*** Economists can and should inform technology management institutions (e.g., irrigation agencies), IARCs and NARCs, policy makers, and others of the economic effects on the farm household, market price formation, and welfare of farmers — in short, profitability, economic viability of, and social welfare returns to the technology design change, and management system in place.

A key issue is the differences in the economic signals and problems on which each type **of** designer/manager focuses (Figure 1, block 2) which is determined by the different mandates, constituencies, powers, resources, and instruments associated with each. For example, LDC imgation agencies are faced, on the one hand, with budget problems and pressures to raise recurrent cost recovery. Hence, they would find it advantageous to increase the operations and maintenance cost burden on farm household **users,** either through explicit user fees, **or** the implicit fee of requiring greater participation by farmers. On the other hand, their goal is to make the irrigation system function efficiently. Efficient operation without **loss of** agency-level profitability is "the bottom line." Some analysts believe that a "public utility" arrangement might be instituted to cover costs, and increase efficiency (for a discussion of this issue, see Svendsen 1986).

Policy makers tend to be more interested in price movements, commodity gluts, market infrastructure, farmer welfare, and income distribution. At the very least, these items are usually more explicitly linked with their functi‹ ns than with those of, say, the irrigation agency. The dual challenge is : a) to ensure cost coverage and efficiency at the agency system level; and b) to ensure that regional economic policy and infrastructural environment jointly maximize the profitability of farm operations in general, and the technology management system in particular. Meeting the challenge depends on an incentive and accountability framework which takes into account household and system-level profitability, and economic analysis to inform them of the status of economic viability, in response to a given technology's impacts.

While reassessment depends on accountability and information, readjustment depends on institutional and technological flexibility, **as** well **as** cooperation. Design and management institutions need sufficient resources and administrative flexibility to test and implement changes in the systems. Moreover, there need to **he** incentives for and cooperation among the diverse actors in order to achieve changes leading to sustainability. If the technology does not contain sufficient inherent flexibility or substitutability, it may not he possible to adapt it to changing economic and physical circumstances.

CONCLUSIONS

I have discussed the need for a mutually informative and responsive relationship among farmers, technology designers and managers, economists, and policy makers, Sustainability of the technology system in the long run depends on its profitability at the farm level and the agency level. This viability is not a static measure, hut evolves with a changing set of economic outcomes involving complex interactions within the household, among households in the marketplace, and between the farm and its resource base.

Maintaining this viability depends on: I) the flexibility of the technology system, **2)** the resources, accountability, and incentives of those actors who need to adjust the system, and **3)** the availability of economic and other analyses describing these interactions, and their impact on farmers and the agency.

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MODELING FARMERS' DECISIONS TO CHANGE: USING COGNITIVE SCIENCE IN THE DESIGN OF AGRICULTURAL TECHNOLOGY

Christina H. Gladwin*

INTRODUCTION

The new technologies developed by the IARCs generally require that farmers change their farming practices and strategies, some of which have been used for generations. Often these strategies are "survival" strategies (i.e., widely-diffused plans) which farmers have developed to survive in often hostile agroclimatic and socioeconomic conditions (Barlett 1980, Bennett 1969, Gladwin 1983, Gladwin and Butler 1984). Farmers are loath to change these, and often for good reasons. The trick to the design of appropriate agricultural technologies is thus to determine ***a priori*** which farming practices will be adopted (or adapted) by local farmers, and which will not. This entails the researchers knowing a priori which of farmers' traditional practices can be changed, and which cannot because they are an integral part of farmers' "survival strategies."

Several new approaches which put the farmer at the center of the research extension project offer some hope of doing just that. These include the "farming systems" approach (CIMMYT Economics Program 1980, Collinson 1982, Hildehrand 1986) the "farmer-hack-to-farmer" approach (Rhoades 1984, 1986), and "On Farm Client-Oriented Research" (OFCOR) developed by ISNAR. The farming systems research and extension (FSR/E) approach uses multidisciplinary teams of physical and social scientists to generate new adoptable technologies via a carefully designed sequence of diagnoses, experimentation (including researcher- and farmer-managed on-farm trials), evaluation, and extension. Although the farmer is clearly at the center of the FSR/E program and makes the final decision about what to adopt or not to adopt, a persistent problem faced by even this new approach (and old philosophy) is how to get the farmers to participate more fully in the technology-generation sequence. Although philosophically the FSR/E approach starts with the farm family's constraints ***us given,*** and tries to work around them to generate recommendations to improve the family's standard of living, getting enough feedback about farmers' constraints and survival strategies during the design stage is still an elusive goal.

In my judgement, the crucial role of the social scientists in a NARC or an **IARC,** is to provide this feedback from the farmer or, more correctly, the farm family. Feedback from all family members is essential because most Third World families

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have farmers of more than one gender and more than one generation who do not necessarily have identical constraints and roles within the family farm operations (Moock 1986). Feedback of this sort has usually been through formal surveys or informal *sandoes* (Hildebrand 1981), and recent articles debate the value of one kind of survey instrument over the other (McIntire 1984, Franzel 1986).

Such debates miss the point. Rather than collect good *quantitative* data about family size, income on and off the farm, size of land holdings, and quantity of fertilizer applied, the social scientist should be trying to understand the farmers' way of life from their point of view. To "grasp the native's point of view, his relation to life, to realize his vision of his world" is the goal of ethnography (Malinowski 1922).

The ethnographer's goals in an agricultural institute and contributions to a research/extension team are twofold. The first is to understand the farm family's perfectly rational reasons for farming the way they do; and the second is to describe to biological scientists the "indigenous knowledge systems" and logic (Brokenshaw, Warren, and Werner 1980) that make some farming practices unchangeable and others changeable. The ethnographer's aim is not only to understand the meaning of native expressions that farmers use to describe their soils, their seeds, their fertilizers, or their irrigation practices, although this knowledge can be very useful (Brush, Carney, and Huaman 1981, Johnson 1974). The purpose is also to elicit the decision rules and traditional strategies that farmers use—and refuse to change—in order to survive in an increasingly bureaucratic world of government and donor agencies which wants them to ***change.***

The remainder of this paper provides examples of farmers' decision rules and strategies that I, as ethnographer-cum-agricultural economist, have elicited in Third World settings. My goal is to show the usefulness of these methods, drawn from cognitive anthropology and agricultural economics, to an agricultural institute that focuses on the farmer in the design stage, and works **for** the farmer in the extension stage.

WHY WON'T THE FARMERS ADOPT?

In 1973-1974, a study was conducted of farmers' adoption or nonadoption of the agronomic recommendations of the Puehla Project, which aimed to increase yields of rain-fed maize in Puehla, Mexico. The project, started by CIMMYT focused on one or two recommendations ahout fertilizer use and timing, and plant population for the local variety of maize. The aim of the study was to view the "Plan Puehla" through the eyes of the proposed adopters of the new technology— farmers in one representative village — and explain why ***so*** few (less than 20 percent of) farmers were adopting the Plan Puehla technologies.

The methodology **used** was the development of "decision-tree models" for each of the farmers' four decisions: to get credit for fertilizer, to increase plant population, to increase the number of fertilizer applications, and to use a recommended level of fertilizer per hectare (ha). Previous studies of the Puebla Project had lumped together all these decisions to describe why the farmers did not adopt the "package" of recommendations (Benito 1976, Moscardi 1979, Moscardi and de Janvry 1977, Villa Issa 1976). This study, however, assumed farmers could decide to adopt one agronomic recommendation without adopting the others. The decision models were developed after intensive interviews with 20 or more farmers in the village to discover their reasoning and elicit their ***perceived*** alternative and decision criteria. They were then tested in interviews with another, a separate set of 34 decision makers. The method can he understood via the following example.

The Decision to Fertilize Twice Instead of Once

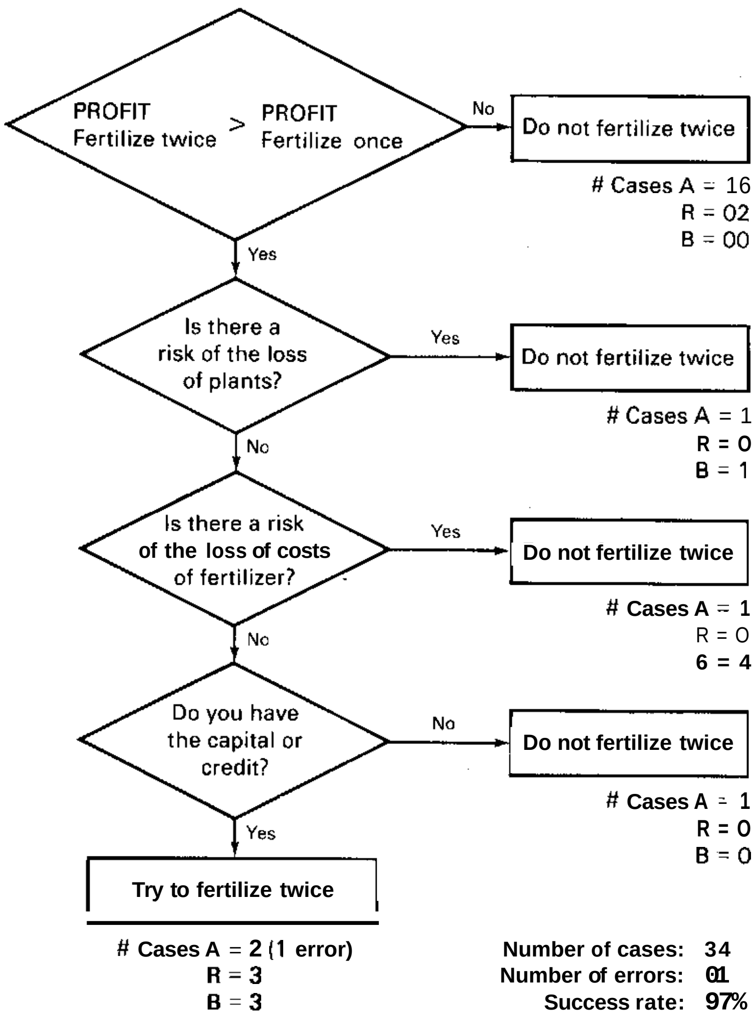
Traditionally, farmers in Puehla fertilized once, at the first weeding, which occurs when the plants are 10 to 20 centimeters (cm) high, or about **20** days after planting. The Plan Puebla, however, recommends fertilizing twice, at planting and at the second weeding, which occurs when the plants are 50 cm high or about 40 days after planting. Nevertheless, from 1973-1974, no farmer fertilized at planting in all of his fields, and few farmers fertilized at planting in one field.

The decision-tree model in Figure I was put together after interviews with 20 farmers. It is read from top to bottom, and asks each decision maker a set of questions in the diamonds about the alternative he or she has to choose in order to reach an outcome at the end of a branch. The models are hierarchical rather than linear additive as in a multiple regression analysis because it is assumed that people compare alternatives on a piecemeal basis (i.e., one dimension at a time, when making decisions).

The model in Figure I states that farmers will try to fertilize twice, at planting and at the second weeding, if they think fertilizing at planting is profitable, and they can pass constraints including the risk of losses of plants and input costs, **as** well as a capital or credit constraint. The model is a bit more complicated than shown, because the profitability criterion is itself a set of criteria of logical statements of the form: **if** you do X in a field of type **Y,** then fertilizing of planting is profitable.

These profitability criteria are different for the various types of fields in the village: type R, fields with irrigation; type **A,** fields without irrigation but with volcanic ash in the soil, which gives them enough moisture if plowed correctly after the preceding harvest so that the farmer can plant early in April; and type B. fields with sodic soils and without irrigation or moisture in April ***so*** that the farmer must wait for the first "regular" rain to plant, which may occur in April or May, but often as late as June.

Figure 1. The decision to fertilize twice: at planting and at the second weeding.



The profitability criteria for type A soils state that it is not profitable to fertilize at planting, if a farmer plants early in April "in dryness" *(en seco)* — as he should — and does the first weeding before the first regular rains come. In that case, the soil is too dry at planting to let the fertilizer (applied by hand above the ground) dissolve, so that it just sits there until the first regular rains come, and does nothing. There is no head start for the plants with fertilizer at planting for a good farmer with type A soils. (Yet most demonstrations of the Plan Puebla were in April, necessarily on type A soils; they used fertilizer at planting and lost credibility with village farmers.)

The opposite is true for type **R** and B fields, however. It is profitable to fertilize at planting in fields that are moist at planting (from irrigation or rain) because the fertilizer will dissolve at planting and give the plants a head start. Plants in type B soils, because of later planting, can use a fast start if they are to withstand the heavy rains (*los aguacerros*) that come in the middle to end of June.

Thus, the main fact limiting adoption of this recommendation was nonprofitability on type **A** soils: 16 out of 21 farmers with type **A** soils did not think it was worth while to fertilize at planting. On type R soils, three out of five farmers tried fertilizer at planting. On type B soils, the factor limiting adoption was risk of **loss** of plants or input costs. The model successfully predicts 97 percent of village farmers' decisions about fertilizing at planting.

The results of developing similar but separate decision models for the other recommendations of the Plan Puebla showed that village farmers did not use the plan's recommended level of fertilizer because it was too low, but 53 percent were on plan-sponsored credit lists. Only seven percent adopted the plant population recommendation because they did not know what the real population recommendation was, and ***no one*** adopted fertilizer at planting for two years in a row. Unfortunately, data at the regional level could not be used to test this model in the Puebla region.

WHY WON'T THE FARMERS CHANGE THEIR CROPS?

The same methodology had been used, however, in another study to help regional policy planners understand their clientele and address issues of ***regional*** importance, such **as:** farmers in the Highlands of Guatemala grow too much corn when there's too little rain for corn, and the growing season is too long. The price of corn is too low. How can we encourage them to grow and sell higher-valued cash crops and buy corn in the marketplace?

The answer to this question was the subject of a study done with the Guatemalan farming systems research and extension program at the ICTA in 1978-1979 (Gladwin 1982, 1983). The goal was to build one decision model of farmers' cropping patterns which would be generalizable to all the different agroclimatic, socioeconomic subregions or "zones" in the Highlands.

The model of the farmers' cropping decision was developed via interviews with 20 farmers in I subregion **or** zone with homogeneous agroclimatic, socioeconomic conditions. It was then tested and revised, based on interviews with another 60 farmers in the 6 different agroclimatic and socioeconomic zones. These include: 1) Totonicapan, which is the geographical and ***indigenous*** commercial center of the Highlands (Smith 1978); 2) Tecpan in Chimaltenango, the department nearest the capital city; 3) San Carlos Sija, a high-altitude region of large-scale farmers with strong Ladino (i.e., Spanish) heritage; 4) the Xela Valley near Auezaltenango, the Ladino commercial center of the Highlands (Smith 1976); 5) Almolonga, an irrigated valley in Quezaltenango; and 6) Llanos de Pinal, an area of rain-fed vegetables, also in Quezaltenango. Some of the features which distinguish the zones from one another include, altitude, average cultivated farm size, crop mix, type of off-farm labor available, socioeconomic features of inhabitants, and percent of the population which is rural, indigenous, and engaged in agriculture.

The study tested the hypothesis that *some* decision rules are ***shared*** by farmers in a geographical region, *so* that one decision model can be built for the region. If crop decisions of farmers in different agroclimatic, socioeconomic zones differ (within the region, sets of crops), the diversity is due to differences in initial agroclimatic, socioeconomic conditions, rather than differences in farmers' decision rules. In short, farmers in a region may "think" the same, but end up growing different sets of crops in different locations in the region because the agroclimatic, socioeconomic conditions within the region are location-specific.

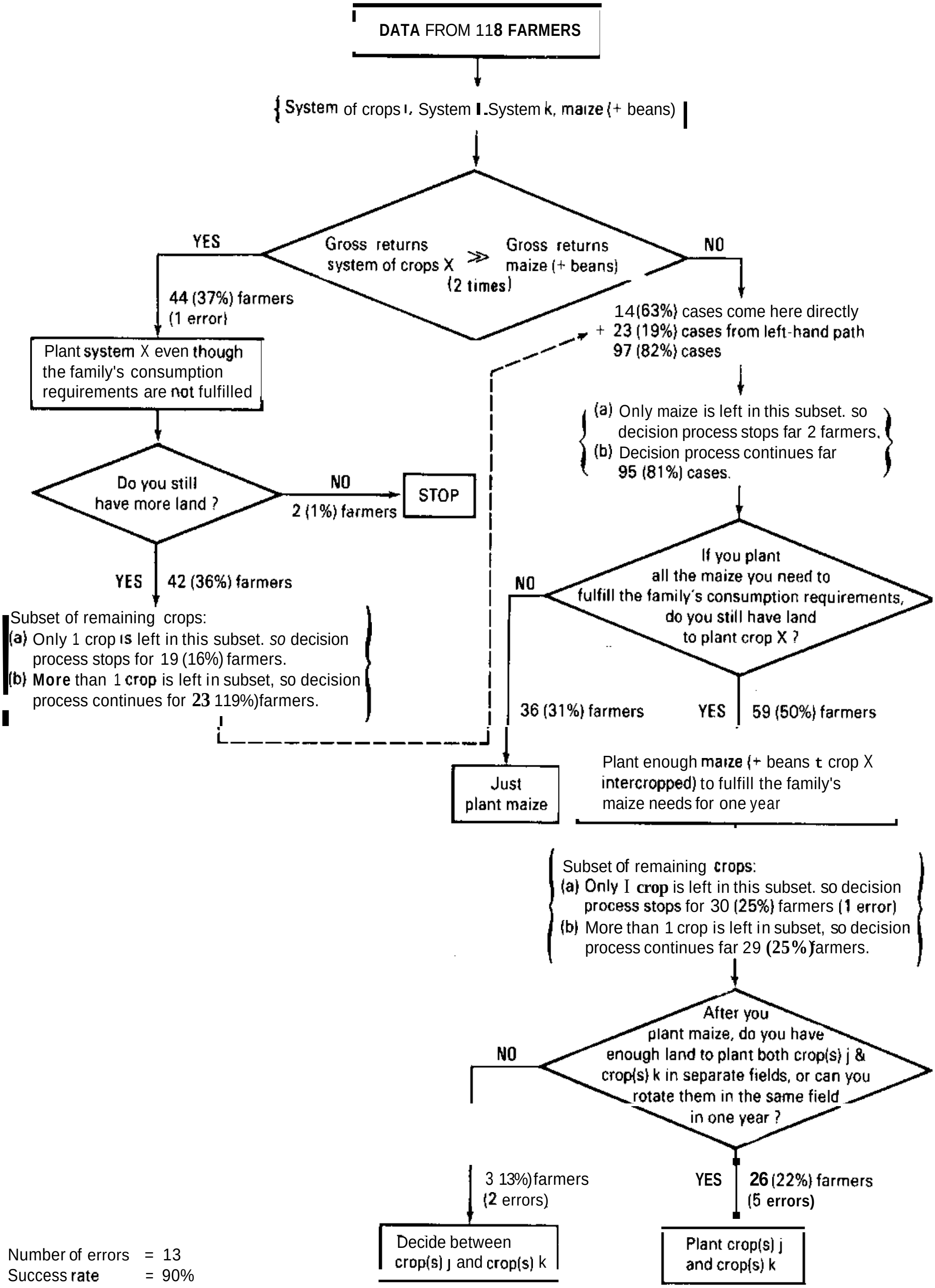
The main subroutine of the cropping decision model, described in more detail elsewhere (Gladwin 1980, 1983), is shown in Figure 2 along with the results of testing it on cropping-choice data gathered from 118 farmers in the 6 zones, As in the previous example, the model tests or processes data from each farmer independently.

The farmer's cropping decision is a two-stage choice process. In Stage 1 he **or** she first narrows down the complete set of possible crops to a feasible subset that satisfies minimal conditions. For example, given 8 to 10 different crops, a farmer may rapidly, often unconsciously, eliminate vegetables because of a lack of irrigation. He or she might not consider planting potatoes due to lack of planting knowledge **or** understanding of how to apply pesticides. Alternatively, the farmer might not think **of** growing coffee, because the land is at too high an altitude. In addition to constraints of altitude, water, and knowledge, Stage 1 criteria also include time, capital, and market demand constraints. With the smaller subset of ***feasible*** crops that emerges from this "elimination-by-aspects" stage (Tversky 1972), the farmer proceeds to Stage 2, the hard-core part of the decision process.

Stage 2 allocates the farmer's available land to the crops in the feasible subset at the top of the tree pictured in Figure 2 that pass Stage 1 constraints. If the farmer has a lot of land, Stage 2 is a simple decision process; all the crops that pass Stage 1 will he planted. If, however, the farmer does not own or operate much land, the crops that pass Stage 1 constraints compete for the little land there is, and the decision process becomes more complicated.

Criterion 1 proposes that farmers give priority to crops or systems of crops that are at least *two* times **as** profitable **as** maize, the main consumption crop. Each alternative cropping system is compared with maize because, **as** the farmers testify, "maize is first." Usually, maize is intercropped with **beans** (*frijole* and *haba*), so is written

Figure 2. Stage-2 results in six zones of the Altiplano



maize (+ beans), for brevity hereafter referred to as maize. A crop system is also defined here as crops harvested on the same field in one year (e.g., a first harvest of wheat and a second harvest of peas, or two harvests per year of potatoes, or three harvests per year of vegetables).

Very profitable crops, which may be up to five times as profitable as maize, are then "sent down" the left hand branch of the tree. Of the I18 test farmers, only **44** (37 percent) have a crop i (or system of crops i) that is twice as profitable as maize. Data from these farmers pass to the outcome "plant that crop even though you may not fulfil the family's consumption needs for maize." Farmers, thus, consider only a handful of cash crops ***so*** profitable that they will be planted before maize. These cash crops require irrigation, which exists in Almolonga, or special soil/climate conditions marked by sandy **soils,** and an afternoon cloud cover, such as occurs in Llanos de Pinal. The results show that one crop per year of rain-fed vegetables, potatoes, or wheat is not profitable enough to be planted first, before maize; they are therefore sent down the right-hand path to criterion 3.

If the farmer still operates more land after planting the very profitable crop i (criterion **2),** the model sends him or her to the consumption criterion 3 on the right-hand branch of the tree. Here the farmer is asked if he or she has enough land to plant the not-so-profitable cash crop(s) ***after*** enough maize has been planted to meet the family's consumption requirements. If there is enough land, the outcome below criterion 3 predicts maize will be planted first, before the decision of how many cash crops will be planted. (In the Highlands, people do not feel comfortable sleeping without at least ***a*** six-month supply of maize stored above their heads on rafters.)

