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Proceedings of the Workshop Social Science Research and the CRSPs

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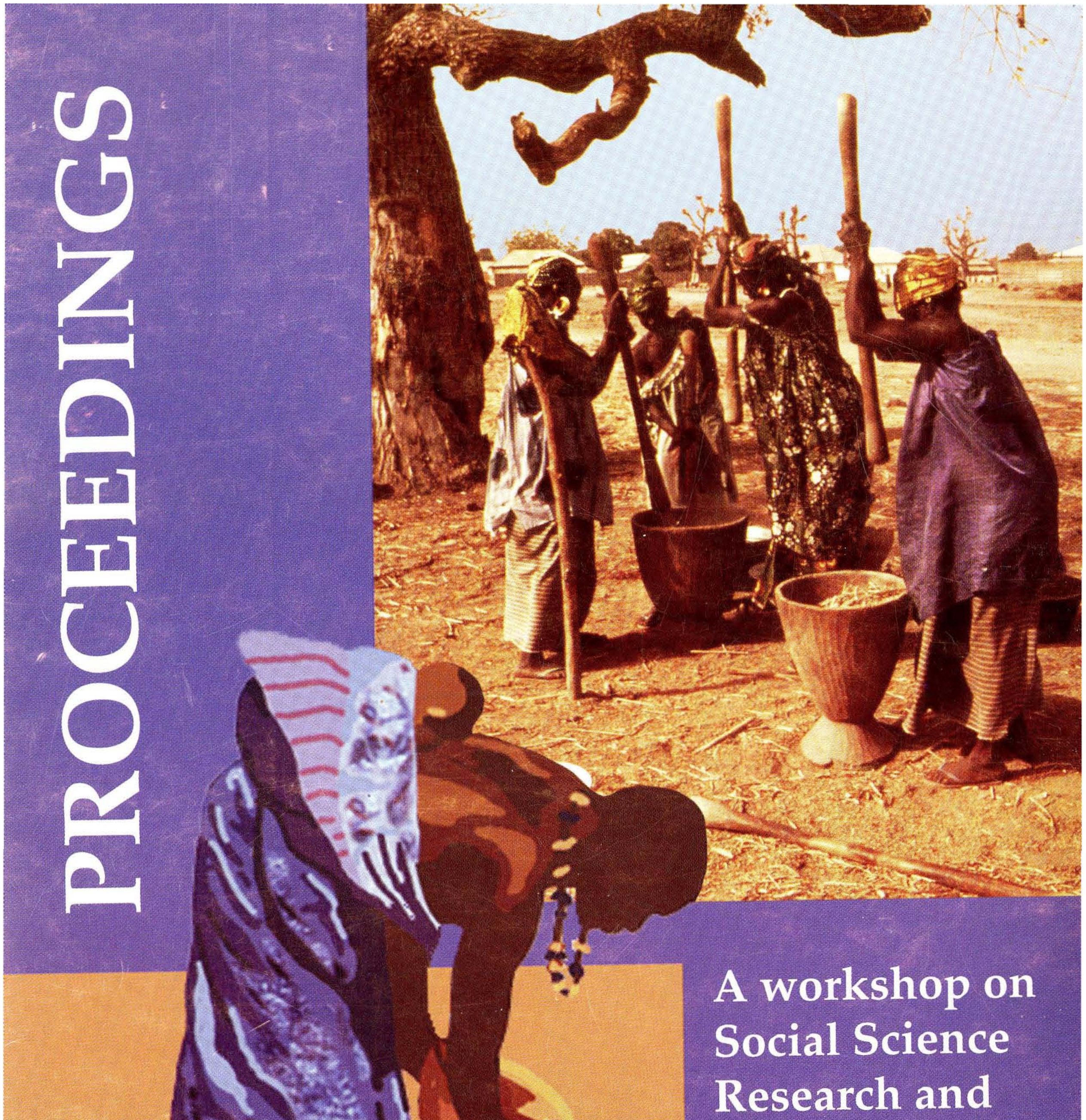

PROCEEDINGS

A workshop on Social Science Research and the CRSP's

June 9-11, 1992

Carnahan Conference Center
University of Kentucky
Lexington, Kentucky

Photos courtesy of the Collaborative Research Support Programs (CRSP)

Small Ruminant CRSP
SANREM CRSP
Peanut CRSP
Pond Dynamics CRSP
Sorghum/Millet CRSP
Bean/Cowpea CRSP
Soil Management CRSP

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Contents

Executive Summary: A New Agenda for CRSP Social Science Research - C. Milton Coughenour vii

Session 1

Developing a Strategic Research Agenda
David G. Cummins, Chair

Framing a Strategic Research Agenda - John Yohe 3

Social Sciences and Collaborative Research: Toward an Agenda for the Social Sciences in Agriculture - Jere Lee Gilles 7

Session 2

Technology Development and
Sustaining Household Food Security
Kathleen DeWalt, Chair

Technology Development and Household Food Security - John M. Staatz and Richard H. Bernsten 21

Differences among Women Farmers: Implications for African Agricultural Research Programs - Anne E. Ferguson 47

Session 3

Issues of Increased Production and
Changing Consumer Demand
John H. Sanders, Chair

Sociopsychological Aspects of Consumer Preferences - Stephen G. Sapp 65

Problems of Commodity Markets in Developing Countries: Implications for Technology Development - Bruce F. Johnston 75

Session 4

Food Policy and Sustained Development
Billie R. DeWalt, Chair

Socioeconomic Implications of Biotechnology for Developing Countries - Lawrence Busch 91

Impact of Food Policies on the Development of Agricultural Technologies George W. Norton 102

Session 5

Increasing Productivity and Sustaining Natural Resources
Jere Lee Gilles, Chair

Sustainability: The Challenge for International Agricultural Research John K. Lynam 119

Using Local-Level Knowledge to Improve Agriculture and Natural Resource Management - Billie R. DeWalt 141

Session 6

Issues of Property and Development
Larry Burmeister, Chair

Land Tenure and Agriculture Structure: Implications for Technology Adoption - Michael Roth, Keith Wiebe, and Steven Lawry 157

Risk and Public Goods: Implications for Technology Development - Jean-Paul Chavas 181

Session 7

Issues of Technology Development and Diffusion
Anne E. Ferguson, Chair

Farmer/Consumer Participation in Research Development - Timothy R. Frankenberger 195

Developing Effective Researcher-Extension-Farmer Linkages for Technology Transfer - David G. Acker 210

Session 8

Estimating Impacts of New Technology
C. Milton Coughenour, Chair

Impact Measurement and Policy Distortions: Results from American and African Fieldwork - James F. Oehmke 235

Impacts of New Technology in Burkina Faso and the Sudan: Implications for Future Technology and Design - John H. Sanders and Sunder Ramaswamy - 244

Session 9

Summarizing the Future CRSP Research Agenda
David G. Cummins, Chair

Issues Related to CRSP Research Agendas: Responses of the CRSPs - David G. Cummins 269

Response to Social Science Research and the CRSPs - Office of Women in Development - Nina Renee Bowen and Pamela Stanbury 272

Conference Participants 277

Executive Summary

A New Agenda for CRSP Social Science Research

C. Milton Coughenour

For more than a decade, CRSP social and biological scientists have worked together to improve agricultural productivity and the quality of life of families in less developed countries. Both the scope and nature of social science participation in this endeavor has varied among the CRSPs and over time, and their contributions to CRSP achievements have varied accordingly. The experiences during the first half of the 1980s were reviewed in *The Social Sciences in International Agricultural Research: Lessons From the CRSPs.*[1] During the second half of the 1980s, social science participation in CRSP research was sharply reduced.

The general purpose of the Carnahan Conference Center workshop on Social Science Research and the CRSPs was to encourage the development of a new, forward-looking research agenda for social scientists in the CRSPs. In the opening session, CRSP Council Chairman John Yohe pointed to the growing incidence of AIDS among farm families in less developed countries, environmental problems, population growth, and the problems of women as crucial issues to which the CRSPs must respond. These developments raise new issues about the impacts of technology on people and make it necessary to re-examine the place of social science research both in setting CRSP research agendas and in implementing technology development goals. Articulation of a social science research agenda is important, Jere Gilles (Small Ruminant CRSP, University of Missouri) emphasized, in helping CRSP biological scientists and administrators understand the relevance of social science research to attaining CRSP goals. This new agenda, Gilles argued, must not be confined either to the post-hoc types of studies that social scientists have traditionally conducted, which are limited to a critical appraisal of current technology, or to ex-ante research, which only helps identify new technology to be developed. CRSPs must incorporate social scientists throughout the technology development, dissemination, and evaluation processes. Accordingly, the specific aims of the Carnahan Conference Center workshop were (1) to enable a panel of distinguished social scientists to present theory and research relevant to the research and technology development aims of the CRSPs, and (2) to initiate a process in which CRSP scientists and administrators could develop forward-looking research agendas involving social scientists.

Historically, the technology development goals dominating CRSP research agendas have been based on the assumption that the pervasive food and nutrition problems of less developed countries could be solved by improvements in farmers' food production technology. A general theme running throughout the workshop presentations, however, was that this strategy of agricultural development, at best, is only partially adequate and that failure to recognize the economic, institutional, and policy factors, which also affect agricultural growth, results in misdirected scientific effort, inappropriate technology, and continued agricultural stagnation. The thesis, repeatedly sounded by the panel, was that these difficulties can be reduced, if not avoided, by supporting social science research on farmers and on the socioeconomic context of farming. By bringing this type of information into the research and agenda-setting process, the CRSPs gain the capacity to develop more realistic research goals and appropriate technology as well as to secure its utilization by limited-resource farmers.

One of the recurrent specific themes in several presentations was that food and nutrition problems in less developed countries are primarily due to the inaccessibility of food supplies to poor people rather than to the inadequacy of the food supply. The problems of markets, distributional facilities, tenure security, governmental aid, and purchasing power, which ensure access to food, are political and economic rather than biological in nature. Thus, the focus must be on the adequacy of government food policies and operation of the food sector as a whole as well as on the production of more food. Information on constraints to the operation of the food sector can be obtained through social science research.

Another major theme of the conference was that research planning and technological development that take place largely in isolation from their clientele are likely to be inappropriate, if not misguided. Many factors (gender, ethnicity, socioeconomic class, local ecology, management capacity, and economic resources) are critical to developing appropriate technology for limited-resource farmers. Evaluating the constraints of these factors, which is necessary for fine-tuning technology development for diverse clientele needs, requires social science research and advisory assistance.

A third theme pervading the conference was that research and development are human activities with important human consequences, some of which may be unintended and harmful. Consequently, social scientists and research administrators are morally, if not contractually, obligated to consider the probable social and economic impacts and the ethical implications of the technology being developed. The impacts of new technology on the poor and vulnerable groups of society are measurable through social and economic studies and, thereby, facilitate informed policy debate.

The fourth major theme pervading the panel presentations was that limited-resource farmers already possess a profitable resource (that is, technical knowledge), which they develop by investing their time, energy, and other resources. Farmers do not accept new technology that comes from sources external to their local community as part of their technical knowledge without additional personal investment. Thus, the aim of technical transfer programs must be to engage farmers in this investment process, which requires more than carefully crafting a new technique. Through the investment process, change agents and farmers develop a relationship whereby farmers become involved in the development process itself, which has a satisfactory probability of being successful, in return for support and counsel. One task of social science research, then, is to acquire information with which to develop relationships between farmers and change agents for technical development.

These four general themes were articulated in different ways by the conference contributors. The ideas and research suggestions made by each member of the social science panel are summarized below.

Improving food security is a central aim of most CRSPs, and the social sciences have much to contribute to understanding this problem. In strengthening food security, John Staatz and Richard Bernsten (Michigan State University) pointed out that access to food is usually more problematic than is the quantity available. Dealing with both issues necessitates a food systems' approach in which all the actors and institutions that are involved in the production and distribution of food can be analyzed.

Household strategies of food security, in contrast to village and national strategies, involve decisions on the mix of food crops, cash crops, livestock raising, off-farm income, seasonal migration, and reciprocal obligations. Because household food security tends to be a direct function of both diversity and markets, access to food can be increased by driving down the real cost of food. This is one outcome of improved technology. But, due to the varied household strategies utilized to provide food security, social science research often must determine the types of technology appropriate to the target groups. Staatz and Bernsten also emphasize that the capacity of social science research to amass information about farmer resources, constraints, goals, opportunity costs, technology adopted, and the like can substantially improve research priority setting, facilitate the screening of technologies, and increase the efficiency of technology impact analysis.

Often neglected in research priority setting and technology development, due to a lack of client information, are gender, social class, and ethnic differences in household food production. Citing mistaken research targeting by Bean and Cowpea CRSP agronomists, Anne Ferguson (Bean and Cowpea CRSP, Michigan State University) shows how the addition of social scientists to the research teams increased the effectiveness of research planning and technology development. Information about gender, social class, and ethnic differences in the technology used by farmers enabled CRSP scientists to improve varieties appropriate to client needs.

The development of agriculture in less developed countries is the long-term aim of the CRSPs. This takes place, as Bruce Johnston (Food Research Institute) pointed out, through four interlinked processes: technological change, specialization at the farm level, institutional change (development of research and extension, establishment of credit agencies, and other infrastructure), and "structural transformation" (shift from an agrarian to an industrial economy). Agricultural development expands the flow of inputs to the farm sector and the flow of commodities to consumers. The key issue is whether these increased flows will be handled by markets and prices or administered by bureaucratic agencies. The right balance is important. Neither approach is problem free. But, the appropriate response to marketing problems is not to replace markets with administered systems but, rather, to make the necessary institutional changes to improve market efficiency. Making the proper public choices requires information on constraints and costs, which often can be obtained most reliably and efficiently through social science research. Johnston emphasizes that CRSP social scientists can provide invaluable information for decisions related to their commodities or systems through studies of the market structures and constraints; the relative abundance/scarcity of land, labor, and cash income; the possibilities for improvements in irrigation or moisture retention techniques; the opportunities to develop and market small equipment; and the different kinds of technologies needed by different-sized farms.

As the supply of farm commodities increases, the interests and preferences of consumers become increasingly important in maintaining satisfactory demand. Because consumer interests are neither immutable nor necessarily well known by those supplying consumer products, socioeconomic studies of the structure of consumer demand and the underlying beliefs and values can inform product development. Stephen Sapp (Iowa State University) reviewed sociopsychological theories of consumer behavior and the advantages and disadvantages of two methods of determining consumer preferences: sample consumer surveys and focus groups. He argued that, in many cases, the focus-group technique is the most cost-effective way of getting consumer preference information.

The agricultural sciences are being transformed by the worldwide development of biotechnologies, and this poses difficult choices by CRSPs and host countries. Lawrence Busch (Michigan State University) noted that the consequences of this development for less developed countries are market instability, secular decline in commodity prices, greater competition from developed countries, and loss of genetic diversity in commercial crops. These consequences, Busch contended, press CRSP scientists and administrators to adopt a subsector perspective in research planning; develop long-range strategic research plans; foster interdisciplinary research that involves social scientists; and consider ethical and value implications of the impact of technology.

Whether the research plans and activities of CRSPs and their host countries result in economic and social benefits depends, in part, on the food policies promulgated by the state. Given the opportunity, CRSP social scientists can play an important role in improving understanding of the linkages between food policy distortions and the incentives to invest in new technologies. George Norton (Virginia Polytechnic Institute and State University) pointed out that government food policies can affect the net benefits of agricultural research either positively or negatively; hence, the impacts require socioeconomic analysis. CRSPs face fundamental decisions on whether funding is to be provided for social scientists to determine food policy impacts on producer incentives to invest in new technology and on incentives to fund agricultural research and technology development.

Using United States and African examples, James Oehmke (Michigan State University) demonstrated that agricultural policies can have either a positive, a negative, or no effect on the adoption of technology with a corresponding impact on the costs/benefits. Social science research, thus, is necessary to measure the impact of economic policies on research benefits and to determine whether CRSPs should actively develop and promote a particular economic policy perspective.

The importance of social science research for technology development planning was highlighted by John Sanders and Sunder Ramaswamy's (Purdue University) studies in Burkina Faso and Sudan. Their research indicates that limited resource-farmers will turn to yield-increasing technologies as the land supply becomes inelastic. They also found that the economic returns to investments in research and technology development are substantial and that women are not made worse off even when the technology is applied to communal lands.

The new development goal of sustainable growth poses a number of challenges for social science research and the CRSPs, asserts John Lynam. One of the most important goals is to make sustainable agriculture compatible with economic growth. Doing so requires that social science research determines the development trajectory timing of investments in soil-building technologies; on sustainable growth agricultural systems; on equity issues, including gender, that inhibit implementation of sustainability goals; of the valuation—individual, social, economic—of tropical forests and wetlands; and on the human management of biodiversity.

Lynam argued that another challenge arises in using sustainability as an organizing framework for agricultural research. To achieve this goal, social scientists must work with biological scientists to study the size of agroecological zones; to guide the siting of intensive natural resource management research studies; and to determine how to integrate the management of cropping, livestock raising, and natural resource use. Achieving a better coincidence between the objectives of resource sustainability and the farmers' objectives of maintaining and improving family well being so that farmers' will adopt new technology is a third challenge. Meeting this challenge requires that social scientists become involved in the study of management systems to identify key constraints and to design educational methods for improving them.

Planning research to improve sustainability is the fourth challenge; this requires that the social sciences develop new methodologies for tracking and evaluating the benefits/costs of new techniques of improving sustainability.

The evolving relationship between scientific knowledge and agricultural scientists, on the one hand, and the practical knowledge of farmers in less developed countries, on the other, has been one of the major technological development issues of the past two decades. In reviewing the history of the development and adoption of *langosta* (pest) control, no-tillage, and forest-ecology management, Billie DeWalt (University of Kentucky) argued that agricultural science and local knowledge are complementary. Effectively using both types of knowledge for agricultural development requires that social scientists participate in the research and development loop and that scientists, extension personnel, and farmers establish effective relationships to facilitate the understanding of local knowledge systems.

By its nature, the outcome of research and development is uncertain (risky), and the risk is increased by variabilities in the weather, the climate, and the vagaries of farmer learning. Risk reduces the supply and demand of technology, that is, the benefits. Risk-management policy initiatives, thus, make an important contribution, Jean-Paul Chavas (University of Wisconsin) contends, to increasing technology development and its benefits. Social science research can assist risk-management initiatives by developing information that increases the effectiveness of "conditional contracts" to decrease downside risk; increases the probability of farmer acceptance of new technology; and fosters the establishment of risk-sharing arrangements.

One source of risk, which can adversely affect technology adoption, is lack of land tenure security. Michael Roth, Keith Wiebe, and Steven Lawry (Land

Tenure Center) address this issue in the African context. Although present knowledge indicates that the principal constraint, which lack of tenure security imposes, is long-term agricultural investments (such as alley cropping or irrigation), social science research is needed to better understand the impact of land tenure insecurity on women farmers, on areas where population pressure on land resources is rising, and on existing inequalities in the distribution of resources.

Difficulties encountered historically in the diffusion of new technology in less developed countries and the critical analysis of such efforts by social scientists has fostered a slow evolution of technology development models from technology transfer, in which agricultural scientists determine the agenda, to farmer-led learning models, in which scientists assist farmers. David Acker (Oregon State University) insists that social scientists can help CRSPs answer several questions critical to successful on-farm technology development. These questions involve topics such as linking successfully with farmers; communicating about technology; organizing researchers, extensionists, and farmers; incorporating a gender perspective; using communication technology effectively; and identifying relevant topics for training scientists and extension workers.