Ninety-seven farmers proceed to the decision process on the right-hand branch 74 go directly to criterion ***3*** because they do not have a crop that passes Stage-I constraints and is twice as profitable as maize. Twenty-three cases come from the left-hand path because they have more land left after planting the twice-as-profitable-as-maize crop, and have two or more crops left in their feasible subset from Stage I. At this point the decision process stops for two farmers, because maize is the *only* crop left in the feasible subset.

Of the 95 remaining farmers, 59 (50 percent) pass the consumption constraint. They have the land to plant enough maize to fulfil their family's consumption requirements and one or more cash crops. After planting enough maize to satisfy their consumption needs between harvests, these farmers allocate their remaining fields to the cash crops that remain in their feasible subsets. Only one cash crop is left, for 30 of the 59 farmers, in the feasible subset at this point. The remaining farmers have two or more cash crops still in the feasible subset, ***so*** their decision process continues on to diversification criterion **4.**

The latter diversification decision between two or more cash crops is simple if the fanner has enough land to plant both crops. If there is not enough land and the farmer cannot rotate the crops within the year, then he or she may decide between them by trading off the profitability and risk of the cash crops. This model is presented elsewhere (Gladwin 1980). Results show that 26 of the 29 farmers with 2 feasible cash crops manage to grow both crops; or the climate and altitude are such that they can rotate the 2 crops on the same field within the year, **as** occurs in Llanos de Pinal and Tecpan.

Thirty-six of the 95 farmers on the right-hand branch of the tree fail the consumption criterion: they do not have enough land to be self-sufficient in maize and plant a cash crop. Their data are therefore sent to another subroutine presented elsewhere (Gladwin 1983), which tells them to plant only maize ***unless, .***., and then lists the relevant conditions: if cash crops can he interplanted or multicropped with maize, if land can be rented for the cash crop, if special agroclimatic conditions limit production of maize on all fanners' fields, and if the farmer needs cash badly. In those cases, the farmer will plant the cash crop even though he or she will then not be self-sufficient in maize. Exceptional circumstances include high risk dependency on the marketplace to purchase maize, lack of capital to buy maize when it's needed, or low profitability of cash crops. Three-quarters of these test cases end **up** planting a cash crop, even though it means sacrificing self-sufficiency in maize.

The decision model in Figure 2 has a 90 percent success rate (i.e., the model successfully predicts what crops, 105 of 118 farmers in the test sample plant, across the region as a whole). The results in each of the six zones show success rates ranging from 69 to 95 percent in the different zones (i.e., the model predicts ***every*** crop in the crop mix for 69 percent of the farmers in Tecpan, and for 95 percent of the farmers in Totonicpan and Llanos de Pinal). **A** Chi-square test shows that these differences are not significant, so that the assumption of ***one*** decision model for the region is not rejected.

IMPLICATIONS

Because the results consist of data collected over a region rather than only a village, they have policy implications for the highlands and can answer the question posed earlier by revolutionaries and conservative politicians alike. The counterargument to the claim that "maize is not the right crop for the highlands" is, of course, that farmers are the real experts at deciding what they should do. They know all the reasons why they should plant maize. In the subregions sampled, 60 percent of the farmers plant a cash crop only if they can first meet their consumption needs for maize, because dependence on the marketplace for a subsistence crop is risky, especially because maize is eaten **3** times a day, with no complementary foods.

Because farmers are the real experts in making cropping decisions, their **"expert** systems" (which is another name for decision trees in the field of artificial intelligence) can be used **by** policy planners to help them diversify their cropping strategies. Such diversification strategies will become more crucial in the future. As population increases and farm size decreases further, farmers in more zones will not have enough land to plant their maize consumption requirement first and a cash crop second. Because a majority of farmers will plant maize first, one diversification strategy is to increase maize yields so that more cash crops can be planted. This should prove to be the most effective diversification strategy of **all,** capable of reaching the ***majority*** of highland farmers, and obviously acceptable to the maize program at ICTA. (Some success has already been achieved in this direction, with the widespread adoption of an improved open-pollinated ICTA variety, ***San Marceno.)*** Another strategy is to introduce irrigation in more subregions, so that more twice-as-profitable-as-maize cropping systems can be planted. Results show these systems include two crops of potatoes or vegetables per year, a rotation of wheat and potatoes (or vegetables), coffee, and a monocrop of fruit trees. Few fanners perceive ***one*** crop of rain-fed vegetables **or** potatoes or wheat to be twice **as** profitable as maize; these crops are incapable of replacing maize as the "number one" crop. Another diversification strategy for farmers with very small land holdings (five ***cuerdas*** or **less)** is intercropping or multiple cropping with maize: unfortunately, knowledge of "relay crops" of "double rows" (Hildebrand **1976)** has not yet diffused widely in the highlands. But in the future, **as** population increases and farm size decreases, this strategy may be the only way farmers can diversify and, thus, raise their farm incomes.

WHEN **WILL THE** FARMERS CHANGE?

By now the reader must be wondering under what conditions will farmers change, because examples have focused on cases when farmers will *not* change their traditional farming practices. Fortunately, work with ICTA also allowed me to observe farmers who ***were*** changing their cropping strategy. This occurred when irrigation, terraces, and vegetable technology were introduced into the region of San Ramon and Santa Rita in the State of San Marcos. When these new complementary technologies were introduced, policy planners and technicians wondered whether farmers would switch to higher-valued vegetables and potatoes. If they did, would they then take land out of maize, the lower-valued subsistence crop, or wheat, also a lower-valued crop? If they did take land out of maize, the subsistence crop, what would happen to their family's consumption requirements **for** maize?

To answer these questions, the decision model described in Figure **2** above was tested on another set of **20** farmers in the San Ramon-Santa Rita region who had invested in irrigation on some of their land (with the ***mini-reigo*** project) and had also built terraces. Their cropping patterns were elicited before (in **1978)** and after (in **1979)** irrigation, terraces, and vegetable technology were introduced. Their responses to the questions in the decision model were also analyzed to predict their cropping pattern before and after irrigation.

The results show that before irrigation, the farmers on average cultivated **0.83** ha in all. On average, farmers had 0.66 ha in maize, 0.14 ha in wheat, and only 0.04 ha and 0.16 ha in potatoes and vegetables respectively. After irrigation, terraces, and vegetable technologies were introduced, farmer cultivation averaged 1.04 ha in all. On average, farmers had 0.59 ha in maize, and 0.14 ha in wheat. But **as** a **result,** they also planted 0.25 ha in vegetables, and 0.04 ha in potatoes. Clearly, in order to double- or triple-crop higher-valued vegetables on irrigated terraces, farmers took some land out of maize, the consumption crop. The overall effect of this change was that total land under cultivation increased rather than decreased.

What effect did this change have on the family's consumption requirements for maize? Of the 20 farmers sampled, half reported that they planted ***less*** maize after the change, while 40 percent reported that they planted the same .amount of subsistence maize. Was this a drastic change? Sixty-five percent of the farmers reported that the family's consumption needs were met in the year before the change, and *70* percent reported that they were also met in the year after the change to irrigated vegetables. Although farmers took some land out of subsistence maize, they did not take out enough to **risk** their family's consumption requirements for maize. In my judgement, any change to higher-valued irrigated crops must proceed in a cautious way, always mindful of the family's consumption requirements for the subsistence crop, be it maize, rice, potatoes, or cassava.

Testing the decision model in Figure 2 on this new sample of farmers resulted in a 95 percent success rate for the "hefore" decisions, and a 90 percent success rate for the "after" decisions. In the case of large-scale farmers, (av-1.3 ha) the tendency **is** to switch from wheat and maize to wheat, vegetables, potatoes, and maize; while in the case of small-scale farmers the pattern **is** to switch from maize intercropped with fruit trees to maize, vegetables, and potatoes. In both cases, farmers benefit from the introduction of irrigation and change of cropping pattern.

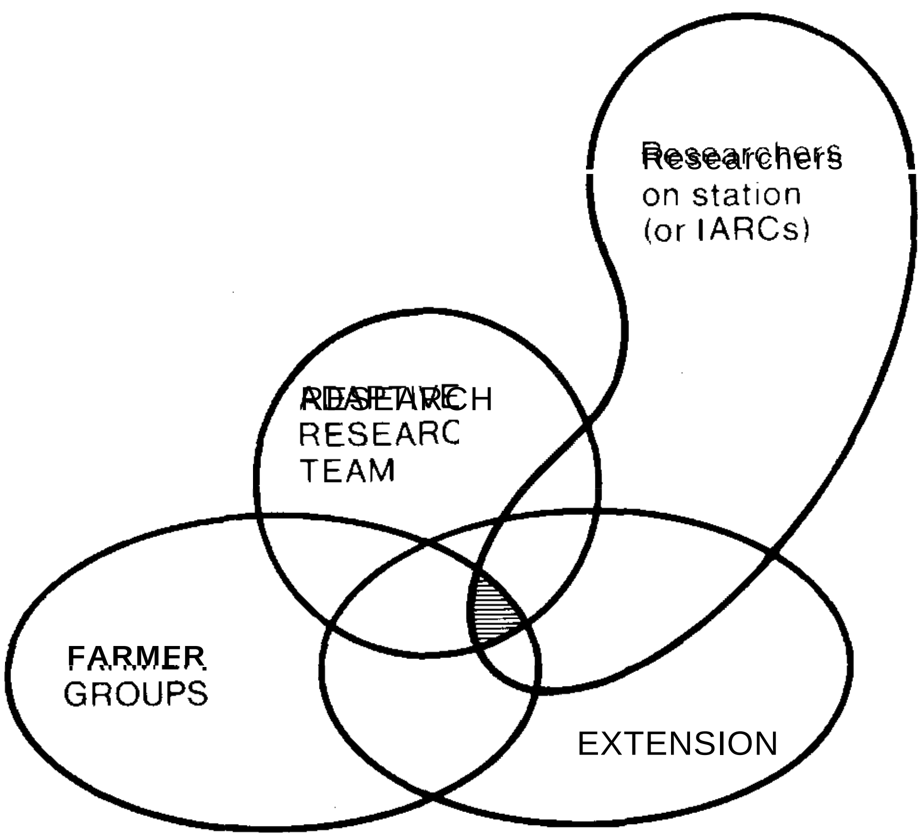
FUTURE DIRECTIONS WHY DON'T THE INSTITUTIONS CHANGE?

A **big** problem facing IARCs, whose clientele are agencies rather than farmers, and NARCs, which can employ the more direct FSR/E approach, is how to institutionalize a new approach, like the new FSR/E adaptive research team, into a Third World country with a set of separate research and extension institutions already in place. How can this be done while minimizing intra- and interinstitutional conflict (University of Florida: **FSSP** 1985)?

The change of cropping pattern in the region of San Ramon-Santa Rita in the State of San Marcos is an example of how institutions or agencies can work together for the farmer's benefit. The unusual cooperation of four agencies or institutions with farmer groups in San T/Ramon in **1979** was rare. The institutions included: ICTA, which provided the adaptive research team and vegetable technicians; DIGESA (the extension service), which provided the extension manpower and also housed the USAID donor agency research team who were experts in terraces and mini-riego (little irrigation) systems; and *Educación Extra-Escolar* (the adult education monitors) who worked with the farmer groups to make the terraces and plant the vegetables. Incredibly, all these teams worked together to bring a twice-as-profitable-as-maize cropping system to farmers in this region.

Figure 3 shows why cooperation is rare among institutions each of which tries to put the farmer at the center of its work: the common core of interest among all four sets of activities representing all the work of all the institutions is a very small set indeed. Yet workers in the four institutions are all doing their work energetically. The moral of this story is that institutions, like farmers, do not change because they have pressures imposed on them from the outside. Like farmers, they have developed "survival strategies" to allow them to survive in an often-hostile environment. Research on institutional decision-making processes and strategies is needed to identify the conditions under which institutional change is possible.

Figure 3. Cooperation among researchers, adaptive research teams, farmer groups, and extension agents.



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AFTER THE GREEN REVOLUTION: TECHNICAL CHANGE IN BEAN PRODUCTION IN COLOMBIA, COSTA RICA, AND GUATEMALA

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Although the "Green Revolution" fertilizer-responsive rice and wheat varieties had a major impact on production, their impact was controversial because of concerns about the accessibility of these technologies to poor farmers. This was due to the technical characteristics of the new varieties as well as the socioeconomic context in which they were released (Frankel 1971, Griffin 1975, Lipton and Longhurst 1985).

Particularly problematic was the need for complementary inputs of fertilizer and crop protection chemicals. It was feared that these essential inputs imposed a capital requirement that could put the new technologies outside the reach of many poor farmers, especially those producing principally for subsistence. Moreover, imperfections in the institutional delivery of credit permitted wealthier and more influential farmers to overcome capital constraints when small-scale farmers could not. The better-off farmers also had preferential access to sources of improved seeds and other inputs as well as to information on the management of the new varieties that was critical to their use.

The adoption of the new varieties by small-scale farmers was also impeded by the greater exposure to risk entailed in their cultivation. This was due both to greater capital investment and to increased susceptibility to disease and insects. Lastly, the new varieties were selected for performance in favored conditions of high fertility and timely irrigation, situations that often failed to correspond to the reality faced by small-scale farmers.

Recognition of this situation by the IARCs led to the search for more appropriate technologies adapted to the problems and resources of small-scale producers. Three guidelines were followed to achieve this goal higher priority for crops produced in less-favored environments, increased attention to stress resistance, and greater emphasis on farming systems research.

Agricultural research priorities were directed more toward crops grown principally by poor farmers and towards disadvantaged regions. This resulted in greater attention to such crops as beans, cowpea, cassava, millet, upland rice, and sorghum. These are all produced primarily by resource-poor farmers in developing countries, and they are more important where climatic and fertility conditions are less favorable.

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Second, greater effort was placed on improving the stress resistance of crops, instead of focusing single-mindedly on maximum yield potential. Selection of genetic material with superior resistances to diseases, insects, drought, and adaptation to poor soils, would reduce both the dependence on agrochemicals outside the reach of poor farmers and lead to a more secure and stable production and food supply, thereby contributing to poor farmers' risk-avoidance objectives.

Third, farming systems or on-farm research were developed as a research strategy explicitly to tailor agricultural technology of the particular needs of resource-poor farmers by taking fully into account the need to develop technology compatible with farmers' current systems, testing new technology under actual conditions that farmers face, and evaluating technology on the basis of actual farmer decision criteria.

THE CIAT BEAN PROGRAM

When the Bean Program was initiated at CIAT in 1973, there was a clear awareness that demand for crop improvement technology varied according to distinct target groups. Although in Brazil and Mexico — the two leading bean producers -- more than half the total bean production came from small farms, there was also a significant sector of large commercial bean growers producing principally in mechanized monoculture. often with irrigation, and underfavored fertility conditions. For such producers, high yield potential and an erect mechanizable plant type would be obvious research priorities.

The CIAT Bean Program opted for a strategy focused on technology suitable for small-scale resource-poor farmers. This target group was selected, because it comprised the principal source of bean production, and because CIAT has emphasized equity objectives (see Lynam 1985 for a discussion of trade-offs inherent in this decision). The Bean Program's research strategy is derived from what was understood to be the characteristics of this target group. Small-scale farmers were seen to produce beans under rain-fed conditions, often on poor soils, without the use of either chemical fertilizers or crop protection chemicals, and frequently in complex associations or intercrops with other crops. These perceptions of the resource-poor bean farmers' situation, coupled with an awareness of the susceptibility of beans to a wide range of pathogens led to the decision to concentrate on breeding low-input disease-resistant varieties rather than high-yielding varieties.

Breeding was chosen as the central focus of the Bean Program because technical change embodied in the seeds of improved varieties is more easily transferred to resource-poor farmers than, for example, a technology based on fertilizers or other agrochemicals. The central core of the CIAT Bean Program involves a group of plant breeders and pathologists working to identify parental material with sources of disease resistance. A large number of recombinations are made with those sources, and selection from early generation populations onwards (F3 or **F4)** are typically made not at CIAT, but decentralized to national programs so that selection pressures are closer to actual farmer conditions. Therefore, the Bean Program does not produce and release varieties, but provides specific genetic variability to national programs for local selection and varietal release. Regional trials and on-farm research with a strong element of socioeconomic evaluation ensure that advanced lines are evaluated in farmers' production systems and based on farmers' criteria.

Consequently beans were selected for disease and pest resistance under high disease pressure without any chemical control. Varieties were selected without irrigation and were not selected for response to high fertility. Moreover, breeding was carried out for a wide range of architectural types adapted to various cropping systems (e.g., climbing beans in association or in relay with maize) with little attention to developing mechanizable plant types (CIAT 1981a).

This strategy was expected to generate varieties of improved disease resistance. thereby responding to the resource-poor farmers' risk avoidance objectives without requiring any increase in agrochemical use. It was also expected to remain feasible for capital-constrained poor farmers and suitable for use in farmers' current production systems. New bean technology was to be carefully tailored to small-scale farmer objectives within the context of their existing production systems without requiring major management changes. It was thought that once farmers had more stable disease-resistant varieties with less **risk,** they would be encouraged to adapt more intensive management as **a** second level of technical change.

CASE STUDIES OF THREE COUNTRIES

A large number of improved bean varieties have been released by national programs in collaboration with CIAT. Analysis of the acceptance of some of these bean varieties provides a basis for assessing the success of the post-Green Revolution strategy for improved technology. Case studies of adoption will be reviewed to: 1) assess the degree to which it has been possible to adapt the characteristics of technology to the needs of resource-poor farmers, **2)** consider the relation between adoption of new varieties and changes in farm management, and 3) re-examine the socioeconomic and institutional factors conditioning opportunities for technical change.

Case studies are presented from three countries where improved bean varieties were released for major small-holder areas. The Costa Rican study is based on survey data from the Rio General watershed, the country's main bean producing region. The region supplies 33 percent of the total output of the country. Of the farmers in the region, **43** percent have less than 10 hectares (ha) of land and **84** percent have **less** than 50 ha of land (Pachico and Borbon 1986). The Guatemalan study is based on survey data from the southeast Jutiapa-Jalapa area. This is the country's main bean region, accounting for about one-fifth of the national production. Three-quarters of that country's bean farms are under 6.5 ha (Viana and Pachico 1985). The Colombian case study is based on survey data from eastern Antioquia, the country's main bean region, which contributes about one-third of the national bean production. Farms average 4.4 ha (Ruiz de Londono, Pinstrup-Andersen, Sanders, and Infante 1978).

Costa Ricn

The tapado system. Until quite recently beans in Costa Rica were produced principally in a shifting cultivation system called *Tapado* (covered beans), little changed from pre-Colombian times (Chapman, Martinez, Ammour, Caso, and Cuvi 1983). Under this system, seeds are broadcast into bush fallow. Then the weeds are chopped down to cover the seed and the crop is left unattended until harvest. This system has the advantage of enabling farmers to produce their subsistence requirement for beans with no cash costs and very low labor input (Ballestero 1985). Moreover, the mulch provided by the weeding cover reduces the incidence of web blight (*Thanatephorus cucumeris*), the major disease in the humid conditions of Costa Rica (Galindo, Abawi, Thurston, and Galvaz 1983). The mulch also provides ground cover to impede erosion.

Production under this system did not suffice, however, to meet the demands of Costa Rica's rapidly growing urban population, so the country depended on imports for 48 percent of bean consumption in the period 1970-1983 (Stewart 1984). Moreover, the sustainability of the system is critically related to an ample supply of low-opportunity-cost land. Not only are bean yields low, but land use is extensive, involving fallow periods of at least 2 years between crops for 83 percent of the farmers, and 3 or more years for 32 percent of the farmers (Pachico and Borbon 1986). The fallow periods are needed to permit the growth of the weed cover, restore soil fertility, and reduce the build up of populations of bean pathogens.

The tapado system does not respond well to a single type of management intensification because of the multiple stresses the system faces. For example, due to the broadcast seeding method which does not include incorporation into the soil, germination is highly erratic and plant population frequently low (Quiros and Araya 1986), thereby making agrochemical application uneconomic. Likewise, the total lack of weed control undermines the viability of fertilizer application because the improved fertility will contribute to more vigorous weed growth. Thus, the marginal productivity of any single input is low because the mean levels of all complementary inputs are also low.

The poor land productivity and the low returns to marginal intensification with the tapado system are increasingly problematic, particularly for small holders. Only 16 percent of farmers with less than 10 ha report having enough land to maintain the fallow rotation for tapado, compared to 50 percent among the farmers with 10-50 ha, and 88 percent among farmers with more than 50 ha (Pachico and Borbon 1986).

New varieties. Technical change in agriculture depends on institutional innovation, and this has certainly been the case with beans in Costa Rica. A key innovation occurred in 1978 with the formation of an integrated program of research and technology transfer. The rapid achievement of widespread adoption of new varieties has been intimately linked to a coordinated set of institutional services. The Ministry of Agriculture (MAG) and the University of Costa Rica have worked on breeding and varietal selection, and MAG with the National Production Council (CNP), conducts on-farm trials; in addition, MAG undertakes extension and CNP produces and distributes the improved seed while guaranteeing farmers a market at a fixed price for their entire production.

The Costa Rican National Bean Program followed the disease-resistance breeding strategy discussed above, and in 1981 released *Talamanca*, the first improved variety selected for web blight tolerance, a line originally developed by the ICA in Colombia. By 1985, this variety and other products of the same program covered an estimated 63 percent of the area planted to beans in Costa Rica (CNP 1986). The combination of improved disease resistance and more upright architecture which reduces damage to pods in humid conditions permitted farmers to obtain average yields of 586 kilogram (kg)/ha with the new varieties, versus 488 kg/ha with traditional varieties in the tapado system with no management changes.

The espequeado system. Even more attractive for farmers, especially for small holders, has been the practice of combining the new varieties with a more intensive management system. In the late 1970s a few farmers were using the espequeado (digging stick) system under which land is usually prepared by hoe or oxen, the beans are planted with a digging stick, the crop is weeded by hand, chemical fertilizers are applied, and plants are sprayed to control diseases or insects.

In the early 1980s this system began to spread rapidly, especially among small-scale farmers (Borbon 1984). On farms less than 10 ha, 57 percent of the bean area is now under espequeado compared to 41 percent on farms over 10 ha. Small-scale farmers get higher returns for their scarce land holdings not only because bean yields are higher under espequeado, hut also because they can use more intensive land rotations, with nearly three-fifths of the farmers getting two crops annually — usually, beans first, and then maize — for at least two consecutive years (Pachico and Borbon 1986).