Constraints to doing technology development with farmers as active participants were addressed by Timothy Frankenberger (Office of Arid Lands Studies). Rapid rural appraisals and farmer participatory rural appraisals, involving social scientists, can increase farmer participation at the diagnostic stage. But, farmers also need to be involved as collaborators in the design of on-farm experiments to help ensure the usefulness of the final product. Social science research along the following lines helps promote farmer participation: trade-off of food security for livelihood security, which may adversely affect the adoption of technology; identification and location of vulnerable populations; technology screening for different farmer groups; studies of informal (farmer) technology development; studies of the cultural context and social protocols to facilitate farmer participation; and evaluation of approaches to elicit farmer participation in developing different types of technology.

Representatives of the participating CRSPs and of the Office of Women in Development (WID) met periodically during the workshop to reflect on the significance of the presentations. At the closing session, David Cummins for the CRSP Council and Nina Bowen for WID presented responses to the workshop discussion of a new social science agenda for the CRSPs. In summarizing CRSP-scientist responses, David Cummins (Peanut CRSP) drew special attention to the need for both the biological and social scientists to expand their knowledge of each other's domain of study in order to facilitate communication and effective working relationships. He noted that the workshop highlighted several questions, which CRSP boards would have to resolve; for example, when is gender a relevant factor, to what extent should farmers and extension workers be involved in technology development, and how large a social science component should a CRSP have? Finally, David Cummins called on social scientists to pay more attention to food sector problems and to develop more cost effective evaluation methodologies.

In its response to the workshop presentations, the Office of Women in Development noted that, "while the CRSPs have a global mandate, research cannot be done in isolation from the reality of production systems. Attention must be paid to both the sociocultural and socioeconomic as well as physical dynamics of agrobiological systems." Gender relations are an important aspect of this and will impact research agendas, methods, and technologies. The range of these impacts highlights the importance of addressing gender issues throughout the research, technology development, and adoption processes, not just at the beginning. Moreover, the gender perspective on research and development should be incorporated into the operational agenda of CRSP governing boards and evaluation and technical committees, as well as at project levels.

Notes

[1] This volume was edited by Constance McCorkle and published in 1989 by Lynne Reinner of Boulder, Colorado

Session 1

Developing a Strategic Research Agenda

- Framing a Strategic Research Agenda
- Social Sciences and Collaborative Research: Toward an Agenda for the Social Sciences in Agriculture

Session Chair: David G. Cummins

Speakers: John M. Yohe
Jere Lee Gilles

Framing a Strategic Research Agenda

John Yohe

The Collaborative Research Support Program (CRSP) is a unique concept that emerged from a community of persons in the late 1960s and early 1970s, who were interested in bringing the massive capability of the land-grant university community to bear on the needs of developing countries worldwide. The CRSPs were originally conceived and designed by the Joint Research Committee (AID and University representatives) of the Board for International Food and Agriculture Development (BIFAD) and implemented by AID under the auspices of Title XII legislation of the Foreign Assistance Act. The first four priority programs identified were Small Ruminants, Sorghum/Millet, Fisheries and Aquaculture, and Human Nutrition. The next three were Bean/Cowpeas, Tropical Soil Management, and Peanuts. More recently (1992), the SANREM CRSP has been established. These programs were designed to be multi-institutional, multidisciplinary, and interdisciplinary in implementation.

Over the past ten years, social and biological scientists have worked together in the CRSP programs to improve production and levels of living in the third world. Both the scope and nature of the social science role has varied across the CRSPs and over time. These experiences were reviewed in *The Social Sciences in International Agricultural: Lessons from the CRSPs* (edited by Constance McCorkle, Boulder, Colo., Lynne Reinner, 1989). Four considerations, however, prompt a new look at social science research in the CRSPs. First, since the CRSP Council was established in 1979, there has been emerging interest in selected inter-CRSP activities at one or more locations in the developing world. To date, the CRSP Council has been looking at an inter-CRSP program in Honduras and Niger. There will be definite biosocial implications in these inter-CRSP activities which must be addressed and studied. Second, the Research and Development (R&D) Bureau Offices of Agriculture (AGR) and Women in Development (WID) are interested in the social and equity issues associated with CRSP developmental research which impacts environmental resource conservation, food availability, gender equity, and economic well-being of farm families in the developing world. We welcome them as co-sponsors of this workshop. Third, there is renewed interest among directors, boards, and technical committees in greater involvement of social scientists in CRSP research. Finally, theory and research on the social science aspects of agriculture has grown substantially. Consequently, there is need to reexamine the social science research agenda for the CRSPs. What kinds of research should social scientists be doing now and in the future in the CRSPs?

This workshop has been organized to examine the development of a strategic social science research agenda—the general theoretical approaches and expected outcomes to problems associated with the development and change of agricultural technology on farms in developing countries. It is not the purpose of the workshop to propose specific research projects for particular CRSPs. Rather, it is the purpose to enable CRSP scientists

—social and biological—to discuss the relevance of ideas presented for their CRSPs and to consider possible research projects. Each CRSP, of course, has its own mechanism for identifying the social science research that it regards as important, and there is no intention or need to supplant this. Still, there is need to bring together social and biological scientists from various CRSPs and other social scientists working on agricultural development problems to address what social science research can potentially contribute, both to the CRSPs that have little or no current social science research and to those with on-going social science research programs.

Strategic research problems encompass not only studies with results that have immediate application to the design of new technology or its utilization, but to those with more long-term, perhaps broader, implications for the commodity itself or for technological development. Studies regarding the cross-elasticity of demand for substitute commodities, trends in terms of trade for commodities, or land tenure conditions that affect sustainability exemplify studies with broad importance for particular commodities or for developing technology. Such studies can be conducted by social scientists independently of biological scientists and, in this sense, stand alone. On the other hand, studies of the profitability or acceptance of new techniques (e.g., varieties and labor saving techniques), or of sociocultural aspects of biodiversity, for example, have immediate implications for technology development and usually require a close-working relationship between biological and social scientists. Both types of studies are critical to successful attainment of CRSP objectives, and this workshop will be concerned with both types of studies.

Four major factors, external to CRSPs, are changing the face of the world as well as impacting the success of the CRSPs. Because these factors are so pervasive, they necessitate examining the role of social sciences in the CRSPs. These four factors are the (1) dramatic increase of acquired immune deficiency syndrome, (2) vast degradation of the environment, (3) rapid growth of the population, and (4) increase of women's involvement in business and society.

Acquired Immune Deficiency Syndrome (HIV). In the June 4, 1992, issue of the *New York Times*, a leading AIDS research group reported that the worldwide epidemic of HIV, the virus that causes AIDS, threatens to infect 40 million to 110 million people by the year 2000 and that multinational efforts to stop the spread of this fatal disease have stalled. Johnathan Mann, Harvard School of Public Health, says that the World Health Organization is underestimating both the scope of the problem and what will be needed to deal with the problem. No country or community has stopped the spread of HIV, and it is spreading with astounding rapidity in many areas of the world. AIDS is having a growing impact on women, who now account for 40 percent of HIV infections worldwide, up from 25 percent in 1990. During the next three years alone, the number of infected people who develop AIDS will exceed the total who have developed the disease since it was first identified. The number of children orphaned by AIDS will more than double in the next three years.

The Environment. During the 20 years since the first Earth Day in 1970, the world lost nearly 200 million hectares of tree cover, an area roughly the size of the United States east of the Mississippi River. Deserts are expanding by some 120 million hectares, claiming more land than is currently planted to crops in China. Thousands of plant and animal species, with which we shared the planet in 1970, no longer exist. The world's farmers have lost an estimated 480 billion tons of top soil, which is roughly equivalent to the amount of India's cropland. The stratospheric ozone layer continues to thin, greenhouse gases are accumulating, air pollution has reached health-threatening levels in hundreds of cities, and damage from acid rain can be seen everywhere.

Population Growth. Growth trends are profoundly disturbing. The world population is projected to increase by at least 960 million people during this decade, up from 840 million in the 1980s and 750 million in the 1970s. Hundreds of millions of people are hungry, partly because of inequitable distribution of food, but increasingly because of falling per capita food production. As we enter the third year of the nineties, the ranks of the hungry are swelling. This means that, in the nineties, the per capita availability of key resources such as land, water, and wood will continue to shrink at an unprecedented rate. Continuing rapid population growth and spreading environmental degradation has trapped hundreds of millions of people in a downward spiral of falling incomes and growing hunger, with an increasing number caught in this life-threatening cycle each year. The world will soon be forced to reckon with the consequence of years of population policy neglect.

Women in Development. The technical report, *Making the Case for the Gender Variable: Women and the Wealth and Well-being of Nations* from the Office of Women in Development in AID reports that attention to women farmers' skills, incentives, and constraints could be the single most cost-effective approach to alleviating the African food crisis. It also states there is worldwide evidence that the education of women is associated with the following factors: (1) marriage at a later age, (2) increased contraceptive use, (3) lower fertility, (4) dramatically reduced infant and child mortality, (5) improved child nutrition and general family health, (6) greater participation in the modern wage-sector labor force, (7) higher earnings, and (8) increased national development as measured by the gross national product.

I raise these issues because not one of them can be ignored as we discuss "Framing a Strategic Research Agenda." By being interlinked, they set the stage for CRSPs to address and respond to the constraints of increased sustainable food production and natural resource conservation. Solutions to these areas of concern are intimately associated with social and cultural interactions with them. Specifically, we are interested in what critical social inputs are necessary to maximize the effectiveness of technology being developed to assist in the fight against hunger. As these issues are considered, they may suggest changes in the CRSPs' research agendas in context of the rapidly changing biological, physical, and cultural environments in which we are involved. Following are some critical questions that we need to answer:

- How can we interface the research mode with technology transfer in developing countries?
- How can we best interface with key AID issues within the host countries where we work?
- What use will our technologies be in the face of increased morbidity in the lives of people infected with and those affected by AIDS?

- What are the political and socioeconomic issues of the biotechnology revolution? Recently, the United States did not sign the world's environmental treaty in Brazil. Issues of species, genes, and technology ownership are all at issue, with the developing world purporting that the developed world is exploiting their natural resources and environments.

- Can we avoid what appears to be the world's greatest food crisis in the history of mankind? The worst drought in 100 years is taking place in Southern Africa. There is anarchy in Somalia and civil war in Sudan. We have not developed the sustainable food production technology that will allow the developing world to produce their own food or to allow them to adequately participate in the world economic market place.

CRSP programs can make a significant contribution. They cannot provide all of the solutions, but they can contribute to building capacities to manage natural resources for sustainable agricultural development and improved environmental quality in diverse agroecosystems of the developing world. CRSP programs can support research and development activities that provide technological innovations for maintaining and enhancing productivity and agricultural sector performance in the developing world.

In sum, I would like to paraphrase what Mike Nolan said in his forward to *Plants, Animals, and People* (Westview, 1992), edited by Constance McCorkle. We need to examine how technology fits into the social environment. We need to assess how technology impacts different biosocial groups, such as women. We need to evaluate the effects of long-term trends on the current environment and to look at new models for dissemination of technology. We must ensure that people's lives will not be worsened by the technology we develop.

Social Sciences and Collaborative Research: Toward an Agenda for the Social Sciences in Agriculture

Jere Lee Gilles

Thomas Jefferson referred to agriculture as "the science incorporating all the other known sciences" (as cited in Gilles, 1978:13). Unfortunately his vision of agricultural science all but disappeared by the end of the nineteenth century. Until recently, agricultural researchers have worked in the splendid isolation of their disciplines. Researchers assumed that farmers, policymakers, and agribusinesses would synthesize their findings. Today we recognize the interdependence of technology, economy, and society. However, lack of "cross-pollenization" across the lines of social, physical, and biological sciences has continued to hamper agricultural research in North America and abroad.

Today, most people acknowledge that the development of new technologies and their adoption are heavily influenced by social forces and economic interests. Whether the decision-maker is a Ph.D. in biochemistry, an Iowa corn grower, or a peasant with a plow and buffalo, decisions are made in response to incentives and pressures—many of them economic, social, and political. In recognition of this fact, most agricultural research institutions have a social science component.

While, in principle, it is generally accepted that the social sciences are vital to agricultural research, there is little consensus as to the appropriate role that social scientists should play in agricultural research. Lack of a widely accepted research agenda sets the social sciences apart from other agricultural disciplines and contributes to their sometimes marginal status.

For the most part, agricultural research programs are oriented to biological problems and administered by biological scientists who have risen from the research ranks and understand the research agendas of their biological colleagues. Experienced administrators typically understand how political, economic, and social forces affect their ability to obtain research funds. They value the defensive value of social scientists but typically have little idea of the nature of social science research.

However, administrators' recognition of the value of the social sciences has not translated into increased support for social science research. In fact, most attempts to set agricultural research priorities in the past two decades have neglected the rural social sciences (Johnson et al., 1991). Several years ago, North American social scientists recognized that the neglect of the social sciences in agricultural research priorities had resulted in a decline in the funding of social sciences because they lacked an agenda. This resulted in creating the Social Science Agricultural Agenda Project (Johnson et al., 1991), which aimed to put the social sciences on an equal footing with other agricultural sciences.

The goals of this paper and this forum are similar to those of the Social Science

Agricultural Agenda Project. They are to encourage us to work together to create a social science agenda for Collaborative Research Support Programs (CRSPs) that can be understood by the public and by colleagues in other disciplines. Without such an agenda, the contribution of the social sciences to CRSPs will be relatively trivial because we will never be full partners in the agricultural research process. My argument is discussed two parts. The first gives a brief overview of the CRSPs, in general, and the history of the social sciences within them. The second outlines the roles that social scientists have generally played in agricultural research and argues that these traditional roles tend to undermine the social sciences in the context of multidisciplinary research projects such as the CRSPs.

CRSPs: Multidisciplinary Research and the Social Sciences

Collaborative Research Support Programs (CRSPs) grew out of the International Development and Food Assistance Act of 1975. Title XII of this legislation addressed two concerns of the international development community. First, there was a widespread belief that world food problems could only be solved through basic research, which would expand the knowledge base in Third World countries (Lipner and Nolan, 1989). The second concern was to develop a way to solve world food problems by mobilizing the expertise at American universities (Luykx, 1978). Collaborative research programs were one more method for addressing these concerns.

By 1985, eight CRSPs were supported by the U.S. Agency for International Development (USAID). Although each CRSP has a unique research focus and approach, all past and present CRSPs share some common features: they are funded for multiyear periods, they are collaborative in nature, and they are explicitly multidisciplinary (Lipner and Nolan, 1989:24). CRSPs usually receive funding for five-year periods, based on the fact that successful agricultural research requires continuous support over a long period. While five years is significantly shorter than the average time it takes to develop a new agricultural technology, CRSPs represent a radical departure from previous ineffective, piecemeal approaches to agricultural research using short-term grants.

As the name suggests, CRSPs are also collaborative. Research activities are carried out in each CRSP by several universities in cooperation with scientists in developing countries and other research institutions. Participating U.S. institutions are required to contribute 25 percent of the cost of any CRSP-supported project, and host country institutions are also expected to make significant contributions to research programs. Collaborating to solve common problems takes place not only between individuals in the same field but also, because of its multidisciplinary approach, between persons from a variety of disciplines.

The Challenge of Multidisciplinary Research

The multidisciplinary nature of CRSP research presents social scientists with significant challenges and opportunities. The greatest opportunity of doing research with other disciplines on a common problem is to create efficient and appropriate agricultural technologies. The greatest challenge is that few university scientists possess training or experience to participate in multidisciplinary collaborative research. Universities and most research establishments are divided along disciplinary lines. The worldwide community of scholars that makes up a discipline defines appropriate research themes and marks important and significant scientific work through peer review and other more informal means. Success as a scientist, particularly for young scientists, usually depends on demonstrating conformity to disciplinary norms and goals. Consequently, multidisciplinary research that typically falls at the intersection of several disciplines may not receive full attention and support from any single community of scholars.

Persons involved in multidisciplinary research encounter problems that are not encountered by those involved in conventional research. These problems fall into two categories: interdisciplinary communication and team building, and the contradiction between the goals of interdisciplinary research and the priorities of individual disciplines (see Gilles, 1990; Maxwell, 1986). Multidisciplinary research requires a constant investment of time and energy to maintain a common understanding of research goals and to develop and maintain a system of interdisciplinary communication.

If researchers in a multidisciplinary team are located in disciplinary research units, as are virtually all scientists participating in CRSPs, they will face two serious challenges. First, the time and energy spent on maintaining a multidisciplinary research program represents resources that could be used to carry out disciplinary research. So multidisciplinary research is perceived as a cost to persons whose performance is evaluated by disciplinary peers. Second, the key research tasks carried out in support of a multidisciplinary agendas may not be at the center of any discipline's research agenda and may not be accorded as much professional recognition as disciplinary research.

These challenges create centrifugal tension within every CRSP as the temptation to reduce real world problems to disciplinary agendas is omnipresent. This tension is inevitable because each CRSP participant depends on his or her home department and discipline for recognition and rewards. Every scientist within a CRSP attempts to strike a balance between program needs and disciplinary recognition and the management of each CRSP strives to create an environment where these tensions can be accommodated.

These challenges are even greater in projects that involve both social and biological scientists. Most agronomists and animal scientists have some training and experience working with other biological disciplines. But social scientists rarely have much biological training, and biological scientists rarely have a social science background. In addition, most social scientists have little group research experience. The challenges in any multidisciplinary endeavor, then, are compounded when both biological and social scientists work together.

One consequence of the tensions of multidisciplinary research is a tendency to reduce complex problems to a biological "core" in order to simplify program management and to increase "efficiency." This tendency exists in every CRSP where the problems being addressed are far larger than the amount of funds dedicated to their solutions. This issue is particularly acute for the social sciences. The lack of an articulated and understood social science research agenda and the fact that social scientists have not traditionally been involved in technology development undermine the effectiveness of the social sciences in programs such as the CRSPs.

Social Sciences and the CRSPs

While USAID and biological researchers have generally given strong support to the idea that the social sciences are important to agricultural research and the CRSPs, the fact is that social science participation in most CRSPs has been minimal. In 1991, only two CRSPs (Small Ruminant and Bean/Cowpea) devoted more than 10 percent of their research funds to the social sciences. Even in these CRSPs, a significant portion of the funds allocated to the social sciences was not for research per se. Rather, social scientists were employed in planning and evaluating exercises and sometimes were responsible for coordinating on-farm research programs.

Present levels of CRSP support for the social sciences are lower than they were ten years' ago. In 1985 and 1986, USAID funding for CRSP activities was severely reduced and many CRSPs responded by sharply curtailing social science research. In response to this situation, researchers at Missouri organized a conference in late 1985 to document and preserve, for posterity, the contributions made by sociologists and anthropologists to CRSPs. The results of this conference are reported in a volume edited by Constance McCorkle (1989). While the conference did not deal with economics in detail, many of the conclusions of this conference have been applied to economics as to well as to related disciplines.

This conference helped me formulate two conclusions. First, the ability of social scientists to obtain continued funding in CRSPs was not related to the scientific merit of their research. Some of the very best and most innovative social science research was among the first to lose funding and some of the worst research received support far longer than any social scientist would have believed possible. Support for social science research in the CRSPs was largely a function of a researcher's willingness to place the goals of multidisciplinary research above his or her own personal and disciplinary research goals. Most biological scientists did not have to make multidisciplinary research their first priority.