The diffusion of the improved varieties has accelerated the spread of the espequeado systems. The productivity gain in shifting from tapado to espequeado is modest with the local varieties (from 488 to 719 kg/ha), but very high with the improved varieties (from 586 to 1,103 kg/ha). Combining a change in system with the adoption of new varieties triples net returns per hectare while the rates of return on capital doubles. Consequently, over 80 percent of the area under the more intensive espequeado system is planted with improved varieties.

Combining characteristics of the tapado and espequeado systems to achieve an integrated control of web blight has recently emerged as an important new line of research in Costa Rica. This system has the tapado feature of making a mulch from the existing weed cover, but uses a more orderly labor-intensive sowing by digging stick, and follows up with weed control and fungicide applications. The combinations of improved resistant varieties, mulch and fungicide applications provide a more effective control of disease.

Thus, in Costa Rica the new varieties have been adopted by resource-poor farmers, and are widely grown in traditional management systems. However, with more intensive management the varieties are even more favorable to small-scale farmers. Crucial to the rapid spread of the new varieties has been an effective coordinated effort of on-farm research, extension, seed distribution, and marketing.

Guatemala

The selection of improved disease-resistant varieties adapted to small-scale farmer conditions has been the goal of bean research by ICTA and an extensive and effective system of on-farm trials has been a key part of ICTA methodology. Thus, in 1979 new varieties (*Quetzal, Tamazulapa*) with improved resistance to bean golden mosaic virus (BGMV) were released for use in southeastern Guatemala.

Subsequent surveys of farmers show mixed success. Farmers are growing the improved varieties across a range of systems (monoculture or in associations, with maize or sorghum or both), and in all systems obtain higher yields with the new varieties than with local varieties, without any changes in management (Table I).

Table I. Yields and adoption of improved bean varieties, southeastern Guatemala, 1985.

System	Yields		Farmers adopting improved varieties (%)
	Improved varieties (kg/ha)	Local varieties (kg/ha)	
Bean monoculture	1143	906	28.4
Maize/beans	975	801	20.8
Maize/sorghum/beans	989	640	17.9
All[a]	1025	771	23.4

[a]Includes other systems.

Farmers experienced in growing the new varieties rate them highly compared to traditional varieties in yield, disease resistance, and architecture (more upright, better pod quality), while they see no differences in adaptation to associated cropping or fertility needs (Table 2).

Table 2. Farmer evaluations of improved bean varieties in comparison with local varieties, southeastern Guatemala 1985.

Characteristics of improved variety	Farmer evaluation (%)		
	Better	Same	Worse
Yield	65.4	26.9	7.7
Architecture	59.7	33.8	6.5
Disease resistance	45.5	48.1	6.5
Consumption quality	16.9	72.7	10.4
Adaptation to association cropping	6.5	71.9	15.6
Adaptation to low fertility	0.0	93.5	6.5
Time maturity	15.6	58.4	26.0
Drought tolerance	1.3	77.9	20.8

Despite these findings, the use of new bean varieties in southeastern Guatemala still remains limited seven years after their release (Table 1). Farmer evaluations of the new varieties indicate that time to maturity and drought resistance are the most frequently cited unfavorable characteristics of the new varieties (Table 2). These characteristics are related, because early maturity is an escape mechanism to avoid the risk of drought stress caused by premature ending of the rains. Due to this problem, even farmers who grow the improved varieties usually sow them only on part of their bean area (Viana and Pachico 1985). The favored strategy of farmers is to sow part of their land with the new varieties to take advantage of their higher yield potential, while also planting an early-maturing variety as security against drought.

Due to these characteristics of the technology, the new varieties can be expected to gain only a partial acceptance even among adopting farmers. However, most farmers do not grow the new varieties at all. Among farmers who try the new varieties, as many as 30 percent stop growing them within 2 years (Viana and Pachico 1985). While 32 percent of farmers surveyed report that they are dissatisfied with the lateness of the new varieties, 58 percent claim that they would like to continue to grow the new varieties but are unable to obtain seed. Due to short-term exigencies like the need for cash or a food shortage, many small-scale farmers are obligated to sell or consume their seed stock, while others lose their seed in storage. Because there is no formal system of bean seed distribution in Guatemala, these farmers cannot easily re-obtain the seed of improved varieties.

Many farmers have never even heard of the new varieties. Insufficient resources have limited extension, which is currently undergoing a major strengthening accompanied by greatly increased expenditures. (Fumagalli, Ortiz, and Castillo 1985). While farmers **are** not solely dependent on extension for access to new technology, the proportion of farmers reached by extension with the new technology **(10.2** percent) may he too small to provide the critical mass needed for effective farmer-to-farmer spread. Another factor in the slow diffusion of the new varieties may be their extended maturity and hence, decreased profitability.

In the case of Guatemala the strategy of disseminating new varieties selected for disease resistance without provision of an accompanying management change, has led to partial adoption among a minority of farmers. The success of the strategy has been limited by a combination of lateness of the new variety, and shortcomings in institutional support for seeds and extension.

Colombia

The strategy of developing disease-resistant varieties adapted to farmers' current production systems has also been tried in Colombia, and has led to the release **by** ICA in 1982 of the variety ***Llanogrande.*** This variety was selected for its anthracnose ***(Collectotrichum lindemuthianum)*** resistance and its less-vigorous growth which should reduce lodging when relay planted with maize. The variety was evaluated in on-farm trials conducted in eastern Antioquia, Colombia.

Two management changes accompanied the testing of the improved variety. First, because of its increased disease resistance, the number of sprayings with fungicide was reduced from the normal farmer practice of five applications to only two applications, thereby reducing production costs. Second, due to the less-vigorous growth of Llanogrande, it was sown at **a** higher density. In 1981 on-farm trials in Antioquia, the new variety outfielded the local variety **2,063** kg/ha to **1,638** kg/ha, leading to a **12** percent increase in net returns per hectare despite having a lower market price than the local variety (CIAT 1981b).

Two years after the release of the variety, however, farm surveys in Antioquia, found that it was grown by only **2** percent of farmers, and only 10 percent had ever heard of it (van Herpen, Borbon, Guerrero, and Viana 1984). To evaluate this situation more fully, a sample of fanners known to have received the seed for the new variety was surveyed. Of the farmers who had tried the new variety, 64 percent had no desire to grow it again, and **23** percent intended to grow only a few plants of the new variety for home consumption (Ruiz de Londono 1985). This was a surprising response in an area where beans are the principal commercial crop for small-scale farmers. Three management factors were identified as key in restricting the acceptability of the new variety.

First, farmers were not aware of the recommendation to plant the new variety at an increased density. At the low-planting density at which farmers normally grow their local variety, the new variety appeared weak, and 86 percent termed its yield low. Moreover, 32 percent considered the variety so lacking in vigor that they thought it was a bush bean, not a climbing type which is preferred in the region for the maize-bean relay.

Second, farmers were reluctant to reduce frequency of fungicide applications, and therefore did not enjoy the decrease in production costs projected to come from the variety's improved disease resistance. Small-scale farmers in Antioquia have become so accustomed to frequent fungicide applications to protect their high-value commercial bean crop that they were quite unwilling to entertain the suggestion that they could reduce fungicide costs and rely on genetic resistance. Farmers were willing to pay the price of fungicides for peace of mind.

Third, in the market-oriented context of Antioquia, farmers were loath to shift from the premium-priced, highly preferred, and easily marketed traditional variety to a new variety that had a low price and less ease of market access. Adoption problems occurred because the variety was not more productive than traditional varieties in farmers' current systems without changes in management.

CONCLUSIONS

These studies are being followed by similar examinations of technology diffusion in Peru, Brazil, and Colombia. The purpose is to develop a broader understanding of the impact of the disease-resistance improvement strategy. The evidence thus far suggests that improved technology can increase productivity even for small-scale farmers in marginal, high-stress conditions. New varieties can be developed that raise productivity in farmers' existing production systems without requiring management intensification. Such seems to have been the case in the tapado system in Costa Rica, as well as in the mixed cropping systems in southeastern Guatemala.

However, responsiveness to intensified management, far from being a disadvantage to resource-poor farmers, may in some cases be a positive attraction, as with the espequeado system in Costa Rica. When small-scale farmers are well integrated into the market system, they may be quite disposed to intensify both labor and capital use in order to raise returns to scarce land (see, for example, Ashby and Pachico 1983, Pachico 1984). Though some success is evident in the generation of low-management, low-input improved varieties for small-scale farmers, it is unclear whether this strategy will continue to meet the needs of the bulk of small-scale farmers in Latin America today as an increasing number of them use agrochemicals (Pachico and Borbon 1986, Viana and Pachico 1985).

These case studies also illustrate how the impact of new technology is crucially related to the effectiveness of the delivery of a number of ancillary services, such as seed production and distribution, marketing outlets, extension, and on-farm research. The efficiency of these services has undoubtedly contributed to rapid technical change in Costa Rica (and seems to have limited the exploitation of the full potential of new varieties in Guatemala). Institutional factors have also impeded the development and diffusion of improved varieties in Antioquia. In on-farm research the evaluation of the new variety did not fully take into account the farmers' perspective, while the fact that the extension recommendation of a higher planting density did not reach the farmer, certainly depressed the chances of the new variety.

There are important limits to what can be done with breeding technology alone, without investment in infrastructure, adequate extension, on-farm trials, seed distribution, and access to markets. Institutional factors make transfer of new technology to small-scale farmers particularly difficult. The data from Guatemala imply that some 4,200 farmers have adopted the new varieties on 3,700 ha. In contrast, in Argentina some 1,000 farmers, constituting 85 percent of the country's bean farmers, are estimated to have cultivated 42,000 ha with new bean varieties in 1985 (Garguilo 1986). Clearly, there are lower costs in extending new varieties to a few large-scale farmers in Argentina than to many small-scale farmers in Guatemala and the impact on production has been 10 times greater in Argentina, even though only one-fourth as many farmers have adopted new varieties.

The development of improved technologies for small farm systems is a difficult and resource-intensive endeavor. Though gains can be made, there are stringent stresses to he overcome, and required solutions must often be tailored to highly specific biotic and socioeconomic circumstances. The new breeding strategy of a disease-resistance focus for small-scale farmers in marginal areas entails major challenges and is unlikely to show the massive, widespread, rapid impact characteristic of the semidwarf rice and wheat varieties. However, the case studies outlined in this paper show clear signs of progress which can sometimes be dramatic as in the case of Costa Rica where bean production has nearly doubled in the 1980s.

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RECENT TRENDS IN SMALL FARMER INPUT USE IN ANDEAN AMERICA

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One of the main goals of IARCs is to develop crop technologies that will help small farmers improve their agricultural production. Since the 1970s the integrating philosophy for small farmer-oriented research in the Andean, countries (Bolivia. Colombia, Ecuador, and Peru) had been the "minimum-input approach." Reduced to its essentials, the argument underlying the "minimum-input" orientation is that small farmers, generally defined as those holding less than 20 hectares (ha), either cannot or will not use expensive, complex technological packages. As a result, research centers hoping to reach this group have assumed that these farmers in particular will not be handling large amounts of fertilizers, pesticides. herbicides, etc.. although they may invest in improved seeds. Thus, in their breeding programs, the centers prefer to select stress-resistant. high-yielding varieties that do not rely heavily on purchased inputs to realize their genetic potential (Nickel 1985).

This paper attempts to show that the "small farmer" concept built into the minimum-input approach suffers from severe difficulties. On a conceptual basis. the small farmer concept lumps together disparate Socioeconomic groups. Close examination of data which are used to justify generalizations about small farmers reveals that these are not solidly grounded. A review of the same quantitative sources upon which the minimum-input argument was developed shows that small farmers no longer significantly lag behind other classes of larmers when it comes to adopting inputs. Changes in the small farmers' socioeconomic situation since the minimum-input approach was first formulated have resulted in small farmers becoming familiar with agricultural inputs. Many Andean smal! farmers purchase and use chemical fertilizers. and include fertilizer costs and benefits in their agricultural calculus. As this study will show, small farmers are not necessarily well served by the minimum-input assumptions: there is a danger of turning the minimum-input assumptions into self-fulfilling prophecies.

The conflicting evidence presented in this paper about small farmers' input use practice points to the need for finer categories and better information in order to make research policy more effective. Strong arguments in favor of a minimum-input approach remain. even if some of its premises are no longer correct. The direction that is suggested here is towards re-assessing the empirical evidence about small farmer input use to allow breeding programs to respond better to the diversity of technology types demanded by small farmers.

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BACKGROUND TO THE PROBLEM

The basic parameters **of** Andean agriculture have undergone tremendous change since the years when the minimum-input approach was first conceived (Lope7 **1982).** If the trend towards modernizing agriculture in these countries is clear. however, the role of the small farmer in this changing agriculture is not. Three general questions are relevant here. First. how do small farmers fit into the overall configuration **of** Latin American agriculture? Second. what role do purchased inputs play in changed production patterns within the Andean countries? Third, and most important for the purposes of this paper, to what extent are small farmers taking advantage of new agricultural technologies'?

Despite the predominance of large landowners in the export sector, the importance of improving the social and economic lot of small farmers cannot be overstalcd. The place of small farmers in national agricultural production in Colombia, Ecuador, and Peru can be seen in Table I. Although they do not possess more than 20 percent of the land arta in any country, **small** farmers produce most of their nation's food. and food security is a fundamental issue in all Latin American nations.

Table **I.** Contribution of small farms (< **20** ha) as percentage of national food crop production.

Crop	Colombia **(1983)**	Ecuador **(1974)**	Peru **(1972)**
Maize	**85**	**40**	**60**
Wheat	**93**	**49**	**82**
Barley	**65**	**68**	**81**
Beans	**94**	**75**	**74**
Potatoes	**89**	**60**	**73**
Caasava	**60**	**45**	**77**
Plantains	**50**	**31**	**74**
Vegetables	**80**	**78**	n.d.[a]
Coffee	**80**	**49**	**55**
Rice	**12**	**43**	**41**

"No data

Sources: **Colombia** — *Caja de Credito Agrario, Industrial, y Minero. Depto. de Semillas* ***1984.***
DRI-PAN *Diagnostico del Sector Campesino* 1981
Ecuador — II *Censo Agropecuario Nacional* 1974.
Peru — II *Censo Agropecuario Nacional 1972.*

The sheer number of small farmers in Andean America further ensures their continued importance to any agricultural development program. Although recent decades have seen the role of agriculture in the Andean countries diminish notably.

to approximately 50 percent of the total economically active population, agriculture remains the dominant source of income. In addition, despite a decline in the relative importance of agricultural occupations in the overall workforce, the absolute number of agricultural workers continues to increase: between 1960 and 1970, more than 850,000 agricultural workers and their families were added to the population of the four countries.

The growing number of agricultural workers vastly exceeds the number of colonists who are opening up new lands on the tropical frontiers. Although some additional lands have become available to rural workers because of the various land reform programs implemented over the past three decades, both quantitative and qualitative research suggests that land redistribution programs have not made a notable difference in patterns of overall land distribution: the semilandless and small farmers continue to make up the bulk of the farm population in Andean America.

Population pressure on farms translates into threatening patterns of soil erosion and declines in soil fertility. At the same time, increased social and economic integration with urban centers has created strong pressures to individualize farming and maximize short-term profits. Slash-and-burn farming with long fallow periods, sectorial rotation systems, community-based infrastructural management, and integrated cropping systems that replenish depleted soils no longer provide the same regenerative capacity they once did. Throughout Andean America, farmers must compensate for declining soil fertility and dropping man/land ratios through land-use intensification.

The research focus of this paper is on one particular way that farmers are intensifying agricultural production: through the use of chemical fertilizers. The aggregate evidence shows that purchased fertilizers have played a key role in augmenting the region's agricultural productivity. Lynam (1981), for example, found that for the period 1960-1980 increased fertilizer adoption was the single most important factor in explaining greater agricultural productivity. Fertilizer consumption rates per hectare also rose markedly over these two decades, most notably in Colombia and Ecuador, where average weight per area increases registered 22 percent in Colombia and 17 percent in Ecuador. Fertilizer consumption skyrocketed in certain crops (especially export crops but also staples such as rice and potatoes), with increases of 100 percent or more. This occurred in the face of considerable real price increases during that period.'

The farm-level reasons for many of these changes are not hard to find. In addition to the negative impetus provided by decreasing soil fertility, positive factors have pulled farmers towards increased input use. The rapid growth of urban demand and international agricultural exports have given farmers of all sizes new incentives to expand production. Changes in patterns of land tenure apparently have removed disincentives for landlords and tenants alike, while increased contact with the media stimulated farmers to produce surpluses that they can use to buy televisions, educate children, and redecorate houses. Improved internal communications, most notably more roads and enhanced rural marketing systems, have greatly facilitated agricultural modernization; farmers formerly too remote from urban markets can now purchase agricultural inputs without paying tremendous transportation costs. More important, they can profitably grow the highly perishable crops that show some of the greatest returns to input use. Case studies, such as USAID's (1979) analysis of a rural road-building project which found extensive input adoption one year after roads were completed, illustrate the role of infrastructural development in fostering new forms of agricultural production. In many areas of Andean America, simply the improvements in roads have made market-oriented production a viable proposition.

To sum up, production possibilities and practices have changed enormously in the past three decades. Agriculture has become increasingly infused by market-derived and market-oriented production strategies. The result has been a steady rise in yields, an increased emphasis on efficient production, and notable changes in production techniques, among them a sharp rise in the use of fertilizers. The following section discusses the extent to which small farmers are participating in these changes.

WILL SMALL FARMERS ADOPT INPUTS?

Even though overall infrastructural improvements in the Andes have made commercial agriculture more attractive at the same time that ecological and market developments have made it more necessary, there are good reasons to think that small farmers have not embraced high-input agriculture with great enthusiasm. Common wisdom holds that agricultural modernization is inevitably biased towards larger farmers. Improved seeds, increased input use, mechanization; and better technical supervision are changes best used by those best positioned to take advantage of them: the well-off, well-educated, cash crop-oriented farmers. Several theories of rural development suggest that small farmers are unlikely to benefit from these improvements, either because technology appropriate to their needs is not available, or for frequently cited reasons that range from risk-avoidance to cultural conservatism, small farmers will not adopt modern agricultural techniques. Other models of agricultural development focused on the structural obstacles that prevent small farmers from modernizing their farms: rigid factor markets and archaic land tenure systems expose small farmers to greater risks and fewer incentives (Griffin 1975).

The belief that small farmers would not or could not accept high-input crop varieties was bolstered by certain field experiencces. One response to this, developed in the 1970s by several CGIAR centers, was the "minimum-input" approach towards research aimed at the small farmers whom they hoped to reach through crop improvement programs. By concentrating on genetic improvement rather than synergistic technological packages, risk-averse small farmers could still benefit from technology research, without incurring discouraging bills for chemical supplies.

How valid is the assumption that small farmers will not use inputs? Although this paper investigates this question at a macroscopic level, the impetus accrues from a number of field studies carried out by the social scientists attached to the IFDC/CIAT Phosphorus Project. Studies of small farmers in Boyaca and Narino (Colombia) showed that there is no intrinsic reason for small farmers to resist input use; farmers in these areas would apply 1.5 tons or more of N-P-K fertilizers/ha, and government extension agents were more concerned with getting these high-altitude. high-velocity farmers to reduce input use than with replacing archaic technology. Diagnostic studies in Dagua and Pescador (Colombia), and Imbabura (Ecuador), showed that while, in general terms, farming systems historically avoided input use in favor of low-risk production strategies, certain crops, such as tomatoes, would burst upon the agricultural scene, doused with sufficient fertilizers and pesticides to bring a smile to the face of the dourest input supply salesman.

Case studies from Andean America (Brush 1976, Goldstein 1984, Guggenheim 1986a and b, Guillet 1981) show that small farm systems are characterized by crop diversity with corresponding fertilizer practices. Thus, the ***same*** farmer is likely to grow heavily fertilized crops and crops that he does not fertilize at all. Furthermore. a considerable number of field studies report rapidly rising levels of fertilizer use by small farmers throughout the Andes (see Ashby and Guggenheim 1987, for a review of this literature).

These field studies underscore an additional relevant point: small farmers do not use purchased inputs in the same ways that larger farmers do. Whereas larger farmers plan primarily in terms of monoculture and immediate returns, for small farmers the residual and associative effects of crops are often as important as their direct benefits. Thus, for example, researchers working in highland Colombia found that farmers had recently moved peas out of the unfertilized maize-pea-squash-broad bean cropping system into an association with the heavily fertilized potatoes (Guggenheim 1986b). In a similar effort to capture secondary fertilizer benefits, small farmer crop rotations in Dagua, Colombia, shifted from the highly diverse cropping system characteristic of swidden agriculture in the medium-altitude Andes to a stricter tomato-bean rotation in order to eliminate direct input applications to their beans (Guggenheim 1986a). In both cases, while small farmers were quite explicit about using associations and rotations to provide inputs needed by their major crops, neither censuses nor surveys revealed fertilization for either crop. In many areas of the Andes, the role of purchased inputs in the small farmer's planning is probably considerably greater than is generally estimated through aggregate source material.

This study was motivated by strong circumstantial evidence suggesting that significant input adoption has indeed occurred in small farm agriculture. Three questions guided the research reported here. First, do small farmers differ from large farmers in their propensity to **use** inputs? Second, what variations in input use can be observed in the small farmer category? Third, what trends can be seen (and perhaps explained) concerning input use by small farmers?

To anticipate the analysis, where farmers see that inputs are profitable (and where they have access to them), farmers of any size class will use them. In several populations of Andean small farmers, the notable trend is to increase input use, and this trend cannot be explained simply on the grounds that small farmers use so much less than large farmers that any increase at all will produce a disproportionate growth rate.

In short, the term "small farmer," though useful in some cases for macrolevel analysis, masks important distinctions within the category when looking at any specific group of farmers. Establishing specific input-use environments on the basis of empirical information is a necessary first step in any technology development program. Given the long lead times needed for plant breeding programs to develop new varieties, it is of obvious value to he able to anticipate emerging trends.

Within the limitations of the available evidence, the paper also suggests that the trend to use more inputs is one that is likely to continue in the future. Increased market integration, rising wants, and better access to inputs provide a strong pull towards enhanced input use, while declining resource bases and augmented competition provide a strong push. Purchasing inputs makes increasing sense to farmers squeezed by competition, declining soil fertility, and a growing concern with profitability.

Data and Assumptions about Small Farmers

Much of the data that informs policy arguments about small farmers comes from national agricultural censuses. This source is notoriously unreliable. Nevertheless, reviewing this evidence on its own terms can only support the argument that small farmer-oriented agronomic research could stand a new look at some field-level data.