Second, support for social science research also depended on the ability of social scientists to convince their biological colleagues of their value as researchers instead of their value as people who "talk to farmers for us." When a basic social science research agenda was viewed as supporting CRSP goals, the social sciences were more likely to receive continued funding when budgets were cut. For example, range scientists in the Small Ruminants CRSP saw research on the efficiency of different types of local resource management as important (Gilles, Hammoudi, and Mahdi, 1992; Gilles and Jamtgaard, 1982). Although much depended on the persuasive ability of social scientists and their commitment to multidisciplinary research, the organization of the Bean/Cowpea and Small Ruminant CRSPs facilitated their efforts. The management entities of both these CRSPs clearly defined the social sciences as core disciplines and the research strategy of the Small Ruminant CRSP facilitated interdisciplinary communication.

It is interesting to note that these two observations underscore the need for the social sciences to articulate research priorities and agendas for the social sciences in agriculture. The research agendas that have dominated our disciplines for the past decades are not adequate for multidisciplinary projects designed to create new technologies. Looking at the roles and limitations that the social sciences have traditionally played in agricultural research will help to emphasize this point.

Social Scientists in Agricultural Research

The term "social science" covers a wide number of disciplines including sociology, anthropology, economics, geography, psychology, management, and education. Each of these disciplines, in turn, contains a bewildering array of specialties and methodological emphases. There is considerable overlap between many of the social sciences, and social scientists in one area frequently utilize information and methods developed by related disciplines. Sociology, anthropology, and economics are the disciplines most commonly involved in agricultural research, but all disciplines have made some contributions.

While delineating the boundaries between different social sciences may be an important exercise for university administrators and professional societies, it has little relevance to the present discussion. In spite of disciplinary differences in method and theory, the situations faced by all social sciences involved in agricultural research are remarkably similar. For example, social scientists working in agriculture typically work in research institutions where they are a minority and where research agendas are largely determined by nonsocial scientists (Maxwell, 1986; van Dusseldorp 1977; and Heberlein, 1988). Research administrators acknowledge the importance of the human factor in agricultural production, but this insight does not translate into an acceptance of the social sciences on par with other agricultural disciplines. Administrators typically do not have a clear idea of the exact role that agricultural economists and other social scientists should play as researchers (DeWalt, 1989; Ruttan, 1982). They value social scientists as people who can answer thorny questions about agricultural research that are raised by persons outside of the research community such as farmers, extension workers, and funding agencies. Consequently, social science research is seen as secondary to the core mission of agricultural research institutes and their level of financial and institutional support is often precarious or insufficient (Heberlein, 1988; McCorkle and Gilles, 1987).

In the United States, where most agricultural research and extension work is conducted by university personnel, there is a long history of social science research in agricultural colleges. Social scientists are seen as making valuable contributions to university extension efforts and to questions related to rural development, but they have traditionally played a minor role in the core area of agricultural research and technology development. The mission of North American agricultural research institutes and their allocations of funds and personnel give priority to the development of biological and mechanical technology. Because social scientists have not usually been involved in these activities, they occupy uneasy positions within American agricultural research establishments.

Although more economists are employed in agricultural research than sociologists or anthropologists, they too have had difficulties getting sufficient funding.

This is one of the reasons that agricultural economists led the effort to create a rural social science agenda in the United States. The roles that rural social scientists have traditionally played in agricultural research settings did not, in themselves, suggest a need for additional financial support. In the case of the CRSPs, traditional social science agendas not only marginalize the rural social sciences, but actually provide a justification for excluding them from full participation in most CRSPs.

Classical Post-Hoc Approaches

Until recently, the social sciences have not been directly involved in the development of new agricultural technologies. Traditionally, social scientists were devoted to ex-post or post-hoc analyses. That is, social scientists began their research once their colleagues in the production sciences had developed a technology they wanted farmers to adopt. Social science research efforts were typically responses to questions raised by producers and extension specialists about specific agricultural technologies. An agronomist typically worked for 7–15 years developing a new variety or tillage method. Social scientists only entered the picture if questions were raised about the appropriateness of the technology or if farmers were reluctant to adopt it. Most social science research today, as in the past, is devoted to evaluating the possible costs and benefits of newly developed technologies and assessing the likelihood of their adoption by producers. When producers do not adopt a promising technology, social scientists identify the social and economic barriers to adoption and help develop programs to overcome them. Social science research results are sometimes given to researchers to help them modify technologies to meet producer demands.

The social sciences have always been biased toward post-hoc studies, so the role of the social sciences in agricultural research is not surprising. The social sciences have always emphasized critical, post-hoc research. Ethical considerations preclude most social experiments so the social sciences have emphasized explanations of the causes and implications of social and economic phenomena. Social scientists are trained primarily to "evaluate and criticize" rather than "interpret and act" (Maxwell, 1986:28; Chambers, 1983). Because agricultural research is basically proactive, social science training does not predispose social scientists to contribute to developing technological innovations. Even today, a summary of funded NSF projects shows that most basic social science research emphasizes developing better theories and methods for post-hoc analyses or for examining the relationship between technology and society. Graduate training in the social sciences continues to emphasize evaluation techniques and approaches that are not particularly suited to the early phases of agricultural research.

Traditional post-hoc analyses have contributed much to agricultural research and society, such as helping to develop better tools of financial analysis, to make price forecasts, and to design effective extension and marketing campaigns. However, an emphasis on post-hoc analyses has several severe limitations: (1) it has impeded the exchange of ideas between the social sciences and other disciplines, (2) it has led to the inefficient allocation of scarce research resources, and (3) it has led to publicly sponsored research with some undesirable social and or economic consequences.

Traditional social science research requires little or no contact between those who develop the technology and the social scientists who study these innovations. In the past, social scientists have not regarded agricultural scientists as a clientele. Rural social scientists worked closely with extension professionals, producers, administrators, and policymakers but not with agricultural scientists. In fact, there are good reasons why social scientists who evaluate a technology should distance themselves from those who develop it. Unfortunately, this split has often reduced the relationship between social and biological scientists to one of the "critic and the criticized." One consequence of this situation is that most social scientists do not have enough knowledge or experience to provide biological and physical scientists with productive criticism necessary for their research programs.

The traditional confinement of the rural social sciences has led to the inefficient use of scientific resources. This arrangement assumes that the agronomist or animal scientist possesses a detailed understanding of local farming systems and that they will conduct research that addresses the concerns of farmers and the public. While this situation may have been true in North America at the turn of the century, when a majority of rural residents were mixed farmers and when virtually every agricultural researcher grew up working on a farm, it is not true today. Most agricultural scientists conduct research they hope will benefit the public, but today they work in isolation from their ultimate clients. Research agendas are shaped more by disciplinary agenda and funding sources than by an understanding of farmer problems. Biologists and engineers would sometimes toil for years to develop a new practice or technology, only to be informed by a social scientist that producers had no need for it. At other times, researchers have found their research programs scuttled by powerful interest groups or public fears that opposed the diffusion of the new techniques. In many cases, years of frustrating research could have been avoided if social scientists had participated in the initial stages of agricultural research.

Finally, some agricultural technologies have not yielded the public benefits hoped for by their developers. The mechanical tomato harvester is one example of a technology that benefited some producers and consumers at the expense of farm laborers and small farmers (Hightower, 1973). In addition, the development and introduction of new grain varieties and new irrigation techniques did not always benefit small farmers or consumers (Kloppenberg, 1988). Social science research revealed many of these negative consequences, but post-hoc research could not prevent them from occurring.

The critic's role may also reduce the impact of social science research by increasing the distance between social and biological scientists. Negative evaluations of the economic and/or social soundness of one's research are rarely appreciated because they come at a time when the agricultural researcher's work is completed and when there is no opportunity to easily modify a technology to make it more socially appropriate. Social science research is only useful to agricultural researchers when it is conducted while their research is still in progress. As long as social science research concentrates on post-hoc analyses, it is understandable why interdisciplinary dialogues have been rare and why agriculturalists regard the social sciences as peripheral to the mission of agricultural research.

Ex-Ante Research in Agriculture

By the late 1960s, the limitations of ex-post social science research were widely recognized. People began to recognize the value of involving social scientists at the beginning of the technology development process. The National Environmental Protection Act mandated that environmental impact statements (including social and economic impacts) be developed for major public projects. In the case of USAID-sponsored programs, the "New Directions" mandate of Congress specified that more emphasis be placed on expanding the poor's access to economic development and requiring assessments of the "social soundness" of agency investments (Mickelwait, Sweet, and Morss, 1979). As part of this new direction, the "Percy amendment" required USAID to give special attention to activities that contribute to the welfare of women and recognize their role in the development process (USAID, 1991). The purpose of this legislation was to ensure that U.S. foreign assistance programs were socially sound and benefited the needy.

This type of activity has been referred to as *targeting* or ex-ante research (McCorkle, 1989; Byerlee and Tripp, 1988). While the main thrust of the New Directions mandate was to include social and gender considerations in the planning of development programs, it also encouraged the development of ex-ante approaches in agricultural research. Two important types of ex-ante research have emerged in international agricultural research. The first type is what I would call "social impact assessment" and the second is "farming systems research." Social impact research is most common in research programs that emphasize technology transfer and adaptive research rather than programs like the CRSPs which are designed to increase our knowledge base. Research sponsored under the rubric of "Women in Development" represents some of the best of this research. This research has helped orient researchers and policymakers to gender issues and has ensured that technology transfer programs will have a positive impact on women and their families.

The second type of ex-ante research that has become part of most agricultural research programs is farming systems research (FSR). The methods used by social scientists involved in FSR are quite similar to those used in social impact analyses and in traditional ex-post analyses. Although many people have tried to define farming systems research as a methodology or as a special field of science (see Merrill-Sands, 1986), Byerlee and Tripp's (1988) definition of it as a research perspective seems more appropriate. The basic tenet of farming research seems to be to overcome disciplinary blinders by providing researchers with a farmer orientation to agricultural research. While researchers may often work in isolation of one another, agriculture does incorporate all the sciences at the farm level. One important aspect of FSR is that many of its activities are carried out by multidisciplinary teams, which include a significant social science presence.

The farming systems research perspective is not simply an ex-ante research approach. The perspective assumes that there will be farmer inputs throughout the entire agricultural research process, not just at the beginning and end of a project. Nonetheless, the greatest advances in farming systems research have been the development of methods for assessing the constraints faced by farmers in their fields. Once identified, these constraints can be addressed by the research of production scientists. Social scientists have made such important contributions to FSR that some people mistakenly define it as a social science activity. The value of ex-ante studies in agricultural research are widely recognized, but the role of social scientists in farming systems research after initial baseline studies are conducted is ambiguous. In fact, social science research involvement in FSR seems to be confined to ex-ante and ex-post analyses (Byerlee and Tripp, 1988). Social scientists, who are involved in FSR after initial targeting exercises are completed, usually act more as coordinators or facilitators of on-farm agricultural research than as researchers (Knipscheer and Suradisastra, 1986).

All CRSPs employing social scientists have utilized FSR approaches in some sites. In most cases, the contributions that social scientists can make to CRSP objectives through ex-post and ex-ante analyses are explicitly recognized. Nonetheless, social scientists have had a relatively precarious position in many CRSPs, perhaps due to the fact that the social sciences are not viewed as core disciplines by many production scientists. Even some of the most enlightened biological scientists see social science research as valuable, yet external to agricultural research, because its only purpose is to help identify research objectives and to evaluate research products. The social sciences are not seen as part of the research process itself. They are not integral parts of agricultural research because, unlike their sister disciplines, they have no recognized research agenda.

The Need for a Social Science Agenda

In my opinion, the somewhat marginal position of the social sciences within agricultural research institutions and many CRSPs is a direct consequence of not clearly enunciating a research agenda in agriculture. In our efforts to sell our colleagues in the agricultural sciences on the benefits of ex-ante research, we have sent the wrong message to many of them. We have defined our role as external to the process of research in which most CRSP scientists are involved. That is to say that we are only involved in the ends of the research process and not in its heart.

To illustrate this point, plant breeders typically conduct research for 8 or more years to develop a new plant variety, while animal scientists and range management specialists often perform research lasting more than 15 years. Because agricultural research requires a large time commitment, one of the benefits of CRSPs is that they provide researchers with modest amounts of long-term funding. In other words, a successful agricultural research program can be expected to last 8–15 years. Agricultural scientists recognize the value of using social science research to evaluate new technologies. Many biological scientists now accept the notion that multidisciplinary studies that include a social science component are also useful for setting research agenda. The problem with this situation seems to be obvious. A research program lasts 10 years, for example, but social science inputs are only valued during the first three years of a project and sometimes in the last two years. In this scenario, the social sciences are the primary targets for budget reductions after the initial phases of a project are completed. Once funding for the social sciences is cut, it is difficult to restore it to any significant extent. The ultimate losers are the CRSPs themselves, the farmers, and the consumers.

The idea that social science research is only relevant to the first and final stages of the technology development process is based on several dubious assumptions and misconceptions about agricultural research and the social science disciplines. Many research administrators ignore the process by which social science insights are incorporated into agricultural research and give too much attention to the products of research. They assume that the directions and priorities of research are firmly established in the first year or two of a project so that an initial survey or study is all that is required to ensure the development of appropriate technologies. In reality, most scientific research is iterative—this year's results influence the direction of next year's research. Given this reality, continual contact between social and other agricultural scientists is imperative throughout the life of a research project.

Informal interaction between scientists of different disciplines results in some of the most valuable multidisciplinary research. For example, early in the Small Ruminant CRSP in Peru we discovered that production constraints in agropastoral communities were different from those in livestock cooperatives, but these communities contained more than 50 percent of the small ruminants in the Sierra. Before we finished analyzing the data and publishing it, (see Jamtgaard, 1986), our biological science colleagues, who were familiar with our research, had altered their research priorities. Our experience is not an isolated one. The experience of the University of Missouri and of our colleagues in other programs suggest that the greatest benefits of social science involvement in agricultural research are derived from social science participation in on-going research.

Those who reduce the role of the social sciences to conducting social science research appear to make another curious assumption. Apparently they feel that the social sciences are not like other sciences and neither have, nor require, a research agenda. The social sciences have all of the tools and knowledge necessary to do post-hoc and ex-ante research. If a social science research agenda exists at all, it has nothing to do with agricultural research. Nothing, however, could be farther from the truth. Considerable long-term sociological and economic research are needed to support the conventional roles of social sciences in agriculture.

Conclusion

CRSPs cannot be strong without a strong social science component, and the social sciences cannot be strong if they are limited to planning and evaluating exercises. There must be a continuous social science presence in each CRSP if the potentials of the social sciences are to be realized. This can only be realized if the social sciences, like the other disciplines participating in the CRSPs, have a recognized research agenda similar to that possessed by other disciplines. Contrary to popular belief, good social science research is not a short-term proposition; rather, it can only be achieved through long-term studies.

Creating a social science agenda for CRSPs will not only improve the quality of CRSP research, but will enable the CRSPs to attract the best scientific talent in the social sciences. As stated earlier, CRSPs are unique because the researchers who participate in them are still housed in and rewarded by their respective subject-matter fields. Biological and physical scientists are attracted to CRSPs because they provide an opportunity to pursue disciplinary agendas through their CRSP activities. The same should be the case for the social sciences.

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Session 2

Technology Development and Sustaining Household Food Security

- Technology Development and Household Food Security
- Differences among Women Farmers: Implications for African Agricultural Research Programs

Session Chair: Kathleen DeWalt

Speakers: Richard H. Bernsten
Anne E. Ferguson

Technology Development and Household Food Security

John M. Staatz and Richard H. Bernsten

How do new technologies developed under the CRSPs affect household food security? The answer to this question depends on how we view household food security. This paper examines recent research findings on the determinants of household food security, particularly in Africa, and discusses their implications for the organization and goals of technology development research under the CRSPs. We stress the collaborative role of social and technical scientists in that process.

The analysis presented here draws heavily on our experience working on food security issues in Africa. Some of the food security challenges in Asia and Latin America differ from those described here. A central challenge, however, to improving food security throughout the world is the need to drive down the real cost of food to poor rural and urban consumers. Achieving this cost reduction requires technical and institutional innovations throughout the food system. The CRSPs can make a major contribution to this process of innovation.

The Concept of Food Security

The concept of food security has evolved markedly since the mid-1970s, when Congress passed the Title XII legislation giving birth to the CRSPs. The term "food security" first came to prominence during the World Food Conference in Rome in 1975. At that time, crop failures in Asia and the Soviet Union combined with low carry-over stocks in major grain-exporting countries to lead to rapidly rising world food prices. Many observers felt that the planet was teetering at a precipice, and that small reductions in food production could trigger widespread famines. The conference, therefore, endorsed a two-pronged approach to improve global food security. The first element involved efforts to increase food production in food-deficit countries so the food supply would at least keep pace with the burgeoning population. This has been the main focus of the CRSPs. The second element called for establishing national and international emergency reserve stocks to deal with temporary local food shortages.

Since 1975 the world food situation has changed dramatically, and with it the perception of food security. Food production per capita in developing countries increased by 12 percent between 1974/76 and 1987/89, despite a population increase in those countries of nearly a billion people (FAO, 1985, 1989). Increases in food production and per capita incomes were greatest in Asia, the area of most concern during the World Food Conference. Yet, while per capita food availability increased throughout most of the world during the 1980s, Africa was living out the fears of 1975, when widespread drought and civil disruption led to severe famine in several parts of the continent and, in many countries, per capita food production stagnated or fell. The world witnessed the terrible paradox of Africans starving when world food prices were at an all-time low and farmers in food-exporting countries were going bankrupt because they could not sell their crops at remunerative prices.

Even in Asia, however, it became apparent that increased per capita food availability did not solve all the problems of hunger. For example, India became a net exporter of foodgrains during the 1980s (even sending emergency food aid to Ethiopia in 1985), although many Indians still went hungry.

These changes led to growing recognition that improving food security involves more than just increasing the supply of food. It also requires that poor nations and individuals have access to that aggregate supply. This changing view of the food security problem is reflected in the definitions of food security that came into widespread use during the 1980s.

Defining Food Security

An individual is food secure if he or she has access to a diet that is adequate to ensure a healthy and active life. The individual's access to food is in turn determined by the supply of food available locally and the individual's claim on that food (what Sen, 1981, refers to as the individual's "food entitlement"). Whether the diet is "adequate" for a healthy and active life depends on the individual's ability to utilize the food. For example, chronic diarrhea caused by bad water supplies limit the individual's physiological capacity to absorb nutrients. Hence, underlying conditions affecting health strongly influence food security (Mellor et al., 1992).

The food security of a household, country, or region reflects the degree to which the residents of that group or area are food secure. Most formal definitions of food security have focused on food security at the more aggregate levels of country or region. As explained below, one of the challenges in food security research involves analyzing the relationships between food security at the regional or national level and that at the individual and household levels.

The World Bank (1986:1) has defined food security as "access by all people at all times to enough food for an active and healthy life." A similar but more detailed definition has guided much of the work under Michigan State University's Food Security in Africa Cooperative Agreement: "Food security is the ability of a country or region to assure, on a long-term basis, that its food system provides the total population with a timely, reliable, and nutritionally adequate supply of food" (Eicher and Staatz, 1986:216). These definitions have several implications for how one develops policies and technologies to improve food security.[1]

Implications of the Definition

Access Is as Important as Availability. Improving food security requires not only increasing food *availability* (or supply) but, also, the poor's *access* to food (or, to use the economist's term, "their effective demand for food"). A person can gain access to food through producing it himself or herself, by using money earned in other activities to purchase food, or through gifts and transfers from others. It became evident by the mid-1980s that lack of purchasing power was a major cause of food insecurity in many African countries that experienced widespread hunger while world markets were awash with grain.