This paper follows the standard practice of defining small farmers as those having less than 20 ha of land at their disposal. As a general guideline the figure of 20 ha, agrees well with the quantitative sources and the figures used by national agricultural research programs. Very often this distorts the evidence: a farmer with 20 ha of potatoes in the intensively worked, land-scarce area of Carchi, Ecuador, is a rich man indeed; a man owning 20 ha in the eastern plains of Colombia would sum up his worldly goods as two head of cattle. How much this "simplifying assumption" distorts reality is a matter for conjecture because land quality correctives are rarely calculated and virtually never applied to Andean census data.

National-level agricultural censuses were carried out in three of the four Andean countries in the early 1960s and again in the early 1970s. Regional breakdowns were available for Ecuador and Peru; Colombia lacks breakdowns by farm size in the national census, but throughout the 1970s it conducted several regional samples which include this variable. Quantitative information for Bolivia is extremely scarce, and for that reason it has been excluded from the quantitative analysis.

Census research in the Andes is fraught with many pitfalls. A particularly frustrating problem is census noncomparability. Peru’s 1972 census dropped the distinction between organic and inorganic fertilizers, while Colombia’s last two national censuses dropped distinctions of farm size. Throughout the Andes, fear of current or anticipated land reform laws has led large landowners to mask their estates under many titles; for the same reason, census questions about tenancy and informal credit face serious difficulties.

Andean censuses have not faired well in attempts to validate them with in-depth, empirical studies. Detailed analyses such as Deere‘s (1978) study of female labor force participation show that definitional problems have produced errors of great magnitude in national statistics. As study after study of Andean land tenure demonstrate (Ossio 1983, Brush 1976, Guillet 1981), the complex landholding and land-access systems characteristic of middle- and high-altitude communities do not fit neatly into the census categories that characterize small holder communities and inform the development policies directed towards them. Unfortunately, there is not yet sufficient information to allow for valid corrections to census mistakes, While the continued use of national censuses is commonly justified by the lack of alternative sources, researchers increasingly rely on the proliferating diagnostic surveys, case studies, sample surveys, etc., that provide better-quality and more complex portrayals of how farming systems work,

With these caveats in mind, the following categories are used to refer to the amount of land under a farmer’s control:

Semilandless	(< 1 ha)
Minifundio	(≥ 1 ha but < 5 ha)
Small	(≥ 5 ha but < 20 ha)
Medium	(≥ 20 ha but < 100 ha)
Large	(≥ 100 ha)

Analysis

The guiding assumption behind the minimum input approach is that small farmers will not adopt fertilizers. A weaker, less consistent but perhaps more widely held variant is that small farmers will use some agricultural inputs, but adoption rates will be far lower than for the larger farm categories. Both these assumptions are discussed here.

Given the unequal distribution of land in Latin America, it is not surprising to find that the number of fertilizer adopters when measured by the number of adopting farms is highly skewed in the opposite direction when measured by area fertilized.’

In general terms, small farmers use their land much more intensively than do the more affluent farmers. Whereas Colombia as a whole had 8 percent of all farmland under permanent cultivation in 1970, small farmers cultivated 25 percent of their land; for Peru the figures were 2 percent and 8 percent. Here too, however, there is a considerable gap between small farmers' proportional land share and their percentage of fertilized area. As Table 2 illustrates for Peru and Ecuador, small farmers fertilize relatively greater portions of their land. Less predictable, however, is the fact that there is no significant difference in adoption *rates* within size groups except, at times, among the semilandless and the largest farms.

Table 2. Distribution of total area and fertilized area, by farm size.

	Peru		Ecuador	
Farm size group	% total land area	% fertilized land area	% total land area	% fertilized land area
Semilandless	0.8	5.6	0.04	0.1
Minifundio	5.9	19.6	0.95	7 6
Small	8 6	13 6	6.00	10.1
Medium	9.3	10.0	dS70	16.5
Large	75.4	51.2	d7.30	65.0
Total	100.00	100.00	100.00	100.00

Sources: Peru — II Censo Agropecuario Nacional 1972.
Ecuador — II Censo Agropecuario Nacional 1974.

Whereas the large and medium-scale farmers using fertilizers closely approximate their representation in the overall farm population, it is the "middle peasants" — the *minifundistas* and small farmers — who are over-represented (Table 3). As might be expected, the semilandless farm population has the greatest percentage of farmers unwilling to invest in fertilizers. Time series data available for Peru show the fastest growth in fertilizer adoption in the small farm sector, while large farms actually show negative growth rates. (This is probably due, in part, to the rapid growth of livestock farming in this group.)

The aggregate evidence does not bear out several of the simpler hypotheses commonly advanced to explain fertilizer adoption. One is that agroecology determines fertilizer use, and by inference, adoption by farm size. Table 4 shows the tremendous role of agroecology in influencing fertilizer adoption rates. Although the differences between fertilizer adopter categories in the three zones are significant, nevertheless there is little deviance from the overall adoption-rate trends *within* the zonal categories.

Table 3. Distribution of farms using chemical fertilizers, by farm size group in Peru and Ecuador.

Farm size group	% of farms	% using fertilizer	Difference (%)
	Peru		
Semilandless	34.8	16.4	- 18.4
Minifundio	43.1	**55.5**	+ 12.4
Small	16.7	21.6	+ 4.9
Medium	4.3	***5.0***	+ 0.7
Large	1.1	1.5	+ 0.4
Total	100.0	100.0	
	Ecuador		
Semilandless	22.1	16.8	- 5.3
Minifundio	51.1	**46.0**	- 5.1
Small	16.4	23.0	+ 6.6
Medium	8.1	9.0	+ 0.9
Large	2.3	4.8	+ 2.5
Total	100.0	99.6	- 0.4

Sources: Peru — II Censo Agropecuario Nacional 1972.
Ecuador — II Censo Agropecuario Nacional 1974

Table 4. Percentage of farmers using fertilizer by farm size in three ecological zones of Peru and Ecuador.

Farm size	Coast	Mountain	Jungle
	Peru		
	Adoption rates		
Semilandless	2.1	6.0	**1.5**
Minifundio	48.8	16.8	5.0
Small	57.8	16.8	7.0
Medium	67.6	17.5	6.9
Large	85.1	15.4	9.5
	Ecuador		
Semilandless	3.2	**4.5**	1.7
Minifundio	4.0	9.6	***0.5***
Small	3.0	13.4	0.2
Medium	2.5	8.3	0.1
Large	6.0	27.9	0.1

Sources: Peru — II Censo Agropecuario Nacional 1972.
Ecuador — II Censo Agropecuario Nacional 1974.

The willingness of farmers to adopt fertilizers varies according to which crop they are growing (Table ***5).*** However, there **is** no simple stratification of cropping systems by farm size — that **is,** that large farmers grow all or nearly all of the fertilizer-demanding crops while small farmers confine themselves *to* unfertilized crops. Highly fertilized crops such as potatoes and vegetables are produced overwhelmingly by small farmers.

Table **5.** Fertilizer adoption rates by crop.

	Peru Small farm crops %farmers adopting fertilizers, by crop						
Farm size	Potatoes	**Maize**	**Wheat**	**Beans**	**Cassava**	**Rice**	**Horticulture**
Semilandless	22	15	4	10	16	82	57
Minifundio	25	12	3	7	4	60	53
Small	27	12	3	8	2	40	57
Medium	31	12	5	6	1	20	42
Large	36	27	13	21	2	[illegible]	[illegible]
Total farms	25	12	3	7	4		
	Ecuador						
Semilandless	12	0.4	3	1	0	6	4
Minifundio	16	0.5	7	2	0	11	9
Small	21	1.1	15	3	0	10	10
Medium	24	1.2	25	4	0	5	10
Large	36	4.1	57	8	0	19	18

Sources: Peru -- II Censo Agropecuario Nacional 1972.
Ecuador -- II Censo Agropecuario Nacional 1974

Agroecological zone alone similarly does not sufficiently explain discrepancies between crop usage and farm size, although overall adoption rates do vary notably between zones. High rates of fertilizer adoption can be found in high-altitude cropping systems (e.g., potatoes, maize, wheat, horticulture) as well as for some crops commonly found on the low-altitude farms (e.g., rice, cassava, maize, horticulture).

Unfortunately, the quality ***of*** the census data does not permit a more detailed analysis of the reasons why there exist differences in crop mix selections by small versus large farmers. Case materials suggest a wide range of factors, including elements such as ease of transportation, access to informal credit sources, labor management, and cash availability. It should be pointed out that these factors can work in ways considerably different from those normally anticipated. In general, crop type is a better predictor of a farmer's input use than is the size of his farm. Farmers growing crops that respond well to inputs will use inputs irrespective of farm size; similarly, farmers producing crops where little gain is obtained through fertilization will not use them.

CONCLUSIONS

The minimum-input strategy was developed on the basis of information suggesting that a large CGIAR client population — small farmers — was not likely to be interested in high-input agriculture within the foreseeable future. Responsible policy demanded that centers adapt their technology development strategies to meet these farmers' needs. This article presents evidence that the input-use environment of small farmers has changed in several key respects since that policy was first developed.

For a number of small farmers, input use has become desirable for raising their incomes, necessary for farm survival, and feasible because of improved communications and markets. Small farmers do not lag behind large farmers when it comes to adopting chemical fertilizers; indeed, in some respects, they lead the way. While undoubtedly there are still areas where ignorance and lack of access effectively inhibit fertilizer adoption, in many areas of Andean America small farmers are already familiar with, and use fertilizers. In these cases, low-input use levels cannot be explained by psychocultural factors. The research imperative for social scientists helping to develop agricultural technologies is systematically and empirically to study the combination of circumstances that makes fertilizer use attractive on some crops and not on others. For breeders, removing the "zero-input" assumption would allow for technologies more suited to small farmers' requirements and capabilities.

For breeding programs, "small farmers" as an analytic category can be more of a hindrance than a help in defining target populations. The evidence presented here shows tremendous variations in fertilizer use masked beneath the small farmer label: while 100 percent of the minifundistas in Boyaca, Colombia fertilize their potatoes with **2 tons/ha** of **N-P-K** formulas, 100 percent of the similarly situated potato farmers in Cotacachi, Ecuador, do not. Several attempts to develop small farmer typologies that go beyond the amorphous "recommendation domains" of farming systems research have been proposed in recent years (Ashby 1986, Deere and de Janvry 1979, Lehmann 1986, Pineiro and Chapman 1984), but to date little has been done at a policy level to break down the "small farmer category" into more precise and useful divisions.

The futility of seeking a "one size fits all" answer to technology development becomes frustratingly obvious once the heterogeneity and dynamism of small farm systems form the center of analysis. Plant breeders would be better served by analyses of specific institutional and socioeconomic environments than by overly general and frequently wrong generalizations.

At the same time, many of the rationales that have been adduced for the minimum-input approach are valid and admirable. The need for environmentally sensitive technologies is obvious, especially in situations where there are few controls over environmental abuse. Common sense argues for low-input technologies that result in sustainable, high production levels at lower real costs. The case for low-input technologies can stand on its own merits without unsupported assertions about small farmer propensities.

NOTES

[1]Source: FAO Fertilizer Yearbook, 1972 and 1982

[2]In Peru 61.2 percent of the fertilized area is found on farms exceeding 20 ha, while 93.5 percent of the farmers adopting fertilizers own no more than **20** ha. The corresponding figures for Ecuador are 91.5 percent of the area, and 85.8 percent of the farmers. One implication of these figures for public sector research centers **is** that the overwhelming majority of beneficiaries lie in the small farm sector.

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Part V
MANAGEMENT AS AGRICULTURAL TECHNOLOGY

WHEN THE HONEYMOON IS OVER: MANAGERIAL REALITY AFTER TECHNOLOGY GENERATION AND ACCEPTANCE

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"If we have good varieties and clean seed, farmers will automatically adopt them. The technical part is the key, the rest is noise." — An expatriate technical advisor in Bhutan, **1986.**

'The technical part is easy. Getting people to accept and use our technologies and ideas is the hard part." — An expatriate field agronomist in Bhutan, **1986.**

During a recent evaluation of an agricultural program in the small Himalayan Kingdom of Bhutan, I had a unique opportunity to discuss with personnel working on several projects their philosophies on planned technological change. The verbatim quotes cited above were fairly typical of viewpoints which were debated among program workers as we visited farmers' fields and reviewed project activities. There were those who adhered to what I call the "self-propulsion" theory of agricultural development, as exemplified by the first quote. In this view, problems are essentially technical. Solutions are likewise technical. A "good technology moves by itself and once a technology is sent forward the designers have largely completed their task. If, for example, potato yields are low in Bhutan, then self-propulsionists would argue that what is needed are clean seeds of new varieties that contain natural resistance to diseases. Adoption and use will be largely automatic.

Other individuals whom I call "Bird Doggers" for lack of a better term, typically expressed their viewpoints along the lines of the second quote. They see problems and solutions as more complex. The technical part is considered as somewhat easier than the challenge of translating existing scientific knowledge into workable solutions that would be adopted and used by farmers. "Bird Dog" theorists believe that new technology must be adapted to fit local conditions and that backstopping and monitoring of the technology is necessary as it spreads, or is rejected, whichever is the case.

This paper takes a closer look at the assumptions held by development specialists about technological change and discusses those assumptions within the context of the management of agricultural technology. My objective is not to take sides with either "self-propulsionists" or "bird doggers," as I believe both are overlooking some crucial aspects of agricultural development. Indeed, they may have more in

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common than one would think. Both keep their focus somewhat narrowly on the hardware of technology rather than on the institutional and resource management contexts within which the technology will be used after the initial stages of generation and adoption. The thesis of this paper is that generation and adoption are necessary stages but not sufficient for successful long-term use of a technology. However, most efforts in agricultural research and development are given to these earlier and easier steps without consideration of whether project beneficiaries have the managerial capabilities or resources to put the technologies to a productive use beyond the stages of initial adoption.

For discussion purposes, I will describe three cases of different types of development projects that I have been involved with over the past eight years: I) an improved seed scheme, 2) food processing, and 3) crop storage. These three topics have received a great deal of international attention and funds from donor agencies over the past decade. They are seen as specific technological areas which can have high payoff in terms of increased yields, better nutrition, and reduced postharvest losses. The rationale behind most seed, processing, and improved storage projects is well founded in technical and economic terms. They are the kinds of development efforts that attract government interest and are highly demonstrable given proper project backstopping.

By following on the fates of these technologies in specific transfer contexts, the role of management at various levels and stages becomes clear. The three case studies illustrate that technology design and innovation adoption are only part of the "true transfer process." The other part involves the longer-term management skills to keep good ideas and technical hardware viable.

Management, as applied to agricultural technology is the organization and direction of complex resources toward production of crops, animals, or produce to satisfy the physical and cultural needs of the producing units. Management relates to the interface between specific technologies and the human user or users. Placing a set of tools within grasp of a human user or group of users, will not necessarily result in productive activity. Different individuals and groups have different managerial capacities and motivations for handling a specific production technology. This simple fact is often overlooked in agricultural research and development. I would even go so far as to argue that most failed or underused technologies introduced through agricultural development projects are rarely pure 'lemons" in and of themselves. Their successful use depends on the management capabilities of the people who, on a day-to-day basis, will use the technologies after project support and subsidies are withdrawn.

MANAGEMENT AS A BOTTLENECK THE CASE OF AN IMPROVED SEED PROGRAM

Clean seeds are vital to any farming system. Seeds are so important at the farm level that many agricultural scientists and policy makers argue that the supply of clean stocks is the most cost-effective way to improve farming systems. This is particularly true for the potato, a vegetatively reproduced tuber prone to virus degeneration. **For** this reason, potato improvement programs often emphasize government seed farms and schemes that can provide basic seed to selected growers who are encouraged to multiply it. Once this seed has reached regular growers, it can be used under normal climatic conditions, and if storage allows, **3-4** years before being renewed. There are other persuasive reasons for producing seed within a country **as** opposed to importing it. **These** include savings on foreign currency exchange, more flexibility for farmers in meeting planting dates, and lower production costs.

The basic principles and techniques for seed improvement have been well researched in developed countries. In particular, the technology for laboratory and experiment station production of clean seed material is well advanced for the potato (e.g., green house techniques and engineering, in vitro methods, true potato seed, rapid multiplication, and varietal screening). Seed programs in a score of developing countries in Africa, Asia, and Latin America have shown encouraging results **(CIP 1984).** The technical and economic arguments for such programs are persuasive, a fact which helps explain the popularity of seed projects.

Most development projects are required to have specific goals which can be measured quantitatively. Seed programs are no exception and such goals are generally set in terms of how many tons of clean seed are produced on the station and by contract growers — those farmers who have an agreement to produce seed under strict regulations of the seed program. Rarely, however, are seed projects evaluated in terms of the ultimate payoff; that is, increase in production by common table growers who make up the bulk of potato farmers and produce over **90** percent of the crop. Impact at this level is often assumed or extrapolated from estimated increases derived from experimental research.

Successful seed **programs** in the Himalayan countries of Bhutan and Nepal can serve **as** examples of the importance of management as a factor determining success of seed schemes. The aim in both countries is to increase yields per unit area, rather than to expand production areas, largely through providing improved seed via state farms and registered contract growers. **A** trickling down to ordinary growers of quality seed **is** expected in both countries. The goal is to produce **10-20** percent of the national seed needs which, when further multiplied by common growers over a number of years, would have rippling effect on overall production.

In these mountainous countries where transportation and communication are difficult, the basic technical development stage of a potato seed program is not an easy task. Establishing greenhouses, seed farms, identifying contract farmers, and conducting basic seed production training are all difficult activities that require a major effort on the part of project implementors. The initial phase of producing small amounts of basic seed *can* take three or four years. Agronomists and seed specialists who are particularly trained for this first stage, are the ones who must dedicate themselves to the fundamental task of producing basic clean seeds.

It is, however, not unusual that seed projects become so involved during the first stage in meeting government production goals that the next stage, that of reaching common producers, is almost forgotten or at best set aside mentally for consideration at some distant future date. Unfortunately, this next stage, if not considered early, can turn a seed program into a managerial nightmare. Once seeds are produced on the seed farm they must not only be multiplied by contract growers, but collected and graded, bagged, and labeled, transported to stores where they must be unloaded and kept properly until the next season when they will once again be distributed to both seed and regular growers. It is important to know where seed demand is located and what varieties are needed in these various locations. Delivery to farms too early or too late can cause a disastrously low production season or no production at all. The long and short of a seed program is that the crucial work begins after the basic seed is produced.

The importance of delivery was learned the hard way in Nepal when the postproduction stage following a difficult season of getting quality seed stock, posed special coordination problems. An agronomist from the western region describes his experiences after the seed crop was harvested as follows.

> Seed from the program was taken across the border to an Indian cold store. Upon arrival, [we discovered that] the customs documents had been misplaced. In getting the seed out, they had to be taken from the cold store during the heat of the day. Before they could reach Nepal, the seed began to rot. The whole amount had to be sold at lowest rates to a local trader. The entire seed load for Nepali farmers was lost (NPDP 1985).

In the neighboring country of Bhutan problems are similar. Even before basic seed is collected from contract growers, seed requests must be collected by program management from Agricultural District Officers (ADOs) around the country. This seed is then sold at a preset price to registered seed growers. Delivery will be made at planting time which means the seed must be stored for seven to eight months. Bhutan also sells seed on the export market to India so it must take care not to sell too much of its basic seed stock and thus end up with a domestic shortage. Production in Bhutan, as in all seed schemes, is only one stage which must be followed by grading, sacking, loading, transporting, distributing, and storing for long periods.

The point of this case is to illustrate that what is essentially thought of as strictly a technical task is in fact a major managerial undertaking. The real challenge of a seed program is to produce a downward spread to common growers for major national payoff. This involves much management skill. Ironically, people who manage seed programs are often well trained as technicians, but are given no training at all as managers.

FOOD PROCESSING MORE THAN THE TECHNICAL COMPONENTS

While it may seem clear to the reader why the management factor is crucial in a seed scheme, a less obvious case deals with the development of food processing techniques and nutritional mixes for use by low-income groups. Food processing projects are typically developed by nutritionists or food processing specialists — not production specialists — and aim to make better **use** of locally available food resources. Concerns focus on nutritional impact, lower-cost foods, assistance to mothers, and local self-help to reduce dependency on outside suppliers.

Attempts at food processing and development of nutritional mixes in Peru over the past **30** years provide an example. Peru has a high availability of food products and crops which can be processed into mixes or other forms that can be stored well (e.g., fish meal, cotton seed, and Andean crops such **as** potato, *tarwi*, *quinoa*, and other native crops). Peru is also a developing country with severe malnutrition problems among its poorer population. Earlier efforts focused on concentrated forms of fish meal or cotton seed meal for better protein intake of the poorer segments of society. During the last five years emphasis has shifted to better use of Andean crops some of which are high in protein and quality. Several such projects have concentrated on the potato, a staple food which originated in the Andes and remains an important crop to the Peruvian people, both nutritionally and symbolically.

The development of a processed food product or blended mix is essentially a technical undertaking. Techniques and principles of food processing have been developed worldwide by all types of populations to suit their needs over time. In Peru, for example, native processing of roots and tubers, such as potatoes, is an ancient practice in the countryside. However, large-scale migration to urban areas has created a situation of imbalanced food supply, and uneven nutritional pathways heavily loaded toward starchy, high-carbohydrate, low-protein foods. In some population segments, there is a high dependence on imported food aid supplies which tend to he low-cost and lacking in nutrition. Locally available foods which can be properly mixed with other available food stuffs or processed can help low-income groups become more self-sufficient. Processed products, especially dehydrated foods, can be stored more easily and used at a later time, **or** a high-carbohydrate bulky food can be mixed with a low-cost protein concentrate.

Both Peruvian and expatriate food scientists have, over the years, conducted first-rate technical research on the use of low-cost foods **as** well **as** refining and developing specific techniques and technologies (dryers, peelers, slicers, grinders, cookers, etc.). Developments in the Peruvian food processing experience closely parallel the case of the seed programs discussed earlier in this paper. The technical phase proceeded rapidly and successfully. Relying on knowledge and blue prints developed in other countries, the tools and hardware of processing technology were quickly refined. Demonstrations and model plants were established. Field days were held, and farmers and others trained in the use of the technology and techniques. As project leaders had hoped, adoption and consumer acceptance of the products began to take place within a short period of time. However, generation and acceptance of a technology proved to be only the beginning.