Viewing food security as a question of access, as well as availability, helps make clear the distinction between food security and food self-sufficiency. *Food self-sufficiency* refers to the capacity of a country, region, community, or household to produce directly all the food it consumes. In contrast, *food security* refers to having access to an adequate supply of food, which may come from one's own production, purchases, or gifts. Food self-sufficiency is, thus, a much more restrictive concept than food security. A country such as India may be food self-sufficient, in the sense that it produces more grain than can be sold domestically at prevailing prices and, yet, not be entirely food secure. On the other hand, a country such as Singapore may be largely food secure without even having an agricultural sector. Such a country relies on its earnings from other sectors to import an adequate supply of food. Similarly, households or individuals may be food secure even if they are not food self-sufficient. Such households and individuals typically have either diversified income sources that allow them to obtain food through the market or social ties that give them claims to food through nonmarket channels.

Even for largely agrarian countries, the single-minded pursuit of food self-sufficiency may not be the most effective way of assuring food security. It may be more efficient, from the point of view of both the country and the individual farm family, to devote some resources to other activities, such as producing cash crops or nonagricultural goods, and use the money thus earned to buy food. In effect, such a strategy involves producing one's own food, but indirectly, by using resources to produce other goods that are then traded for food. The strategic question facing both the individual farmer and the nation is which use of resources is the least costly (most efficient) and most reliable way of getting one's food. An integrated food security strategy thus needs to consider more than just domestic food crop production.

Need for a Food Systems Approach. Food security depends on the ability of the entire food system to provide access to an adequate supply of food. By *food system* we mean the entire set of actors and institutions involved in input supply, farming, and the processing and distribution of agricultural products (including their links with international trade). Improving the ability of the food system to deliver food at low cost to consumers requires increasing the efficiency at each level of the system and improving the coordination among the various levels. Thus, while developing higher-yielding or more stable-yield crop varieties for farmers is one important step in strengthening food security, it is not enough in and of itself. Efforts to improve the reliability of food markets (e.g., through technologies aimed at improving the storability of commodities as well as policies making it easier for farmers and private traders to operate) represent other crucial activities to improve food security.

Taking a food systems or subsector approach is particularly important if one wants to try to improve food security through encouraging specialization and trade. It makes little sense for a farmer to produce cotton or nonagricultural products to sell for food if she cannot rely on the market to make food available when needed at reasonable cost.

Food Security at What Level? Food security can be analyzed at many different levels of aggregation, such as the region or subregion (e.g., the Sahel as a whole); nation; zone or district within a country; village; household; or individual. The focus of this paper is food security at the household level. During the 1980s, researchers increasingly shifted their attention from analysis of food security only at the national level toward food security problems at more disaggregated levels, such as the village, household, and individual. A common finding of a lot of this research was that much greater heterogeneity exists than was previously thought in the level of food security among rural households and in the strategies they followed to gain access to food. One of the key roles for social scientists in the CRSPs is to describe this heterogeneity and analyze its implications for technology development.

In particular, key steps in food security analysis involve analyzing who the food insecure are, what they eat, and how they secure access to food (what Sen, 1981, refers to as their "food entitlement mapping." See also Timmer, Falcon, and Pearson, 1983.) Another key step is analyzing how recent or potential changes in technologies, institutions, and policies affect the poor's access to food. For example, how would the development of a grain variety that matured two weeks earlier than current varieties affect the access of food-insecure small farmers to basic staples? Without this type of disaggregated information, it is impossible to trace through the impact of improved technologies on the food security of the poor.

Agricultural research contributes to both sides of "the food security equation" (availability and access). Technical research that drives down unit costs of production lowers the real cost of food for consumers, including farm families. Furthermore, new technologies have the potential to raise farm incomes. In the short-run, costs may fall more quickly than prices, leading to higher farm profits for early adopters of the technology. Increased productivity in food-crop production also may permit farm households to assure their own food needs with fewer resources, thereby releasing resources for other income-earning activities. Higher incomes allow increased access to a larger and more varied diet as well as improved health care and sanitation, all of which strengthen household food security. In addition, higher farmer incomes translate into increased demand for other goods and services produced in other parts of the economy, stimulating economic growth and employment more broadly.

Nonetheless, most technology development work, including that of the CRSPs, has focused primarily on the supply dimension of food security. The implicit assumption has been that increased supplies would increase urban food security by driving down real prices to consumers. For rural areas, the implicit assumption, at least for Africa, was that most farmers were self-sufficient or net sellers of grain, or at least aspired to be (Staatz, 1991). Therefore, the most direct way to increase rural household food security was to increase the rural households' home production of food.

Household Food Security Strategies

One of the most striking results of social science research conducted under the CRSPs and elsewhere in developing countries is how much rural households differ from one another in their resources and institutional environments. Recognition of these differences has been incorporated into how technical and social scientists, working in family systems research (FSR) teams, define their recommendation domains (McCorkle, 1989). It is now well recognized, for example, that technology that is well-suited for an extended family that has clear title to its land may be inappropriate for a female-headed nuclear family that share-crops.

Less well-appreciated is the wide range of strategies that rural households use to assure their own household food security. These strategies incorporate varying mixes of home-production of staples, production of cash-crops and livestock that are sold or exchanged for food, reliance on nonfarm activities to generate income to buy food, seasonal and long-term migration by one or more family members, and development of networks of reciprocal obligations that lead to non-monetary exchanges of food (Campbell, 1990; Dioné, 1989a; D'Agostino and Sundberg, Forthcoming). Their strategies often have important gender dimensions, as men and women play different roles in helping assure household food security.[2]

Many household food security strategies rely heavily on earning income to purchase food through the market. The reliance of the rural poor on the market for food is well-recognized in Asia, where there is a large landless class (Mellor, 1990). Less well-recognized, but nonetheless prevalent, is the reliance of rural African households on the market for food (Weber et al., 1988). This reliance is strong, even in the grain belts of many African countries. Dioné (1989b:7), for example, found that following the two relatively abundant harvests of 1985 and 1986, 43 percent of the households in the two best agricultural zones of Mali (the CMDT and OHV) were net grain buyers. Weber et al. (1988) report comparable figures for other areas in Africa.

The dependence of rural African households on the market for food is particularly pronounced during the hungry period just before harvest. Sundberg's (1988) research indicates that in the OHV zone of Mali, 47 percent of the meals consumed by farm families in the two months before harvest were based on cereals purchased from the market. But reliance on the market is not just a seasonal phenomena. Research from throughout the Sahel indicates that in lower rainfall zones, households follow a strategy of diversifying their income sources away from cropping and placing greater reliance on the market for food (e.g., Reardon, Matlon and Delgado, 1988; Staatz, D'Agostino, and Sundberg, 1990; Steffen, Forthcoming). Steffen (Forthcoming), for example, found that across all seasons, market purchases accounted for 36 percent of cereals consumption in the rural households he studied in the southern part of the Gao region of Mali in 1988/89 (a year of record harvests for the region). In the northern Gao region, bordering the Sahara, the percentage increased to 65 percent.

Both Steffen (Forthcoming) and Reardon, Matlon, and Delgado (1988) found that those who followed a more diversified income strategy and placed greater reliance on the market for food had a more stable consumption pattern throughout the year than did those who derived most of their food and income from their own cropping. A central message of this research is that households living in risky environments (e.g., where rainfall is highly variable from year to year) diversify their sources of income and rely heavily on the market to help assure their food security.

A second key message is the importance of driving down the real price of food for the many poor rural and urban consumers dependent on the market for a good deal of their food supply. Cost-reducing technical change in the production of basic staples plays an important role here. But often equally important are improvements in the efficiency of the marketing system for basic foods. If, as is not unusual in many African countries, marketing costs account for 50 percent of the final consumer price of staples, then a 10 percent reduction in marketing costs has the same potential impact on consumers as a 10 percent decrease in the unit cost of production of basic staples.[3]

Implications for Technology Development

Implications of Diversified Household Food Security Strategies

Households vary widely in the resources they command and in the physical and institutional environments in which they operate. Consequently, they follow widely varying household food security strategies. Therefore, when designing technology to improve household food security, the first question to ask is, *whose* food security are we trying to improve? For households in relatively high rainfall areas, having secure access to land, and an adequate family work force, the lack of streak-resistant maize varieties may be the major constraint to household food security. For households in semi-arid areas following a diversified income strategy, improvements in small-ruminant production may be a more cost-effective way of improving household food security, even though these households may eat very little meat. The increased income from greater small-ruminant production allows them greater access to grain through the market. And for those highly dependent on the market for part of their food, both in rural and urban areas, increased efficiency in staple food production in high-potential zones and improvements in the marketing system may be the most effective ways of improving household food security.

What is needed, then, in guiding technical research to improve household food security is a concept similar to that of "recommendation domain" used in farming systems research. The main difference between the "food security recommendation domain" and that used in FSR is that, from a food-security perspective, the intended beneficiaries of the research may be different from those who adopt the new technology. Technological improvements can improve the food entitlement of the poor through many mechanisms. For example, poor urban consumers may be the main beneficiaries of improved technology designed for and adopted by large-scale commercial farmers, if such technology drives down the cost of food to those consumers. Scobie and Posada (1990) showed, for example, that 70 percent of the benefits derived from the introduction of high-yielding rice varieties in Colombia in the late 1960s and early 1970s accrued to the one million poorest urban consumers in the country in the form of lower rice prices.[4] On the other hand, increasing incomes from noncropping sources may in some circumstances be a more efficient way of improving the food security of certain rural poor than would increasing their own food production. Answering the question of *whose* food security is improved by technical change requires the type of disaggregated information on "food entitlement mappings" (mentioned earlier).