Influenced by the emphasis in Peru on community-based development, many food processing projects have looked toward establishment of their plants or promotion of their products in highland Indian communities. The emphasis is typically on using native Andean crops, especially surplus production that cannot be sold profitably on the local market due to depressed prices or pest damage. Various agencies, therefore, established their plants in native communities, trained local personnel, and then left the operation in the hands of the local community. Follow up a year later showed that the efforts had failed due to management problems.

One processing plant, for example, was set **up** in a central Peruvian highland community where it ran well while under the direction **of** project leaders from a national university who brought with them an infusion of outside capital and support services. Community and members were openly enthusiastic about the plant and held high expectations about its future. However, as in the case of seed programs, willing adopters are a necessary but insufficient element of a successful program. The after-adoption management reality of running the plant on a day-to-day basis after the project team left, had been overlooked.

In this case, the realization of the need to coordinate a host **of** inputs and activities came after the initial acceptance of the processing technology. Problems included supply of fresh produce, holding produce in proper shape for later processing, maintenance of equipment, provision of guards for security, quality control, and shipping to reach the proper market. These were again, the unanticipated aspects of running a processing plant.

The critical constraints to the project were not technical, but managerial. Initially the processing plants ran smoothly and the products were deemed acceptable to consumers. But these factors alone did not guarantee project success.

MINDING THE STORE MANAGEMENT IN THE POSTPRODUCTION SECTOR

We turn now to a third example of how poor management can under-cut gains in technology generation and acceptance. The case of large-scale, state-supported potato storage complexes is well documented in the literature, especially in relation to technical and socioeconomic aspects of storage (Rhoades and Booth 1982). Our example here is drawn from Peru. Since the 1950s, the Peruvian government and various development agencies operating in Peru have sought technical solutions to help control the flow of consumer potatoes into the Lima market. Concerned with gluts, seasonal price fluctuations, and periodic shortages, the government constructed potato storage facililities at various locations around the country, including five large storage complexes with a combined total capacity of 20,000 metric tons.

The basic idea was simple: potatoes could be held in the government-controlled stores with minimum losses until prices improved. Theoretically, fanners could get higher prices by waiting to sell, while consumers would gain by paying lower prices during the crucial months when potatoes would otherwise be in short supply. The 'leveling of prices" notion coupled with technical feasibility made the idea popular with donors and the government. As a result, technically excellent stores were built over the countryside. Today these stores stand empty, just as they did on the first day they were built., Some have fallen down in decay, others are rarely used and even then to store nonfood items or to house people but not potatoes. Why did such a logical development scheme fail?

In a few cases, farmers did deliver their potatoes to the state stores. However, poor management by government employees resulted in improper ventilation; the potatoes spoiled and had to be discarded. Farmers rightly felt they had 'lost control" when their produce was stored under alien management and far away from their homes. There are other reasons too why farmers like to keep their produce near their homes. Agricultural robbery is a major problem, and daily and weekly management of the produce is, in any case, necessary to eliminate rotten tubers, and watch for pests such as tuber moths, aphids, and rats. Finally, farmers prefer to maintain direct management of their stored products to increase marketing flexibility.

Even for a small farm, storage facilities constitute a fairly complex package. Ventilation, temperature, light intensity, and pests must be regularly monitored and regulated, and the store loaded and unloaded according to need. Storage management tasks become even more complicated when one is dealing with groups of farmers who have grown many different varieties which may have to be stored in particular ways.

Lack of attention to the management factor helps explain why the developing world is littered with large storage structures rarely used by their intended beneficiaries. It is not that the stores are technically inappropriate, nor that such stores are not needed. What has been overlooked are important variables such as proximity, flexibility, and a sense of self-control or self-management by farmers.

FUTURE CONSIDERATIONS

What positive steps can be taken to ensure the incorporation of a management perspective into the research of international centers and national programs? What are the priorities in this agenda?

First, related experiences in management and technology transfer as discussed in the development literature should be reviewed. To my knowledge, only two areas in agriculture research in less-developed countries have been given some consideration: multinational agribusiness technology transfer and agrarian revolutions. Many international agribusinesses dealing with chemicals and machinery have developed management contracts with host countries (de Cubas 1974). Such long-term support is seen as mutually beneficial in the sense that the multinational continues to share a market while the developing country is guaranteed it will not be left holding the bag if a 'lemon" technological package appears. This contract interaction is seen as a "more viable form of technology transfer than a consultancy" which is normally short-lived (Voll 1980). Perhaps there is a message to the international development agencies in this approach. Would we look differently at our technologies if we were required to extend a "warranty" or "guarantee" to our clients?

Revolutions affecting rural populations have also had to come to grips with problems of agricultural management. Austin and Ickis (1986) recently wrote in an article on management and revolutions, 'The experience of revolutions suggests that the process of gaining power, though long and arduous, may be less difficult than the subsequent task of achieving economic recovery and satisfying peoples' material expectations. The management function and managers are central to this task, yet they are a neglected dimension in the analysis of revolutions."

The Peruvian revolution of the 1960s and 1970s is a case in point, and one which I observed in the past. The overthrow of the ***hacendados*** (landlords) and the establishment of cooperatives was a revolutionary act which brought great hope to all Peruvians, but especially the poor who would benefit most from land reform. As time wore on, however, the problems of managing the agricultural cooperatives on a day-today basis were aggravated. Throughout much of the country, former serfs or laborers who overnight became cooperative owners of a farming enterprise simply did not have the capabilites or the resources to run the cooperatives which, in the end, were broken up or taken over by the credit banks. The cooperative movement in much of the country failed due to a simple lack of management expertise.

Second, more serious interdisciplinary research needs to be conducted on the long-term experiences of rural populations with agricultural technology. This must reach beyond initial adoption and estimated impacts to actual use and management of specific innovations. In turn, there should be feedback from postadoption studies to basic research so that during technology generation we can gear our efforts toward the managerial capabilities of our clients. Early sensitivity to later management problems and potentials can help address the equity issue and ward off undesired consequences of our technological efforts. For example, in storage research we should ask what size and types of stores should be introduced under different conditions. Introduction of large-scale complex stores may not make sense for individual small-scale producers who are not organizationally equipped to manage them. However, the same store in the same locality might be appropriate for large-scale producers with the capital to hire professional store managers. The consequences of technology and the implications for management need to be closely monitored.

Third, IARCs may consider building the management factor into their training programs, especially in those areas where management is clearly a crucial factor for success or failure (e.g., seed programs, irrigation, postharvest, cropping systems, agroforestry). The IARCs often do an excellent job in technical training, but the individuals trained then end up as managers, not as technicians. To introduce management training would require the input of management scientists who are few and far between in agricultural development. If available, they could take a place alongside biological and social scientists on interdisciplinary teams.

CONCLUSIONS AND SUMMARY

In agricultural development circles the dominant paradigm of technical change has assumed that if a technology works in a technical sense, inputs are available, and the technology can be calculated as profitable, then it should stand a good chance of being successful. Lately, we have added a "social" or "cultural" dimension and employed a few anthropologists and sociologists on our projects to monitor adoption or define the sociocultural constraints to adoption. I contend, however, that technology efficiency, profits, and even acceptability are rather beside the point if the technology cannot be managed by the target beneficiaries. It is not that the technological factors are unimportant, but rather that they are only part of a larger package needed for the successful implementation of an agricultural activity. A fitting analogy would be that of an automobile manufacturing firm that limits its efforts to technical efficiency, concern with its own profits and costs and the products' acceptability to customers. These aspects are only the beginning. There must also be distribution of the product, advertisement, supplying of spare parts, maintenance, training of mechanics, and follow-up. In fact, a successful business will tell you that it is what happens *after* design and initial acceptance that counts. The three case studies in this paper have illustrated why it is crucial to keep watch on the management factor after acceptance.

These are common-sense points. However, the obvious has escaped us before. It has taken science decades to realize that agricultural systems are holistic and that farmers have something to say to scientists. There are historical and institutional reasons why our thinking has stopped at adoption, leaving that which comes later shrouded in darkness. Agricultural scientists are under strong pressures to get technologies out and moving; but helping people to manage those technologies after acceptance was not considered part of our mandate. Even farming systems research and constraints research have focused on the gap between technology generation/availability and farmer acceptance, but not beyond. Few development specialists stay around after the honeymoon when project enthusiasm comes face-to-face with daily operation. Certainly generation of technology, extension, and acceptability are important, but they alone will be rendered meaningless without attention to the continued, long-term management of agricultural technology by farmers and national agricultural systems.

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IRRIGATION MANAGEMENT AND THE DEVELOPMENT PROCESS: TWO EXAMPLES FROM SRI LANKA

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The concept of an irrigation system refers not only to physical aspects such as channels and control structures — hut also to the management structure by which the physical system is planned. designed. constructed, and operated. These two aspects are functionally interdependent. and need to he understood as a whole. The choice of technology, the canal layout, and the cropping patterns all constrain the way the physical system can he managed; whereas the management skills of agency officials and farmers constrain the kinds of physical system which are feasible.

This paper discusses the role of social science in IIMI's cross-disciplinary research on two irrigation systems in Sri Lanka. The objective of the research is to identify constraints in the systems (*sensu lato*), to suggest improvements, and, in collaboration with relevant government agencies, to make interventions in the system and monitor the results. Each of the disciplines involved in the research — engineering, soil science. economics, and anthropology focuses on a particular aspect of the total irrigation system: water flows and water use, plant-water-soil relationships, inputs and returns, and organizational aspects. respectively. Following an overview of one research project. this paper describes the management practices of farmers and agency staff, examines ways to improve that management. and discusses how alternative management approaches can he evaluated with respect to the broader development process.

RESEARCH ON IRRIGATION INSTITUTIONS

Field research on two irrigation systems in Sri Lanka was initiated by IIMI staff in mid-1985 during the *yala* (dry season) to understand the effects of irrigation management on diversifying from rice to "other food crops" (OFCs) such as chilli, lentils, soybeans, and onions. Faced with imminent self-sufficiency in rice production hut continuing large-scale imports of non-rice food crops, the government is trying to promote the cultivation of OFCs, which require intermittent irrigation, in schemes designed for rice cultivation and more or less continuous water flows.

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Two IIMI research assistants, an agricultural engineer, and an economist, were posted at each system to collect data. They were joined by a sociology[1] assistant in October, at the start of the *maha* (monsoon season). The role of the sociology component in research directed at crop diversification issues is to identify organizational constraints to the more careful management required for irrigating OFCs, to explain those constraints, and, during a later phase of action research,' to suggest or experiment with interventions.

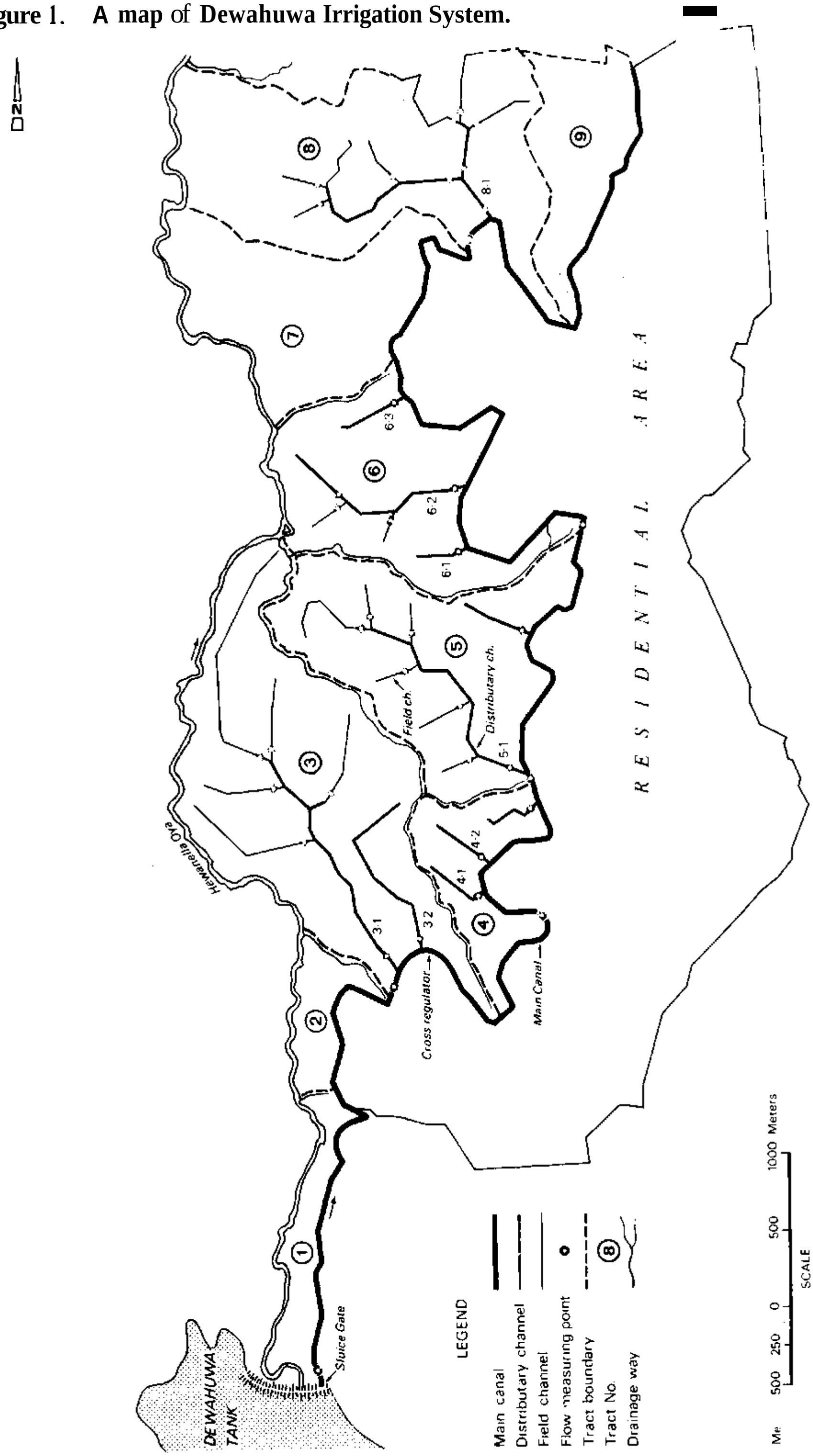
The two irrigation systems selected for the study represent two different kinds of irrigation systems and irrigation agencies: 1) Dewahuwa Scheme, a major tank commanding 1,200 hectares (ha) managed by the Irrigation Department; and 2) Mahaweli System H, a segment of the ongoing Mahaweli irrigation and settlement project which when completed will cover nearly 350,000 ha and is managed by a parastatal agency, the Mahaweli Authority of Sri Lanka.

Dewahuwa Tank

Dating to the 3rd century A.D., the ancient Dewahuwa Tank bad been abandoned for centuries when it was reconstructed in the 1950s. Farmers from the reservoir area, from surrounding villages, and from more distant regions were allotted 2 ha of irrigated land plus 1.2 ha of "highland" plots near the command area. By 1970, the new system had fallen into a state of disrepair and was rehabilitated under a Japanese aid project. Today the designed command area has been expanded nearly 20 percent by unauthorized encroachments; the original families who were allotted land have subdivided their plots several times. While most household economies remain primarily agricultural, many of the second and third generations rely on rain-fed agriculture outside the scheme, supplemented by off-farm employment. Land tenure is fluid, with about half the operators farming land which they do not own. Some nonowners are family members who may someday inherit the land they now lease: others who are classified as owners have taken mortgages and are actually tenants on their own land. Hidden tenancies are the norm because land transfers through either lease or sale are prohibited by law in Sri Lanka's settlement schemes.

The physical layout of the scheme comprises a large tank (reservoir) with a single main canal from which distributary (secondary) channels take off on one side, to serve the command area. The highland residential area extends along the right side of the canal (Figure 1). Each take-off point from the main canal to a distributary or from a distributary to a field channel (tertiary) is controlled by a gate which in theory is opened or closed only by an Irrigation Department worker. Distribution of water within the field channel, which may serve 3-15 allotments (and up to 50 operators), is the responsibility of the farmers themselves. In addition, some allotments are hydrologically independent, receiving water directly from a distributary.

Figure 1. A map of Dewahuwa Irrigation System.



Mahaweli System H

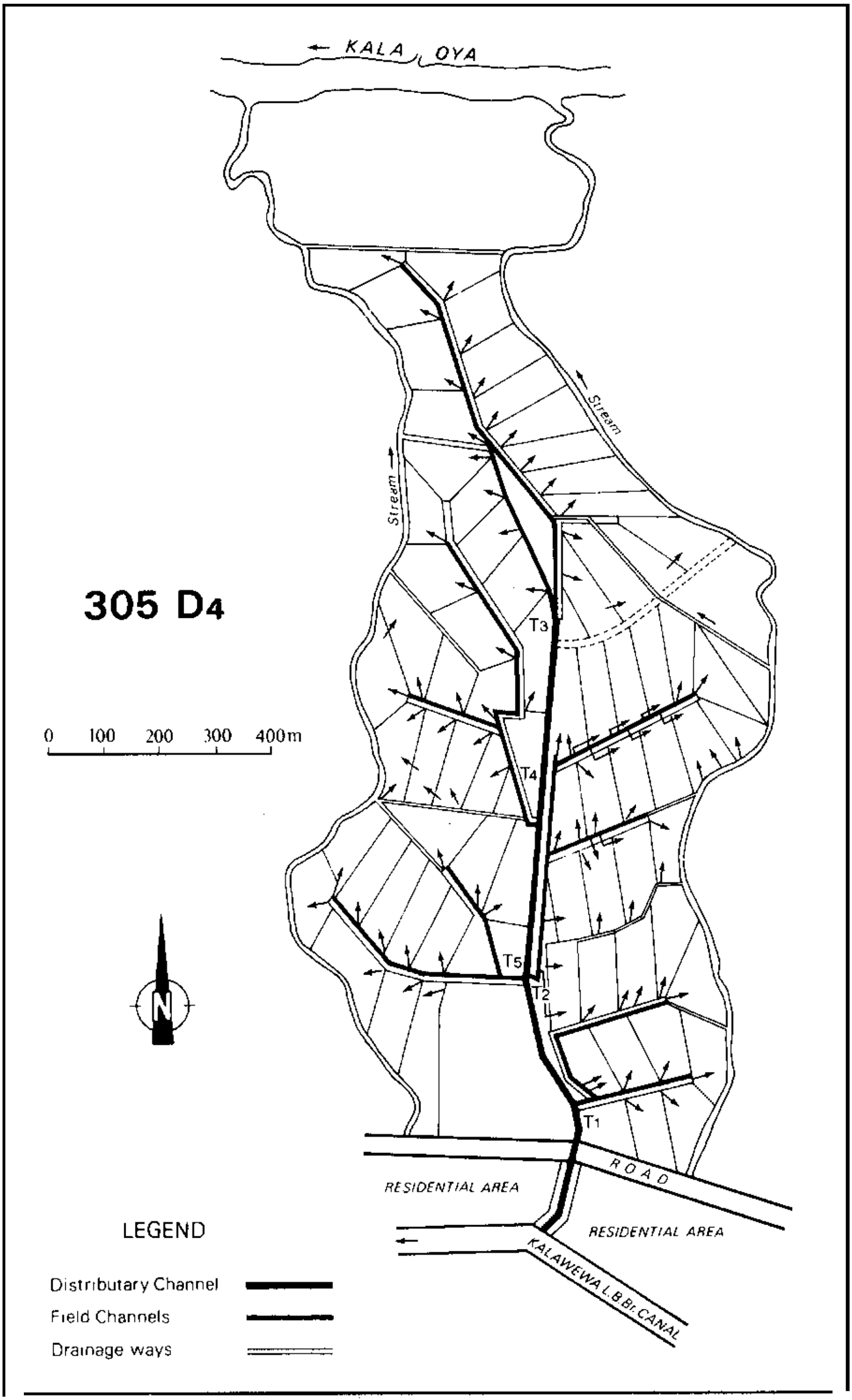
Most of the country's largest irrigated settlement scheme is still under construction. System H was completed in 1983, and is the oldest of five separate units of the scheme, all fed by the Mahaweli River, as well as by smaller streams in each locality. Prior to construction. much of the **24,000** ha which comprise the irrigated area of System H was irrigated by village-owned and managed small tanks. Village economies were based on a mix of irrigated (rice) cultivation and upland swidden. The new canal system and associated land development obliterated many of these tanks, and incorporated others into on-line reservoirs fed by the main system. Settler families from the area, as well **as** from outside the region, were alloted 1.0 ha of irrigated land and ***0.2*** ha for house plots and gardens. Following the precedent of other settlement schemes, the government constructed all irrigation facilities and cleared and leveled the fields.

Operational management of the Mahaweli Systems is carried out through **a** separate administrative structure which supplants the normal line agencies, such **as** the departments of agriculture and irrigation. In System **H,** three resident project managers, are the chief administrators, each supervising about a dozen block managers, with unit managers at the next level. From the farmer's perspective, it is the unit manager, with jurisdiction over about **250** farm allotments, who is the most significant representative of the government. For problems ranging from child care to agricultural credit to irrigation water, the unit manager serves **as a** patron to the farmer and as a liaison to specialized government services.

The physical layout of the residential plots and the irrigation canals in System H reveals a highly regular pattern. The main canal serving the research area feeds **20** distributaries, which take water to field channels. From these, water flows through four-inch concrete pipes into the individual one-hectare plots. Unlike the case in Dewahuwa Tank, there are no fields fed directly from the main canal or from the distributaries. Each field and each farmer is part of a larger irrigated unit defined by the field channel whose water supply is controlled by **a** "turnout gate" (Figure **2).**

Each field channel provides water for between 7-15 allotments, and because the scheme is **a** very new one, most (68 percent) allotments are farmed by the original allottees or close kin.[2] The nominal leader of each field channel unit is a "turnout leader" selected by the farmers or the unit manager or both. At the distributary level, which consists of **74** allotments, there is **a** distributary leader. Both levels of farmer representatives are intended to mobilize labor within their respective units to clean the water channels and enforce water rotations **as** needed. Neither the distributary leader nor the turnout leader is given any remuneration, nor does either carry any real authority. The actual role of these farmer leaders centers on reporting to the unit manager about conditions in the field rather than taking direct management action. One-third of the operators sampled did not even know who the farmer representative was and half were not aware of the distributary leader.

Figure 2. Map showing Distributary Channel-4 in Block 305 in Kalankuttiya Block of Mahaweli System H.



MANAGEMENT PRACTICES

In both irrigation schemes, the turnout gate from which water flows from the distributary to the field channel demarcates the management division between the government agency (Irrigation Department or Mahaweli Authority) and farmers. In general, the agency controls the turnout, and the agency employee who makes adjustments to the gate is responding to orders from above, not from farmers. The administrative structure of farmer representatives serves to channel information up the system to the agency level, with the management decisions flowing down the system to the turnout.

Below the turnout. farmers control the distribution of water and are expected to follow rotations to ensure that each operator receives an equitable share. The role of the farmer representative is to provide leadership in organizing water rotations, and in maintaining the channels. During the rainy season when rice is the only crop, rotations are not normally needed. Each farmer prefers to keep his pipe outlet (taking water from the field channel to an individual allotment) open all the time. This results in a small volume of water flowing continuously into his allotment. Even a trickle of water is useful, because the standing water in the rice fields serves as an irrigation reservoir for that field, which is replenished whenever water flows into the field. Excess water flows into drainage channels.

Tail- end farmers receive significantly reduced water flows when the head-end outlets are open. When tail enders need more water, they block the field channel pipe outlets going into the head-end allotments, thus increasing the **flow** to the tail. If the head-end farmer have enough water in their fields, this action is tolerated. If the head enders are not satiated, however, the tail enders are forced to wait until night, when all farmers prefer not to irrigate and when tail enders face the least competition for water supplies.

During the dry season, slightly more than half the commandable area **is** cropped (depending on reservoir supplies). About half of this is given to non-rice crops, which require less water and risk waterlogging if grown during the rainy season. **As** mentioned earlier, the government is encouraging farmers to grow more non-rice crops because of the low-economic returns to rice. Thus, the primary focus of IIMI's field investigations is to determine how irrigation management can promote that objective. While non-rice crops require less water, they require more carefully managed supplies. Waterlogging will result if too much water is delivered. Water stress will occur if the deliveries are too sparse. Instead of a steady trickle of water, non-rice crops need relatively high volumes delivered in a short period **of** time.

Irrigation rotations are imposed on farmers at the distributary level through management of the main system. During the 1986 yala, cycles of four days "on" and three days "off" were adopted in Mahaweli-H. In Dewahuwa, the average was about two days "on" and five days "off." The Irrigation Department rotated water among field channels in Dewahuwa, but within the field channels, the farmers did not follow formal rotations. Because the flow to each turnout gate was concentrated during one or two of the few days when water was in the distributary, most of the farmers were able to obtain adequate supplies without resorting to rotations among field allotments. The tail-end farmers within the tail-end field channel, however, relied on night irrigation when they could block the head-end outlets within their channel, and block the turnouts serving the head-end field channels.

In Dewahuwa. where a single distributary serving six field channels was selected as the study area. adjustment of the turnout gates is controlled by two farmer representatives and one irrigator. The irrigator is a full-time employee of the Irrigation Department who controls the water flowing into the distributaries, and in some cases, turnout gates within the distributary. Under the Dewahuwa management structure, the farmer representatives fill an official, part-time administrative role and are paid in-kind' by the farmers in their turnout. On an average, there are about 50 operators for each leader. His services include relaying farmer complaints to the project manager, and conveying information about water schedules from the project management to the farmers. He is also responsible for mobilizing farmers to clean channels and to comply with the field channel rotations. Other than the farmer representative, there are no formalized positions of irrigation-related leadership among farmers.

In Mahaweli-H. the agency does not normally rotate field channels within a distributary; all the turnout gates are generally kept open. However, within the field channel, farmers are expected to rotate water in six-hour turns. Of five field channels in one distributary studied, the six-hour schedule was adhered to in two cases, even though this required certain farmers to irrigate at night. In the two field channels toward the head end of the distributary, the rotational schedule was not followed because there was enough water available without resorting to formal rotations. In the tail-end field channel, some farmers tried to organize rotations, but the procedure broke down over scarce day-time supplies. As in Dewahuwa, these farmers resorted to a primarily night-time schedule when farmers in the head-end were not using the water.

Under the Mahaweli system, there is a much more intensive administrative structure involving two levels of unpaid farmer leaders who are either elected hy farmers, or. more usually. are appointed by the unit manager. Turnout gates are adjusted by a field assistant, a full-time employee attached to the unit manager. The farmer leaders (a distributary leader and a turnout leader), do not control water flows at any level. Their function is to convey information between farmers and the unit manager, and to mobilize the cooperation of farmers in cleaning channels. They also encourage farmer compliance in adhering to rotational schedules within the turnout. Neither the turnout leaders nor the unit manager can enforce farmers' cooperation except through informal persuasion.

IMPLICATIONS FOR MANAGEMENT

In both irrigation systems the general prescription for improved water use efficiency within the distributary is the same: equitable water deliveries to the field channels, equitable rotational schedules (taking into account variations in conveyance efficiencies and soil characteristics), and tighter adherence to rotational schedules. If these measures were carried out, the demand for water within the distributary would fall, and supplies could be reduced. Ascertaining the amount of water that could be saved is an intermediary objective of IIMI's research which must await final analysis of the water data. The long-term objective is to develop new management approaches to support more efficient water use to increase dry season cultivated area, and to increase the production of dry season (and in particular, non-rice) crops.

Using less water can be effected either by decreasing supply (induced scarcity) or by decreasing demand. Though this point may appear to be obvious, supply and demand are very much related: abundant water supplies create their own demand as farmers and agency staff fit their management practices accordingly. The current levels of water delivered to the distributaries are excessive from a technical standpoint. With better management, the same crops could be grown with less water. Given the present management arrangements, however, it is problematic whether water supplies could be reduced without suffering yield losses.

There is a circular relationship between improved management and reduced water supplies. Unless water supplies are reduced, there may be little incentive to improve irrigation management. Yet, existing management practices cannot cope with supply reductions. Incentives that can break this cycle and result in a more efficient irrigation system overall, are unlikely to originate from the beneficiaries of poor management: agency staff who enjoy a comfortable margin of error in calculating water deliveries, and farmers who are receiving all the water they need. Rather it is the senior-level agency staff concerned with agricultural production, along with those farmers unable to cultivate during the dry season, who form a potential lobby for management improvements that can save water.

The Sri Lankan custom of *bethma* (whereby water supplies which are not adequate for the full command area are allocated to part of the area, and all landowners are given proportional land shares in the irrigated part)[4] appears to placate farmers on the management issue, since each farmer can be assured of the same proportion of imgated land during the dry season as all the other farmers in the scheme. Unless the disparities in water availability between head-end and tail-end farmers are severe (which in the two examples cited here, they are not), there is little incentive for farmers to seek change. The incentive for improved management must come from above, where it is more clearly felt. Targeting middle- and high-level officials within the irrigation agencies has been an explicit strategy of IIMI's program, as this is the level where change is most likely to originate.

No matter how management improvements are initiated, an organizational structure that could effectively sustain tighter water control would require either an expanded role for agency staff, or greater involvement by farmers, or both. The choice of management strategy — the mix between agency control and farmer control — depends upon the development objectives: Is farmer management participation considered important for reasons of social development? Or is agricultural production of over-ridiiig concern regardless of management structure?

Improved Management by the Agency

Steps to strengthen the agency's administrative control over irrigation management could involve training existing staff, replacing them with better qualified staff, hiring additional staff, or modifying the administrative structure to enhance the effectiveness of staff. In Dewahuwa, all of these steps are being tried to some extent. The post of project manager (created in 1984) is intended to strengthen the role of farmer representatives and to facilitate communication between the Irrigation Department's engineers and farmers.

One important function of the project manager is to supervise the collection of irrigation maintenance fees which are used for repairs suggested by the farmer representatives. The practice of linking Dewahuwa's maintenance budget to fee collection within the scheme, rather than from central allocations at a regional level, is a potentially powerful incentive to farmers to pay their fees and to perform minor maintenance tasks themselves in exchange for reduced fees. However, there are also incentives for irrigation staff to keep the maintenance function and associated funds within the agency, and there is a complementary incentive to elected politicians to absolve farmers in their constituencies from paying unpopular maintenance fees.

In Mahaweli-H the current administrative structure dates from 1981 when the position of Unit Manager was created (Jayewardene 1984). Formalized leadership roles extend further down the scale than in Dewahuwa, with a dual-level of distributary leaders and turnout leaders, the latter covering about 12 ha and perhaps 15 farmers. One-day training programs have been instituted for some of these leaders. As in Dewahuwa, an irrigation maintenance lee is levied. Senior agency officials have encouraged several different approaches to the recurring maintenance task of cleaning the distributary canals. For several years, the agency gave annual contracts to clean the distributaries. An innovation was to award the contract to the distributary leader. effectively providing a payment to him because the contracts were quite generous. More recently, the agency has ceased providing this function on the expectation that farmers themselves will clean the distributaries. There is. however. no provision for farmers to do so.

In both irrigation systems. recent attempts to improve the administrative control of the agency have focused on the distributary level and (though not discussed here) at higher levels within the project. The next logical step might be to introduce incentives to farmers at the field channel level. Including turnout leaders as shareholders in maintenance contracts could be one such approach in Mahaweli. In Dewahuwa where there is no field channel organization, partly because the physical layout of the channel system is not conducive to their formation, the introduction of a lower administrative level becomes more problematic. An expanded role for the Dewahuwa farmer representatives in maintenance contracts might provide a partial solution.

Improving Management through Farmer Participation

An alternative to enhancing the authority of agency staff is to promote management capacity by farmers themselves through local-level organizations. In the two systems under study, there *are* nominal farmer "organizations" in the sense that farmers fill the designated role of farmer representatives, but there is no involvement of farmers in group-management decisions. Even channel cleaning is usually done by farmers individually and not as a group activity. Water is acquired by tail-end farmers not by discussing their problems with head-end farmers, hut by blocking the inlets to those farmers' fields during the night, thus, allowing water to reach the tail end.

Promoting farmer organizations at the level of the field channel and the distributary would not replace any of the agency staff currently involved in irrigation management, although there would be a potential for farmers to fill some of the field-level staff functions eventually. The primary objective would be to ensure the flow of irrigation information among farmers, and to promote the cooperation necessary for equitable, secure water distribution. The formation of farmer groups would require a concerted effort for extension of both farmers and the agency staff with whom farmers would now have closer contact. In cases where farmer groups have been successfully organized for irrigation, catalysts were used for periods of 6-18 months to stimulate interest and help develop the necessary organizational skills (Uphoff 1986, Bagadion and Korten 1985, FAO 1985).

CONCLUSIONS: SELECTING MANAGEMENT STRATEGIES FOR IMPROVED IRRIGATION MANAGEMENT

Strengthening the roles of existing agency staff is often easier than promoting farmer irrigator associations, and has a social advantage in fitting nicely with a long tradition in Sri Lankan society. Farmers tend to look to the government as they once looked to the King; help comes from outside to solve internal prohlems.5 The complacency of farmers, coupled with the willingness of government to provide a broad range of services (and there is a close relationship between farmers' expectations and government services) sets the stage for top-down development.

Yet, farmer participation in imgation management through organizations built up from the grass roots would provide farmers, as well as agency staff, with a potentially valuable learning process which can be viewed as a development objective in itself. Farmers would learn organizational skills while acquiring a sense of belonging and a spirit of self-reliance (Goodell 1984). As Blair (1982) observes, such influences are not always welcomed by established interests. Political empowerment, for example, is not the sort of development objective normally found in project appraisal reports, whereas water savings and increased crop production are generally accepted targets.

The costs and benefits of irrigation management options are determined both by quantifiable variables of water use, crop production, operations and maintenance costs, as well as by qualitative variables such as sense of community, well-being, and security. Socioeconomic analysis of irrigation management arrangements bridges quantitative as well as qualitative aspects, and must be grounded in a clear understanding of the physical parameters of the irrigation system and irrigated agriculture.

This paper has discussed two contrasting management strategies of potential relevance to irrigation systems in Sri Lanka: strengthening the capacity of agency staff, and promoting the organized management participation of farmers. The two approaches are not mutually exclusive, but they imply certain trade-offs in terms of development objectives. If development is viewed broadly to include equity as well as economic improvements, the ***approach*** to management becomes a critical element in evaluating management effectiveness.

NOTES

[1]The term "sociology" is used as a simple label to refer to the social science component of IIMI's research, although the principal investigator was an anthropologist.

[2]Percentages refer to a sample of 56 operators from 3 FCs along I distributary, during maha season 1985/1986.

[3]Their salary is equivalent to about 25 percent of the salary paid to an agricultural extension worker.

[4]*Bethma*, a traditional custom in small, communal tanks of Sri Lanka (see Leach 1961) has been reintroduced recently into the Mahaweli Scheme and in several other agency-administered irrigation schemes, including Dewahuwa.

[5]The theme of farmers' dependence upon government is discussed in Moore (1985).

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SOCIAL SCIENCE MONITORING AS A MANAGEMENT TOOL FOR DIRECTING THE BENEFITS OF NEW AGRICULTURAL TECHNOLOGY TO THE POOR

Steven Romanoff*

Social scientists can help managers involved in the diffusion of new agricultural technologies to know more about the practical ways that benefits can reach small-scale farmers. This is possible whether such managers work in IARCs, national programs, development projects, or local farmers' associations. Conversely, managers need to analyze how their mundane decisions concerning technology design, extension methods, project staffing, or pricing will select the farmers who will benefit from the technology.

The study reported here monitored the introduction of an agroindustrial technology for processing the starchy roots of yuca (cassava, manioc, tapioca, *Mannihot esculenta*) for animal feed. CIAT transferred the technology from Thailand to Colombia, where groups of farmers began building drying plants under the guidance of the Colombian Government's Integrated Rural Development Program (DRI). DRI is a funding and coordinating program that implements projects through existing agencies such as the national agricultural research and extension organization, the land reform bureaucracy, and several credit agencies.

Based on data gathered by DRI agencies and the author, this paper discusses management decisions at different levels of the project, and how those decisions directed or could have directed the benefits of the project to particular beneficiaries. The analytical approach of this paper follows a simple paradigm: a variable that can be manipulated by a manager is correlated with some beneficiary characteristic. A conclusion is then drawn about how the decisions did or could skew benefits to the poor. This method of analysis is fairly generalizable because monitoring and evaluation units are often appended to development projects. Results of this study (Romanoff 1986a, 1986b) and its monitoring approach are being used in Colombia. In Ecuador also, both the project and the pilot monitoring activity have been replicated, and some of the lessons from the Colombian case have been applied (Romanoff and Toro 1986, Romanoff 1987). This paper concludes with a note on the Ecuadorian experience and the limits of management and monitoring.

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BACKGROUND

Between 1981 and the start of this study in 1984, the DRI-CIAT project had stimulated the organization of **20** cooperatives of yuca farmers on the North or Atlantic coast; by 1987, ***36*** cooperatives were in operation. Each cooperative built, owns and operates **a** postharvest processing plant that consists of **a** yuca chipper, a drying floor, and a warehouse — a modest rural industry based on local production.

This study, on the institutional aspects of the DRI-CIAT project, was initiated in 1984 when the CIAT Cassava Program became interested in finding ways of lowering the cost of promoting and assisting the cooperatives. The institutional costs of any rural development project run high, but one that attempts to teach a new technology to **a** region, organize farmers' groups, and conduct studies can become ***so*** expensive that the implementors' costs eventually brake the diffusion of the technology.

The first task of the study was to design a scheme to monitor costs, It was time-consuming, hut not difficult, to describe and quantify the resources that institutions had used to promote the processing plants. In addition to cost data, the DRI-CIAT project needed information on beneficiaries because there were issues concerning who the project's target population ought to he. Gathering such data was easy once a quick hut reasonably clean sampling procedure was designed, based in large part on collecting the sales slips at the processing plants.

The issues about the project's intended beneficiaries included the desire of some functionaries to allow **DRI** to benefit farmers having more than 20 hectares (ha) of land. Still others felt that inclusion of the landless or near landless was **a** potential danger for the project, because the very poor might not he able to expand their yuca cultivation and the cooperatives might become intermediary organizations. They preferred that the plants be supplied by their owner-members, rather than buying from unaffiliated growers, because they felt that "intermediaries"--- even landless people organized to process yuca — are morally had. There was also an issue of feasibility. with some feeling that only the more wealthy farmers were likely to enter the associations.

The justification for t4e project's high-institutional costs, however, is precisely that apart from those costs it is both financially viable while it benefits economically marginal people. Indeed, the plants are more feasible among farmers with problems than among the well situated. For example, Paul Bode, a CIAT anthropologist who had been looking at the farmers' associations found that farmers with marketing problems were more likely to use the processing plants, because of their lack of access to traditional markets.

METHOD

The monitoring data used to evaluate management decisions were primarily derived from cooperative financial records: sales receipts for yuca, lists of wages paid, and membership roles. The agencies involved in **DRI** use these data for accounting purposes, but do not centralize them for analysis. Records are usually complete because the agencies insist that the cooperatives maintain the chits and because the farmer who provides yuca is paid after he turns in the receipt to the cooperative's treasurer. The slips, once ordered and "cleaned," constitute a list of all the people who sold yuca to the cooperatives; the list of beneficiaries was completed by obtaining records of wages paid and the division of yearly profits. In the cases where data on the distribution of profits were lacking, estimates were made.

The concern in this study was with the benefits from producing and processing yuca; some other benefits were not described. For example, because of high-institutional costs, one could consider the functionaries as the main beneficiaries of the project. The purchasers of dried yuca certainly saved money by having access to relatively cheap yuca instead of corn or sorghum. The fact that cooperative members benefited from the subsidies on plant construction was also not considered.

Basic data on beneficiaries were augmented by information on each member and on a sample of nonmembers selected from farmers named on the sales slips. Groups of members were also asked about people present and not present. The topics included approximate age, relationship to members, land tenure, type of land owned, and location of farm. In a separate exercise, government functionaries were asked about their background and their actions in support of the associations. The study also used in-depth interviews that are not reported here.

These methods were effective in this particular situation. The sales slips constituted a ready-made database that was accurate and complete. In many situations, it is possible to find such data, hut one always has to make a judgement regarding their reliability. For example, to estimate the number of houses in uncensused areas, I have used maps made by malaria service workers who spray every roof in an area (this required a correction factor for chicken coops); and to capture household expenditures, I have used the notebooks kept by monopolistic company stores that sold on credit.

In the Colombian case, third-party questions yielded useful information because the cooperatives are part of face-to-face communities, because the questions were matters of common knowledge, and because extreme accuracy was not needed. In many cases it was possible to check verbal data against records (e.g., if the person was a land reform beneficiary, his holding was registered; if a person was a cooperative member, his age was documented). An independent investigator checked some of the data, and made minor corrections in **30** percent of the entries, but with no substantial changes in results. Data were processed using microcomputers. Hand processing was not possible because of the large number of sales slips. Further, it was necessary to weight the sample data to correct for biases due to overrepresenting people who sold frequently to the cooperatives.

MANAGEMENT OPTIONS AND MONITORING DATA

The substantive, as opposed to methodological, discussion pertains to a particular type of technology. In its present form, technology requires an investment that is feasible for farmers' cooperatives, middlemen, feed manufacturers, large-scale farmers, or other businesses. Patterns of dissemination differ from those of, for example, new yuca varieties. But, the monitoring technique is potentially of equal use as shown by the discussion of the diffusion of new yuca varieties along the social networks of community leaders (Diaz 1986).

Decision 1: Choice of the Institutional Channel for Disseminating Technology

The major management decision that allowed the benefits of the Thai yuca drying technology to reach Colombian farmers was simple: The CIAT Cassava Program agreed to work with a development project already in contact with small-scale farmers. In the tripartite project involving CIAT, DRI, and CIDA, CIAT provided technology, technical assistance, and studies; DRI provided the pathway to the small-scale farmers; and CIDA promoted and funded the scheme.

DKI has been committed to working with small-scale Farmers from its inception. It has shown this commitment by having social scientists select areas to work on the basis of population concentrations of low-income farmers. and by placing a 20-ha limit on landownership of "DRI clients." However. DRI had serious problems due to lack of an agricultural technology that would benefit very small-scale farmers. Most of the attempted land reform cooperatives had failed, in part because they had no viable technology that required group cooperation. The remnants of such groups were the predecessors to some of the yuca processing associations (Rode 1986). DRI also had problems with its early attempts at delivering credit to the poor; badly designed loan schemes ended in tremendously high default rates.

The monitoring project found a correlation between the type of institution that disseminated processing technology and the potential recipients. Demonstration at a trade fair, for example. resulted in inquiries from larger-scale farmers. The monitoring data verified that DRI was indeed linked to small-scale farmers and that the yuca technology provided them with benefits. Processing plants had about 20 members each and purchased yuca from an additional 100 nonmember farmers. The majority of benefits from the plants' operations went to farmers with less than five hectares of land because so many of them joined the associations (Figure 1). The greatest *mean* benefits went to members with 7 to 13 ha (Figure 2). In terms of

Figure I. Total benefits by size of farm, 1984-1985, membersanly

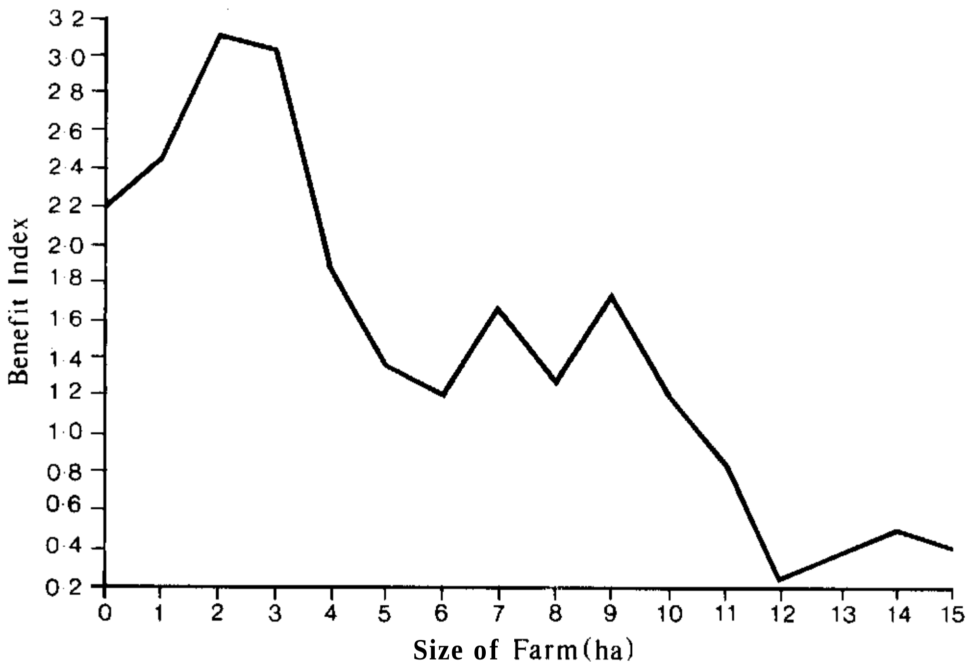
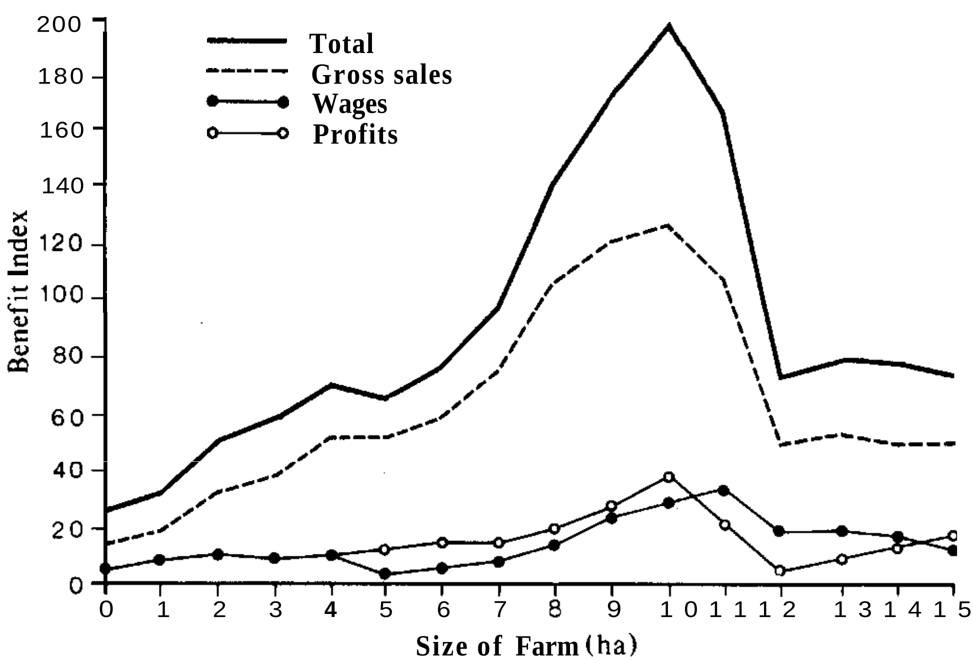


Figure 2. Mean benefits per member. by size of farm. 1984-1985



Note: Running **mean of three classes Benefits = gross sales + wages + profits.**

land tenure, land reform beneficiaries were the most active farmers in the project; even people with no land **of** their own were involved. When we consider the different kinds of benefits, we find that the nearly landless and the small-scale farmers provided half of the yuca processed by the plants as well as most of the labor.

Decision ***2*** Targeting Larger-Scale Farmers

The data just presented to discuss the nature of DRI's beneficiaries show that contribution to the project is ***not*** correlated with size of holding. Rather the relationship is bell-shaped. Therefore, deciding to bring larger-scale farmers into the project would not, ***ceterisparibus,*** have the intended effect of improving the supply of yuca. In fact, the processing plants would not have been feasible had they not attracted large numbers of small-scale farmers. This is a case where a management decision on eligibility requirements incorrectly presumed a linear correlation between size of farm and production of yuca for the project.

Decision **3:** Size and Location **of** Processing Plants

The capacity of a yuca postharvest processing plant depends on the size of its concrete drying floor. At the beginning of the Colombian DRI-CIAT project, the floors were 500 square meters (m^2). Economists demonstrated that it was profitable to increase the size of the drying floor, so new plants now begin with 1,000 m^2, still small in comparison to drying floors in Thailand, which reach 10,000 m2.

The current practice of building many small plants favors small-scale farmers **as** does the practice of locating plants where there is a densely settled population, where farm-to-plant distances can be kept short. Small-scale farmers often use burros to transport the yuca and are limited to short distances. On the other hand, large-scale farmers can transport yuca greater distances by truck. Drawing on distant farms would allow entry for intermediaries and larger-scale farmers.

One need not be among those who claim that intermediaries are exploitative to conclude that it is more efficient, to have farmers sell their raw product directly to a local 'plant. Processing a bulky, heavy raw material close to the fields where it **grows** reduces the cost of transportation, gives the value added to local people, and renders the project (given the current technology) more viable.

Decision **4** Emphasis **Among** Types **of** Benefits

The members of the yuca-processing associations benefit through sales of their fresh yuca, wages earned in the plant, and profits distributed at the end of the year, the latter being divided equally among members. One presumes that people with less land benefit relatively more from profits and wages than do people with more land, who should sell more yuca. This is the case, especially for the nearly landless. However, the minimal size of farm for selling substantial amounts of yuca is extremely low, and even the near-landless can sell something (Table I).

Table I. Types of benefit that accrue to nearly landless and small-scale farmers.

A. Proportion of benefits, by type of benefit (members only). Colombia 1984-1985.

Land holding (ha)	% of all members	% of gross sales	% of all wages	% of all profits
0-I (nearly landless)	35	12	24	25
0-5 (nearly landless and small-scale farmers)	16	52	59	64

B. Proportional distribution of benefits by type and size of holding. Colombia 1984-1985.

Holding size (ha)	Benefit (%)		
	Net gains from sales[a]	Wages	Profits
0-1	32	35	32
2-5	51	25	28
6-15	55	26	20
16 or more	50	31b	20

Notes: [a]Assumes that the farmer nets 50 percent from gross sales.
[b]Due to participation as managers in some of the more profitable cooperatives.

By emphasizing wages and profits, the cooperatives assist the poorest, nearly landless members. Changing the price paid for yuca modifies the relative importance of wages, sales, and profits in the mix of benefits. By lowering the price of yuca, one raises profits and could raise wages. This favors those members who depend on such benefits (Table 2). Thus, the monitoring system shows how to skew benefits to the very poor: increase wages and profits.

Table 2. Effects of yuca price on distribution of benefits. Colombia 1983-1984.

	Benefit (%)		
Yuca price (peso/kg)	Net gain from sales[a]	Wages	Profits
8	139[b]	Id	(-53)[b]
7	114[b]	Id	(-28)[b]
6	89	Id	3
5	63	Id	23
4	38	14	48
3	13	Id	73

Notes: [a]Assumed constant.

[b]The member gains by selling yuca, but loses equity in the cooperative because the cooperative loses money.

One of the notable features of CIAT Cassava Program in comparison to other IARC programs is that it emphasizes utilization technology. While all farmers might benefit from research on agronomy that lowers production costs for yuca, the low-income members of cooperatives benefit most from research that emphasizes utilization technology, new products, higher-value products, and expansion of labor opportunities. Emphasizing profits and wages benefits a particular type of marginal person: the farmer with broken terrain. Farmers with flat-land, which on the North coast are also likely to be better watered, do not lack for agricultural opportunities. Wages and profits from the processing operation are more important to the less favored. Thus, those with flat land obtained 73 percent of their benefits from selling cassava, but those with broken land obtained only 33 percent from sales, with the rest coming from wages and profits.

Decision 5: Cooperative Principles

There are many examples of how diverse factors can affect the relative importance of sales, wages, and profits. One is the conversion of the legally simple associations to complex cooperatives. Higher-level functionaries, eager to enlist the assistance of the national cooperative agency, promoted that change of status. Ideally, cooperatives are governed according to the "Rochdale principles" and a two-inch-thick government volume of regulations. One of the Rochdale principles is that profits or rebates are to be divided according to the degree that an individual uses the cooperative, that is, either buys from it or sells to it. Another is that membership is to be open to all, with free entry.

In the case of the yuca cooperatives, the distribution-according-to-use principle means that profits would be divided according to sales. Those who sell more yuca to the cooperative would benefit at the expense of those who sell less.

Because those who sell more are also likely to have more land, they, and not the very marginal, are favored by a scheme of rebates in proportion to sales. The application of the open membership principle, on the other hand, would make the benefits from profits insignificant. In these instances, the application of cooperative principles would make the associations less able to provide significant benefits to the nearly landless members.

Let us turn to another aspect of cooperatives: internal differences in benefits. An ideology of egalitarianism or solidarity is insufficient guarantee that an organization or institution is capable of providing benefits to its poorer members. In the case of the yuca associations, the degree of internal homogeneity is quite variable, as was shown when Gini coefficients were calculated for the members' benefits. For example, wages or the number of days worked were relatively evenly distributed among members of the cooperatives, except for the specialists who worked many more days than the rest of the members. Recruitment to the roles of manager, president, and secretary is of special interest when half or more of the cooperative's wages are paid to specialists.

Decision *6* Recruitment Techniques

For a local-level manager, a major decision is the mode of recruitment to farmers' associations or simply to selling yuca. In Colombia, recruitment along the lines of friendship and kinship has been beneficial, though we shall see that it resulted in some problems in Ecuador. In Colombia, propinquity is related to keeping the benefits of the plants among small-holders, even considering nonmember vendors. The more concentrated the clientele, the more they are socially integrated, and the closer the social bond, the more they tend to be drawn from the poor (Table 3).

Table 3. Farm size, by social relation of nonmember vendors, Colombia.

Social relation	Mean farm size (ha)
Kin	3.12
Friend	4.17
Known person	12.82
Previously unknown person	10.23

Indeed. propinquity is probably a prerequisite for member-managed processing plants, unlike the installations of, for example, milk-processing cooperatives. When associations try to take members from several towns, difficulties of communication and rivalries result in one town's members becoming dominant.

Decision 7: Recruitment of Functionaries

We now return to the issue of institutional links to farmers. turning the focus from the farmer-beneficiaries to the functionaries. This is an important and under-studied issue. CIAT has already published a report on the cost of the project (Romanoff 1986b). It was shown that the cost of institutional support to start a farmers' association and processing plant was US$30,000 in 1981, the first year of the project. and US$10,000 in 1984, and that it took between half and one person-year of direct effort.

Here we shall examine the social structure of the DRI bureaucracy as it pertains to successfully channeling new agricultural technology. DRI works with small-scale farmers. The social nature of the contact between low-level DRI workers and farmer "leaders" is also of interest. Equally important is the fact that DRI works at the upper levels of society, where it can capture resources.

DRI links the classes and regions of Colombia: the presidency and peasants. the capital and the provinces. and the source of technology and small-scale farmers. The DRI bureaucracy itself replicates these linkages in miniature: people of higher social class (as measured by land ownership) staff its upper levels (as measured by salary), and lower-class people staff the lower echelons.

At the upper end, the success of the project as a conduit for technological change depends on the capacity of the bureaucrats to use the unusual freedom that a DRI project allows. Throughout Latin America. such projects have been situated in the offices of presidents and ministers and given external funding so that they can bypass entrenched political structures. The success of the Colombian DRI agency depends on mobilizing functionaries to unusual effort, overcoming the usual constraints, and using social and official position on behalf of clients.

At the other extreme of the DRI social universe is a constellation of low-level functionaries, farmers. and local leaders. The former are not of farmer origin. but rather of poorer town or city origin. They have established links to recognized community "leaders" who arc not part of the bureaucracy. and thence to farmers. Some of the leaders in Colombia have gained their position through organizing land reform actions; a few are village notables, such as petty merchants. others were brokers who were known for their willingness to seek benefits for the village from outside agents. The link between leader and functionary often predates the formation of the yuca cooperative, having been established to organize land invasions. conduct on-farm trials, etc. In turn, the leaders had pre-existing enduring ties with other farmers, because they were in the same land reform unit. or because the cooperatives are units of kinship and propinquity, as will he discussed below.

A manager staffing a development project with the goal of diffusing new technology to farmers would do well to examine the social reality of the extensionist-leader-farmers complex at the working end of the bureaucracy, including the social characteristics of the people recruited into these roles. The peculiar constellation that characterizes the DRI project in Colombia (nonfarm, lower-class functionaries allied with leaders from the land reform movement) is probably not replicable in other situations, but every research-extension complex has functional alternatives.

The social analysis of bureaucracies is pertinent to topics widely discussed. Excessive turnover in agricultural research and development agencies is common. In the DRI project, the upper-level functionaries come from more prestigious jobs and expect to leave within five years for such jobs or for their own farms. Lower-level officials, from less-prestigious positions, have been in their agencies longer, and expect to stay longer finding them to be attractive in comparison to alternatives, hoping to advance by in-service training.

REPLICATION IN ECUADOR

In October 1985, CIAT introduced the yucadrying technology to Manabi Province, Ecuador. 'The methods used are similar to those of Colombia, and many lessons learned on the North coast have hecn applied in Ecuador with the goal of replicating the technology without incurring the high institutional costs of the initial experience. Some of the patterns among beneficiaries that are emerging from the first Ecuadorian experience are like those of Colombia because in both countries the project works in areas with substantial numbers of small-scale farmers. The mix of benefits is similar, small-scale farmers prevail among beneficiaries, and the correlation between distance and social relations is the same in both countries. The Colombian associations have let in more marginal people, while the Ecuadorian farmers have chosen owner-farmers for the most part (Table 4).

The equivalent of DRI's capacity to form associations among lower-income farmers was found in the Ministry of Agriculture's communal development projects. Working with an existing agency was mutually beneficial in 1986 in Ecuador for the same reason that it worked in Colombia: agencies are able to form groups, but once the groups are formed their persistence requires economically viable activities better performed by groups than individuals. The yuca technology filled that need. The upper-level bureaucrats of the Ministry of Agriculture provided valuable links to funders, buyers, and other institutions, as did the DRI bureaucrats in Colombia. However. an important contrast was the lack of Ecuadorian bureaucrats of lower-class origin.

In Ecuador, lessons from the North coast monitoring exercise were modified and applied. While some prove true and useful, the limits of "management" are becoming clear, Sometimes the only thing that monitoring does is allow one to sce clearly how things are not working out as well as they might. For example, the trade-off between yuca price. wages. and profits is the same in both countries, but in Ecuador.

Table **4.** Comparison of Ecuador and Colombian experiences.

	Benefits	**Ecuador 1985** (%)	Colombia **1984-1985** (%)
A.	Size of farm (ha), members		
	0.0-0.9	**5**	**21**
	1.0-4.9	**65**	**53**
	5.0-19.9	**25**	**25**
	20 or more	I	**5**
B.	Land tenure		
	Permanent use: owner, **land** reform, land reform II, communal assigned	**80**	**59**
	Kin's land	**5**	17
	Renter, loan, sharecrop, for improvement	10	**24**
	Landless	**5**	I
	Total	100	101
	(n)	20	**394**

perhaps because the project is new, strong factions in the associations **seek** to raise the price of yuca beyond the limits that allow profits.

Further, both the reality of local stratification and members' perceptions of internal stratification are problems in Ecuador; factions form about this issue and the effectiveness of leaders is diminished. Knowing that internal stratification was occurring did not result in functionaries taking effective action.

In the Ecuador project, few lower-class people have been brought into the bureaucracy, and the nature of local stratification, and hence of farmer 'leaders" **is** different. In Colombia, very large-scale farmers compete with small-scale tarmers for land, trying to avoid all contact with them; in Ecuador, merchants and small-scale landlords still live and associate with small-scale farmers. Therefore, the equivalent of the Colombian functionary-leader-farmer complex is functionaries of middle-class origin in contact with local notables, who in turn have clients. This social constellation **is** less effective than the Colombian for mounting a farmer-owned company. To cite an example of a problem: a "leader" who was a coffee merchant, convinced his association not to process coffee on the drying floor in the off-season: his interests, diverging from the members, prevailed.

In order to have a farmer-functionary within the project, expert farmers were brought from Colombia to teach drying techniques. This *campesino-to-campesino* (peasant-to-peasant) technical assistance model was efficient, especially in its second stage when the experts were Ecuadorian fanners who taught in a second province. To cite another example of the limits of monitoring, the Colombian data show that members resident in the town where the processing plant is located receive more than 10 times the benefits received by out-of-town members. Therefore, during the formative stage of the Ecuadorian groups, it was suggested that only nearby farmers should be allowed to join. Some groups deviated from this suggestion; some of the more distant farmers are dropping out and there are problems of communication among members. One could see the problem coming, but members made decisions based on such local factors as prior membership in project groups.

SUMMARY AND CONCLUSIONS

The kind of monitoring system that worked in Colombia also works in Ecuador, and the patterns revealed are similar. Monitoring data. and social analysis were useful in setting up the Ecuadorian replication of the technology, but there are limits to the use of such data.

* Methodology. By slightly augmenting project monitoring activities, it is possible to show who benefits from a project introducing new agro-industrial technology, how they benefit, and the basic social factors that are correlated with their participation.

* Benefiting the poor and project feasibility. The monitoring data show that the participation of the landless and near-landless in the DRI-CIAT project was much greater than had been expected. The members with five hectares or less supplied half the yuca provided by all members and more than half of the labor. These data support the position that the small-scale farmers made the plants more feasible, rather than less.

* IARC collaboration with development projects. The principal reason that the new technology reached small-scale farmers was the collaboration between the CIAT Cassava Program and the Colombian DRI program, the latter (with the land reform) being a bridge between the centers of Colombian society and its marginal farmers. CIAT had technology appropriate to small-scale farmers that was not diffusing very quickly; DRI had contact with farmers and resources, but insufficient technology. Both institutions and their respective functionaries benefited from the collaboration.

* Agency social structure. Social analysis of research and extension organizations is pertinent to problems that have been approached from different perspectives. The social nature of the extensionist-leader-farmer complex at the lower end of the bureaucracy has been identified as an important institutional variable.

* **Replicability.** The monitoring data techniques presented here were replicated in Ecuador and similar patterns were found. The central aspects of the project were repeated with some success in Ecuador — and with enough difficulties to make for a realistic assessment of the efficiency of monitoring and management.

The general conclusions of this study are that new technology can reach small-scale farmers in an expeditious and preferential way by developing and refining appropriate institutional means. This process can be described, replicated, and made more efficient by monitoring the results and using those results to make informed decisions.

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INFORMATION MANAGEMENT IN AGROFORESTRY RESEARCH AND DEVELOPMENT: FOR WHOM AND BY WHOM?

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INTRODUCTION

This paper discusses information management in the agroforestry research and development context,' based on the experience of the ICRAF. "Information management" is taken in the broadest sense as encompassing all forms of generation, acquisition, processing, storage, retrieval, and control of information. The main focus of the paper is on information management within the scientific community and between scientists and the rural farming community.

DEVELOPING AN AGROFORESTRY PARADIGM

Agroforestry is an ancient land-use practice among traditional farmers in many parts of the world, but a relatively new field of organized scientific activity. Prior to the scientific rediscovery of agroforestry, the inexorable course of specialization and compartmentalization in the agricultural sciences had created an almost total separation of forestry from agronomy and allied disciplines. Under the **old** paradigm, trees and agricultural crops simply did not belong together.

By the late **1970s**, however, interrelated problems of energy shortages, declining productivity of food production systems and general environmental deterioration in tropical band-use systems had reached crisis proportions, and it was no longer politically tenable for the international' scientific community to persist in its studied ignorance of agroforestry alternatives. Meanwhile, it was becoming apparent that the solutions too were interrelated. Everything seemed to point to agroforestry.

Forerunners of a scientific agroforestry can be found in the horticultural, forestry, and range management traditions (cf. Smith **1950**, King **1978)**, but the first widely acknowledged statement on the scope of the new field of research did not come until **1977** the year in which ICRAF was founded. The essence of the new paradigm is implicit in the definition of agroforestry given in the landmark IDRC study, *Trees, Food and* ***People:*** "Agroforestry is a sustainable management system for land that increases overall production, combines agricultural crops, tree crops and forest plants and/or animals simultaneously or sequentially, and applies management practices that are compatible with the cultural patterns of the local population" (Bene, Beall, and Cote **1977)**.

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This is a *normative definition* that states not merely what agroforestry is (i.e., any cropping system that combines woody plants with herbaceous crops or animals), but also what it should be -- an approach to land use that is productive, sustainable and culturally appropriate. It was soon recognized, however, that these are goals to be achieved by diligent research and design effort, and not attributes to be automatically ascribed to any combination of components that happens to meet the minimal criterion of an agroforestry system.

The line of action envisaged in Trees, ***Food and*** People heralded a clear **break** with the time-honored separation of forestry from agriculture and allied disciplines. While agroforestry is not simply a branch of forestry, the novelty of agroforestry as a new scientific synthesis lies in the realization that many different land-use systems and practices — some of which have fallen into the field of horticulture, some into agriculture, forestry and range management, and a considerable number of which have not had any scientific attention whatsoever — all have a common denominator worth exploring in a more systematic and scientific manner. This is the **role** and potential of woody components to increase, sustain, and diversify the production from the land (Lundgren and Raintree 1983). (Table 1).

Table 1. Potential contributions of trees and shrubs to the satisfaction of basic human needs.

Food

1. Human food from trees (fruits, nuts, leaves, cereal substitutes, etc.).
2. Livestock feed from trees (one step down the trophic chain).
3. Fertilizer from trees for improving the nutritional status of food and feed crops through a) nitrogen fixation, b) access to greater volume of soil nutrients by deep rooting **trees,** c) improved availability of nutrients through raised **CEC** and organic matter levels.
4. Soil and water conservation effected by runoff and erosion controlling arrangements of trees in farming systems (future benefits through enhanced sustainability of cropping systems).
5. Microclimate amelioration associated with properly designed arrangements of trees (e.g., shelterbelts, dispersed shade trees) in crop and grazing lands (indirect production benefits).

Water

1. Improvement of soil moisture retention in rainfed cropping systems and pastures through improved soil structure and microclimatic effects of trees.
2. Regulation of streamflow for reduction of flood hazard and even supply of water through reduction of runoff and improvement of interception and storage in infiltration galleries through various watershed protection practices involving trees.

3. Protection of irrigation works by hedgerows of trees.
4. Improvement of drainage of waterlogged or saline soils by phreatophytic trees.
5. Increased biomass storage of water for animal consumption in forage and fodder trees (higher water content of tree fodder in dry season).

Energy

1. Firewood for direct combustion.
2. Pyrolytic conversion products (charcoal, oil, and gas).
3. Producer gas from wood or charcoal feedstocks.
4. Ethanol from fermentation of high-carbohydrate fruits.
5. Methanol from destructive distillation of catalytic synthesis processes using woody feedstocks.
6. Oils, latices, other combustible saps, and resins.
7. Augmentation of windpower using appropriate arrangements of trees to create verturi effects.

Shelter

1. Building materials for shelter construction.
2. Shade trees for humans, livestock, and shade-loving crops.
3. Windbreaks and shelterbelts for protection of settlements, cropland, and pastures.
4. Living fences.

Raw materials for local processing

1. Wood for a variety of craft purposes.
2. Fiber for weaving industries.
3. Fruits, nuts, etc., for drying or other food processing industries.
4. Tannins, essential oils, medical ingredients, etc.

Cash

1. Direct cash benefits from sale of any of the above products.
2. Indirect cash benefits from productivity increases (or input savings) in associated crops or animals.

Savings/investment

1. Addition of a viable emergency savings or investment enterprise to farms now lacking one.
2. Improvement of existing savings/investment enterprises (e.g., fodder for cattle as savings on the hoof).

Social production

1. Production of goods for socially motivated exchange (e.g., cattle for bride price, ceremonial foods, etc.).
2. Increased cash for social purposes (ritual expenses, development levels, political contributions, etc.).

There was a lot of ground to cover in exploring the implications of the agroforestry approach, and much of ICRAF's early program of work was devoted to the conceptual development of the new paradigm (King and Chandler 1978, Raintree and Lundgren 1985, Rocheleau 1987). One of ICRAF's main activities was to convene a succession of international conferences, bringing together agroforestry innovators from a wide range of disciplines to pool their perspectives and create a shared sense **of** direction for the newly emerging community of interest.

Another main thrust **of** ICRAF's program of work was the development of ***methodologies*** for agroforestry research. Although ICRAF, through its outreach program, has lately begun to play a dramatically increased role in the direct conduct of agroforestry research. However, as a research council with a limited field station capability rather than a fully equipped research institute modeled on the CGIAR centers, ICRAF's major emphasis has always been on strengthening the capacity of developing country researchers to do their own agroforestry research. The development of methodologies, and their dissemination through publications, training courses, and collaborative research activities, has been one of the main vehicles for this institution-building role.

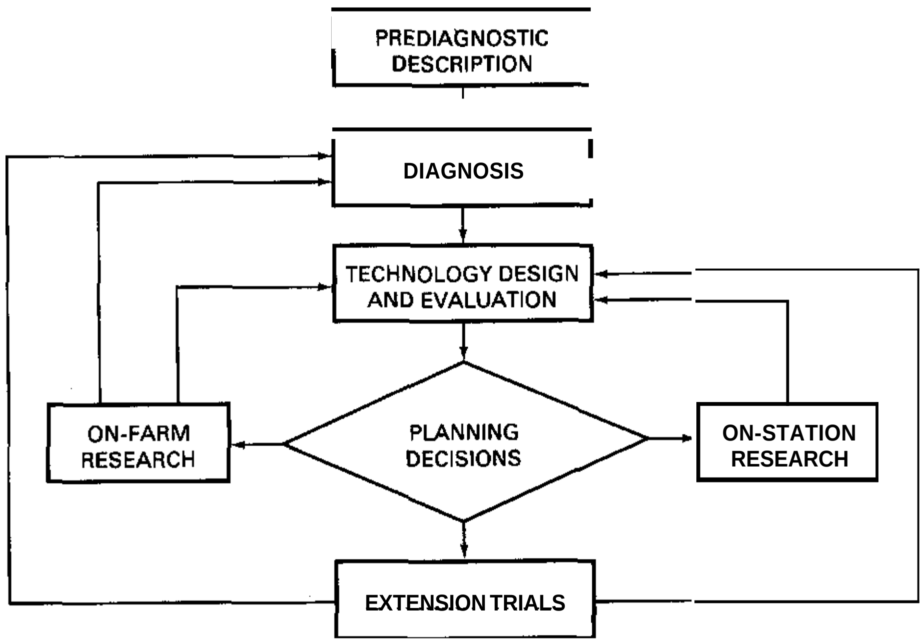
A METHODOLOGY FOR AGROFORESTRY DIAGNOSIS AND DESIGN

In order to operationalize a "systems approach," the priority activity in ICRAF's early strategy and program of work was to develop a diagnostic methodology for the identification **of** research priorities in agroforestry.

The identification of research priorities is seen as being derived from an effort to develop the existing land-use system. A diagnosis is not of much practical use unless it leads (via research in most cases) to a prescription. In order to reinforce the implicit perspective on the role of agroforestry research **as** a means to rural development (the end), the design aspect was made explicit and the resulting methodology came to be known as the "diagnostic and design" or "D&D" methodology for agroforestry (Raintree 1982, 1984). The elaboration and refinement of the D&D methodology is a continuing process, which ICRAF is pursuing through collaboration with researchers and rural development workers in many parts of the world.

D&D is characterized by: 1) a specific focus on agroforestry-related problems and potentials within a general developmental context (i.e., it makes **sure** that the trees within the farming system are not invisible, as is often the case with commodity-oriented research); **2)** a broader diagnostic scope, consistent with the wide range of agroforestry potentials (Table 1); **3)** a focus on the land user's objectives and adoption capabilities as the starting point for agroforestry interventions; **4)** a more explicit set of technology design procedures; ***5)*** variable scale methods for household, watershed/community and ecozonal/regional levels of diagnosis and design; and 6) insistence on the iterative nature of the adoptiondriven D&D process (Figure 1) comparable to the cyclic process of the "farmer-back-to-farmer" model (Rhoades and Booth 1982).

Figure 1. Information flow and processing in an agroforestry research-for-development project which incorporates the iterative D&D process as part of its internal guidance system. Note the feedback linkages between sources of new information (on-site trials, on-station research and, extension trials) and the repeated rediagnosis, redesign, and planning process.



Early methodological guidelines (Raintree and Young 1983, Raintree 1983, 1984) were designed for rapid appraisal applications by a highly qualified multidisciplinary team consisting of an agronomist, a tree specialist, a social scientist, and, if livestock were an important part of the system, a livestock/range management specialist.

Putting such a team into the field is a relatively expensive undertaking; consequently, the pooling of personnel from different national institutions, supplemented by an ICRAF team leader and other staff selected to round out the disciplinary composition of the team, became standard procedure in D&D exercises. The principle of needing a minimal multidisciplinary "critical mass" to plan and implement agroforestry D&D has since become a cornerstone of the on-the-job training approach to the development of national agroforestry cadres (Torres 1985, 1986). In the context of this multidisciplinary team approach, the D&D methodology has served the need for a logical, step-by-step procedure to organize collaboration between team members with very different disciplinary viewpoints and problem-solving approaches.

The logic underlying the D&D methodology embodies a common-sense problem-solving approach. If the agroforestry technologies envisaged in the design already exist, the design can be used directly as a guide for agroforestry interventions by extension agents and rural development workers. If the technologies envisaged for the land-use system have not yet been developed, the design serves as a basis for identifying the research gaps that need to be filled. The logic of this discovery procedure seeks to enhance the practical impact of the research process by relating the ***research objectives*** to specific ***development objectives.***

Any rapid appraisal D&D procedures used to initiate research or development activities must be followed up by continued monitoring and evaluation of the situation as it develops over the course of the project. In the D&D approach, this internal process takes the form of refining the original diagnosis on the basis of more in-depth information resulting from continuous exposure to the land-use system. It also involves improving the technology design in the light of new information from on-farm trials with farmers, more complex and rigidly controlled on-station investigations, and eventual extension trials in a wider range of potential sites.

By adjusting the plan of action to new information, the D&D learning process becomes continuous and self-corrective. as suggested by Figure 1. Starting from a ***generally appropriate*** design concept, based on the initial rapid appraisal D&D exercise, project implementers work closely with farmers to develop agroforestry designs that are ***specifically appropriate*** to the situation at hand. Two main trends have been apparent in the development of the D&D methodology: 1) the expansion of the procedures to accommodate progressively larger spatial and social scales of application, and 2) the gradual transition from an initial concentration on procedural aspects of the methodology toward a sharper focus on substantive aspects of D&D as the knowledge base on agroforestry has matured.

Variable-Scale D&D Procedures

Initially, the methodology focused on household/farm-level D&D (Raintree 1981, 1982). Distinctive features of the methodology at this scale are: 1) a basic needs approach to the identification and evaluation of household production subsystems, 2) a troubleshooting procedure for identifying critical constraints, and 3) a separate assessment of the sustainability of the land-use system under the most likely future scenario.

While the household land management unit will usually provide one of the key focal points for agroforestry development. larger-scale interhousehold social organizations (e.g., women's self-help groups) may facilitate opportunities for agroforestry-related activities that would be missed by an exclusive focus on households (Rocheleau 1984). "Meso-scale" D&D methods have been developed to address agroforestry-related problems and opportunities at the community/ local ecosystem level (Rocheleau 1983a, 1983b, 1984, 1985, Rocheleau and van den Hoek 1984). These methods include: 1) analysis of potential spatial and functional complementaries between different management units within the larger system, and **2)** local small-group process approaches to the organization of agroforestry activities such as group interview techniques and neighborhood nurseries based on traditional self-help organizations (Rocheleau 1984, Rocheleau and Vonk 1983).

Most recently, in order to provide a basis for very large-scale collaborative research networks, a macroscale version of the D&D process has been developed (Scherr, this volume) and used in the formulation of country-level agrofarestry "blueprints" and multicountry research programs within the Agroforestry Research Network for Africa.

Procedural versus Substantive Aspects of Agroforestry D&D

In 1981, when the D&D work was first initiated, agroforestry was still a very new concept. It was a deliberate part of ICRAF's strategy as an "honest broker" (Steppler and Raintree 1983) to avoid prejudicing the development of the field by premature commitment to a particular set of technologies. The diagnostic approach itself was felt to be the best safeguard against "pet technology" biases.

The open-ended multidisciplinary methods are not without problems, however, when applied by inexperienced practitioners. The chief weakness of the open-ended procedures typically occurs in the transition from diagnosis to design. Although a good diagnosis of the situation **is** often all that **is** needed to suggest the nature of the required solution, and while the D&D procedures are specifically designed to lead in a logical fashion from the diagnosis of constraints and potentials through the listing of system and technology specifications to a concrete agroforestry design, the procedural logic in itself provides no guarantee that the result will be appropriate. Design is. after all. a creative process and there **is** a lot of ill-defined "heuristic" knowledge that comes into play when the D&D methodology is applied by expert practitioners.

One of the main tasks facing ICRAF today is that of systematically cataloguing known agroforestry technologies, delineating their recommendation domains provisionally (Tripp 1986), and developing a simple "matching approach by which specific technologies may be called up for consideration when, and only when, the relevant system characteristics and diagnostic conditions are encountered. There will always he occasions on which expert agroforestry designers will want to override the indications provided by such decision aids, but there can be little doubt that the practice of agroforestry D&D would he improved by the existence of such reference tools. The most promising direction for future development of the D&D approach, therefore, seems to be not in the endless refinement of increasingly sophisticated procedures, but in developing the substantive knowledge base for matching particular agroforestry technologies to specific diagnosed conditions.

In practice, of course, there is no need to choose between substantive and procedural aspects of the methodology, because the two are entirely complementary. Comparative knowledge of agroforestry systems can he used to complement information from D&D field surveys, first to identify agroforestry prototypes worth considering (using a "matching" approach), and then to work out a detailed site-specific design for the land-use system in question. Needless to say, all designs should he considered provisional until they have gone through the iterative process of trial and refinement with local farmers.

AGROFORESTRY RESEARCH FOR WHOM?

There are three main sets of actors on the agroforestry scene: scientists, farmers, and change agents (i.e., extensionists and rural development workers concerned with agroforestry). The interactions among and within these groups define the larger set of information management concerns relevant to agroforestry as a whole (Figure 2). Interactions within a group define more or less distinct "informational communities" — the scientific community, the development community, and the rural community itself. The remaining cells represent the communication channels and interface situations that link the different communities.

ICRAF's emphasis to date has been on information processing within the scientific community and between scientists and farmers. The emphasis on these two cells of the matrix is consistent with the role normally played by IARCs under the Farming Systems Research paradigm. As with other international organizations, ICRAF has been hesitant to assume a direct role in extension on the grounds that this would entail an unsustainable dilution of limited resources. There are, however, a number of indirect roles which ICRAF could play, and to some extent has already begun to play, in providing informational support to extension workers in both formal sector and informal sector (e.g., nongovernmental organizations) institutions. There may also he something to he done in support of the processing of agroforestry information within the farming community itself.

Figure **2.** Communication channels and informational communities in agroforestry research and development.

	Scientist	Change agent	Farmer
Scientist	**Scientific community**	**Research/extension** interface	**Researcher-farmer** interface
Change agent		**Development** community	**Extension interface**
Farmer			**Rural community**

Whatever its ideal use and potential might be, as currently practiced by scientists in formal sector research institutions, the D&D methodology falls somewhat short of achieving a true two-way communication with farmers. As recent reviewers **of** ICRAF's variable-scale D&D methods have commented "In a general sense, the ICRAF approach tends to be 'bottom up' at the microlevel, 'top down' at the macrolevel. In either case, ICRAF is working from the outside in" (Steiner, Duchhart, and Bassman, in press).

The limitations of D&D in practice are not in the logic of the methodology itself, but rather in the institutional context in which it is practiced, (i.e., the institutional reasons for doing D&D and the uses to which the information is put — namely, research by scientists in formal research institutions).

Two Centers of Agroforestry Research

Informal agricultural research by farmers has been a continuous feature of the farming scene since the dawn of the Neolithic. Without it we would have none of our contemporary crops and, indeed, very little agricultural technology at all. The vast majority of agroforestry technologies currently recognized and catalogued have originated on farmers' fields.

Even when farmers are only adopting a technology developed on the research station, they tend to do it experimentally — step by cautious step on a little corner of their land. In the process, the technology is usually adapted to fit the farmers' circumstances. Ultimately, it is the farmers' thinking — not just that of professional researchers — that must be influenced if improvements in land use are to come about. This process is not an alternative to what professional researchers do, but a necessary and complementary step in the sequence of rural development processes.

There are two centers of agroforestry research and innovation: a formal sector comprising research institutes, and an informal sector comprising farmers. Either in isolation from the other is a pale reflection of what could be achieved if the potential synergy of the two could be realized. How is this to be achieved? Richards (1985) suggests a number of promising approaches. A minimal strategy would attempt to minimize conflict between formal and informal sector research processes and, more actively, attempt to focus formal sector resources on research problems that the farmers themselves have identified, but cannot handle. A more active strategy would encourage "sideways extension." Extension agents might be trained to record and evaluate indigenous innovations and assist in diffusing this information to other farmers "Participatory research" is a still more active approach in which the scientist would operate as a consultant to local user groups engaged in their own research. In Richards' view, successful participatory research would depend upon I) regular and continuous contact between scientists and their village clients (implying willingness of scientists to live and work for long periods in the village), and *2)* the **prior** existence of strong local organizations capable of formulating and carrying out their own D&D activities.

Extension Research and Development

The new kind of professional fieldworker needed to realize Richards' "participatory approach might be termed an "extension research and development agent" (ER&D), and would seem to offer the most promising mechanism for synthesizing research information to develop locally appropriate designs.

What is envisaged is a complementary relationship between two kinds of research professionals: 1) institutionally oriented researchers with a classical research orientation, modified somewhat by an FSR type liaison with the rural community, and *2)* community-based ER&D agents with a much more applied orientation, who are capable of playing the dual role of technology development catalyst within the rural community and information broker between the community and externally based researchers.

In such a collaboration, between the two types of researchers, the focus of the community-based researcher might be on adaptive research (to adapt and improve researcher-originated technologies for a better fit with local conditions) or what we might call exploratory research (to explore and develop new prototype technologies). Community-based D&D teams are likely to be the best source of relevant prototype designs, but these could probably be enhanced by formal research efforts to identify improved germplasm and to generate experimental data needed to derive the optimal technology design for a given land-use system.

Training of community-based researcher-extensionists. How would one train a cadre of individuals capable of performing this hybrid role and from where might they be recruited? Candidates might be recruited from farming systems teams, from community forestry units, from upper levels of extension service field staff, or from the NGO community.

It would be critical to equip these new professionals with the skills required to stimulate innovations and to facilitate communication. among farmers, researchers, and extensionists. The diagnosis and design methodology could he adapted to serve both of these needs, first as a discovery procedure for keeping the innovation process on track *vis-à-vis* the development needs of the community and second as a basis for communication about relevant technology (Raintree 1987).

To my knowledge, the only organization on the agroforestry scene today that has addressed both these training needs is **CARE** International. CARE's agroforestry extension project in the Siaya District of western Kenya began in **1984** with the setting up of nurseries for multipurpose trees with seven local self-help groups. In the 3 years since this modest beginning. the project has expanded to some 425 farmers' groups and school nurseries and has reached an impressive 10 percent of the households in the district with direct extension inputs. In the last planting season of 1986 these groups produced an incredible 1.5 million tree seedlings for agroforestry plantings on the farms of group members. The Siaya project is regarded as the most successful within CARE's network of agroforestry projects, which now extends to some 30 projects in 29 countries, and there are plans to add a research and training component to the project to enhance the research capability of the project and meet the demand for wider training in its methods.

The choice of tree species, planting niches, and arrangements for locally appropriate agroforestry systems in the Siaya project was made using a variant of ICRAF's D&D methodology modified for extension application with enhanced participation of farmers in decision making. The operational model was based largely on experience with the meso-scale group process approach developed by **ICRAF.**

AGROFORESTRY INFORMATICS: A FOCUS FOR ICRAF'S SERVICES TO THE WIDER ACROFORESTRY COMMUNITY

No single organization can meet all the information management needs of a field as broad and active as agroforestry. **ICRAF** operates as the central node of a large and active collaborative research network, but this type of direct collaboration in research reaches only part of the total agroforestry community. Thus. an appropriate role for a centralized organiration like **ICRAF** compared to the rest of the agroforestry community, may be to provide other actors on the agroforestry scene with informational support. The remainder of this paper focuses briefly on two examples of such services.

User-Friendly Access to ICRAF's Data Banks

In the 10 years of its existence, **ICRAF** has accumulated a wealth of relevant information on agroforestry components and systems in its library and in several large microcomputer databases, such as the multipurpose tree database (Carlowitz 1984), the database of ICRAF's recently completed global agroforestry systems inventory (Nair 1985), and others (Young 1987). In addition, there is a growing body of case study material from D&D applications with ICRAF's national partners. ICRAF operates a widely used information service which provides answers to specific requests from users, but it does not at present provide a service capable of meeting fully the needs of a community-based D&D catalyst.

The problem in making this knowledge base available to potential users is in achieving an efficient turn around on query responses within a user-friendly information access system. For ICRAF to respond to the potential volume of information requests of this type from the field would place an impossible burden on staff resources. This is because, surprisingly, we are still using quill and scroll methods to manage the information contained within our microcomputers, In order to realize the full potential of the growing knowledge base on agroforestry theory and practice, and to get this information out into the field where it can be used, new information management technology is needed. The rate of the expansion of agroforcstry knowledge is simply greater than any single individual or group of individuals can keep tract of by conventional methods of information collation and synthesis.

Given a strategy which focuses on returning relevant design information in response to diagnostically well-structured queries, recent developments in the field of knowledge engineering (i.e., the synthesis of database management with expert systems software) would seem capable of bringing this kind of information service into the realm of possibility. In the absence of an adequate information management system that can cope with the expansion of cumulative experience. agroforesters are destined to keep reinventing the wheel. No information management system is expected to be perfect. but in the age of the microchip it is unimaginative to persist in this kind of muddle. Starting with what we do know we can develop information management systems that learn. To update and maintain an information management system of this type would require a major commitment of new staff resources. but this is precisely the kind of service that a centralized organization like ICRAF is uniquely suited to undertake.

User-Friendly Information Management for Agroforestry Research and Extension Projects

The lack of an efficient and easy-to-use system for processing and keeping track of information relevant to project management is one of the major bottlenecks in agroforestry projects around the world. Even where projects have achieved notable success (e.g., in stimulating tree planting or generating relevant research data), they may fail to achieve their full potential in rural development, because they are simply not able to respond quickly enough to the feedback of relevant information from the project site.

Most agroforestry projects start out with good intentions — ambitious monitoring and evaluation schemes and carefully designed research plans. Many projects actually manage to collect the desired information, in spite of serious time constraints. Typically, however, projects gather far more information than they can process. The all too common result at the conclusion of the project is a room full of unanalyzed data and a project area full of unlearned lessons and missed opportunities.

The need for an adequate information management system is particularly critical to the success of community-based, participatory research and development efforts in agroforestry. Given the unproven or "experimental" nature of most agroforestry technologies, extension projects must come to terms with their moral responsibility to monitor the impacts of their interventions and adjust their extension messages accordingly. On the research side, the approach encouraged by ICRAF, and now being adopted on a large scale in Africa, starts from the premise that agroforestry research must address real needs of local people and that the people themselves must participate actively in the D&D process through collaboration in on-site research. In both types of projects, reaping the potential benefits of local participation in agroforestry research and extension requires an information-intensive approach to project management.

The synergistic potential which is implicit in approaching the information management needs ol agroforestry from both ends (i.e., by developing information systems. for community-based agroforestry projects as well as for centralized clearing houses like ICRAF) will be realized only if the linkage between the two is explicitly developed. The D&D logic may serve as a kind of *lingua franca* for communication across this interface, but one suspects that the improved information systems will not be effectively used until there is a new type of development-oriented professional to fill the gap between research and extension — an "information broker" with an "engineering" orientation and a talent for design, who knows how to get the best out of research scientists hut whose clients and co-workers are the rural people themselves.

CONCLUSION

ICRAF has hecn active in developing the informational linkages commonly addressed by farming systems programs in the IARCs, but there is still a lot to be done to realize the potential suggested by an analysis of remaining information yaps. There is no reason for ICRAF to play a leading implementation role in all aspects of agroforestry research and development and obvious reasons why it would he impossible or inadvisable to attempt it. Nevertheless, as a central repository of agroforestry information, as a source of methodological tools. and as a vigilant guardian of the social and ecological goals of agroforestry's interdisciplinary paradigm. ICRAF has a unique role to play in support of other actors on the agroforestry scene. This is the age ol informatics. Thus. the best way for developing countries to realize the full potential of agroforestry in rural developing is through the efficient use of modern information management technologies

NOTES

'This paper does not attempt to deal with **all** aspects of information management handled by ICRAF, such **as** the acquisition, storage, and retrieval of bibliographic and related information by ICRAF's information division. See Labelle (1987) for a discussion of these more general aspects of information management in agroforestry.

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