The diversified income/food security strategies of poor rural households affect the types of technologies these households are willing to adopt. Noncropping activities, including off-farm employment and seasonal migration, may occupy a large part of household members' time and be an integral part of their strategy to obtain food for the family. These off-farm activities can imply a high opportunity cost for household labor during certain times of the year. The higher the opportunity cost of labor, the more attractive it becomes for farmers to adopt crop technologies that substitute purchased inputs for labor. For example, the estimated cost of production of maize in southern Mali in 1989 varied between 27 CFAF per kilogram (U.S. $.10/kg) and 64 CFAF per kilogram (U.S. $.24/kg), depending on whether one valued household labor at zero opportunity cost or at the estimated rural off-farm wage rate of 600 CFAF per day ($2.22/day). For millet and sorghum, using manual cultivation, the comparable figures ranged from 2 CFAF per kilogram (U.S. $.01/kg) to 63 CFAF per kilogram (U.S. $.24/kg) (Staatz, 1989:23). Obviously, the relative attractiveness of maize versus millet production depends on what types of outside employment opportunities are available to household members.

The attractiveness of different technologies also depends on the value to the household of additional production, which is a function of the household's food security situation. In many African countries, where there are substantial marketing costs, the value of additional food crop production depends on whether the household is a net seller or net buyer of the commodity. For households that are *net buyers* (e.g., smaller households following a diversified income strategy), the value of additional output is the money they would have had to pay for additional food when their supplies from home production run out, typically in the high-priced, preharvest hungry season. For *net sellers*, the value of additional production is more typically the sale price at harvest, which is considerably lower (Jayne, Forthcoming). This higher value of the food crop for net buyers may encourage them to adopt new, more productive varieties of the crop. But it may also discourage them from adopting or expanding cash-crop or nonfarm activities, as the opportunity cost of those activities (in terms of food crop production foregone) may be very high. Therefore, adoption of new technologies aimed at raising incomes by increasing nonfood crop activities may be limited to larger farmers who are already producing a surplus of basic staples (Jayne, Forthcoming).

The attractiveness of new technologies also depends on the land-tenure arrangements of the household, particularly, how the cost of purchased inputs and revenue from additional outputs are shared between the landlord and tenant. Security of tenure also determines the willingness of households to invest in land improvements that pay off over several years.

Similarly, the willingness of rural households to adopt resource-conserving (sustainable agriculture) practices depends on the type of food security strategy followed by the household. Reardon and Islam (1990) observe that many of the practices and investments promoted in the Sahel to conserve resources, such as the construction of dikes and bunds, implicitly assume a very low opportunity cost for household labor during the dry season. The unwillingness of many farm families to adopt such practices, they argue, is a function of the diversified income/food security strategies followed by families in these semi-arid areas (see also Binswanger and Pingali, 1988). The tradeoff that families face in the dry season is not between allocating household labor and capital to constructing bunds or having those resources sit idle. Rather, it is between investing that labor and the family's capital in the bunds versus investing them in a bus ticket to the capital city to seek work as a seasonal migrant. Here again, having a better understanding of the household's food security strategy and the opportunity costs it implies for family resources will be critical in designing technologies that prove attractive to farmers.

Implications of Households' Reliance on the Market

The heavy reliance of many rural, as well as urban, households on the market for some of their food supply has implications for technical research in at least four areas: the commodity focus of research, the need to focus on off-farm as well as on-farm constraints in the food system, the geographic focus of research, and the need for simple market analysis to help target agricultural research.

Commodity Mix. Because farm households, particularly in lower-rainfall areas, derive a significant portion of their access to food from noncrop enterprises, technical research to improve food security needs to embrace more than crop production. The existence of the Small Ruminant CRSP demonstrates recognition of this fact. But other important elements of many households' food security strategies are currently not addressed by any CRSP. In many areas, for example, cash-cropping by smallholders is positively and strongly correlated with increased household food security; hence, technical research on cash crops may make important contributions to household food security.[5] Similarly, technical constraints may limit income from nonfarm activities (Chuta and Liedholm, 1990). While we don't necessarily advocate the creation of a cash-crop or nonfarm enterprise CRSP, we do suggest that national agricultural research systems need to consider these activities as part of their food security research portfolio. In particular, CRSPs should strive to develop food-crop and livestock technologies that are complementary to, rather than competitive with, these other enterprises.

Off-Farm Constraints in the Food System. Given the heavy reliance of many poor families on the market for food, a key focus of research should be on how to lower the cost of food delivered to consumers through the market. Traditional research on increasing crop productivity plays an important role here.[6] But often equally important are technical developments that improve the ability to store, market, and process products as well as institutional changes that facilitate marketing. For example, a major constraint to the development of a reliable market for cowpeas in the Sahel is the problem of bruchid infestation during storage (Coulibaly, 1987). This limits the ability to develop the cowpea market as an alternative source of income for low-income farmers and as a low-cost source of calories and protein for consumers. Currently the Bean/Cowpea CRSP is addressing this issue in Cameroon by breeding bruchid-resistant varieties and evaluating improvements in on-farm storage technologies. Similarly, technical constraints in maize processing appear to be limiting the potential for developing low-cost, maize-based products that could substitute for other coarse grains and rice in Mali. One important aspect of the problem is the need to synchronize technical work in processing with the development of new varieties. In particular, varietal selection criteria need to include not only farm-level constraints but also the ease of transforming the variety into products preferred by consumers (Témé and Boughton, 1992).

In considering how to reduce the cost of food to poor consumers, one should keep in mind that these households, like farm households, may have high opportunity costs of household time. Therefore, the cost to be reduced is the cost of the product delivered to the consumer's plate, not necessarily the cost of the unprocessed product in the market. Particularly in urban areas, women (on whom responsibility for most food preparation tasks still fall) face increasing opportunity costs of their time, and fuel costs are high. Innovations such as parboiled sorghum (developed under INSORMIL) that reduce preparation time and fuel costs may lower the final cost to the consumer of the meal, even though its price per kilogram is higher than the unprocessed product.

In an attempt to add value to raw commodities through processing, many efforts in the marketing and processing areas do not give sufficient attention to the need to drive down the real cost of food to consumers. Some may argue that the development of new, highly processed products is a way of boosting the demand for the raw commodity, thereby increasing the incomes of farmers who grow it (and, hence, increasing *their* food security). But given the skewed income distribution in most poor countries, the market for such products will be very limited. Significantly expanding the demand for the raw commodity in most poor countries implies developing new low-cost products for the masses, not upscale products for the urban middle classes. At the same time, these low-cost products also directly contribute to the food security of the poor urban and rural consumers.

Geographic Focus of Research. The importance of driving down the real cost of food to poor consumers suggests that, from a food-security perspective, there can be high payoffs to focusing technical research in areas where there is potential for large productivity gains. Typically, these are higher rainfall areas. The desirability of focusing a high proportion of research resources on these areas depends on several factors. These include, for example, the proportion of the population relying on the market for a significant part of its food (which is often underestimated), tenure arrangements governing access to land in the high-potential areas, and government capacity and willingness to take measures to increase noncropping income in the lower-potential areas and improve food marketing systems so people in these areas can reduce their real cost of food.

Discussions of where to focus research geographically inevitably raise equity concerns. We are not advocating that research abandon areas that are less endowed with natural resources. But we are suggesting that it may be more efficient and environmentally friendly for people in these areas to produce relatively fewer crops and more noncrop commodities such as livestock, which they could trade for staples, rather than produce the staples directly. Much of the environmental degradation in semi-arid Africa, for example, is not due to a lack of crop-related research for these areas. Instead, it results, in part, from insufficient productivity growth in staple food production in higher potential areas. The lack of productivity growth in these well-endowed areas, combined with increased population pressure, leads to migration of agriculturalists into more fragile areas that traditionally were devoted to grazing or forestry. For example, in semi-arid areas of Kenya, increases in maize productivity in high-potential areas, although impressive, have been less than the very high population growth rate, leading to migration into more fragile areas. In the long term, the best way to address sustainability in the fragile areas may be to focus crop research on higher potential areas, thereby reducing population pressure in the low-resource zones and allow them to revert to their traditional uses.

In the short run, however, a two-pronged approach is necessary. Some work needs to go into stabilizing (and eventually improving) environmental conditions and farm incomes in environmentally fragile areas. But in attempting to deal with poverty and environmental degradation in these areas, the CRSPs should keep in mind that greater productivity in high-potential zones can make major contributions to the food security of the large and growing proportion of the population that depends on the market for some of its food.

Use of Market Analyses to Guide Technical Research. Because so many people rely on the market for part of their food, simple analyses of existing price and market data may help identify research priorities. Such analyses are part of the strategy discussed below of using subsector analysis to guide technical research.

Implications for the Organization of Research under the CRSPs

Traditionally, social scientists have had little direct involvement in technology development aimed at improving food security. Most often, their contribution has been limited to conducting ex-post analyses to assess the economic and social impact of technical change. While such studies provide interesting insights, they have limited impact on the technical research program. First, technical scientists may discount pessimistic appraisals as "cheap shots," since it is far easier to judge the past than to anticipate the future. Second, because most social scientists have a limited understanding of technical agriculture, these analyses are sometimes flawed with inaccuracies—and thereby discounted by technical scientists as "naive" assessments. For example, during the early 1980s, some social scientists, advising the Office of Technology Assessment on sustainable agriculture in Africa called for technical scientists to develop "low-input/high-output" technologies (Staatz, 1986). While such technologies would clearly be desirable, it is not at all evident they are technically feasible.

Finally, because ex-post analyses are typically conducted 5 to 10 years after the research program is initiated, insights gained can only influence the direction of future technical research. Technical scientists facing such ex-post critiques often ask where the social scientists were when the basic technologies were being developed. The problem is that the structure of many research programs relegates the social scientist to ex-post nay-sayer rather than active participant in technology design (Staatz, 1989).

Setting a Social Science Research Agenda to Address Food Security

If social scientists are to contribute to the challenge of increasing the impact of technical research on food security, new approaches are required. These approaches must consider not only the diverse household food strategies discussed above, but also the basic structure of the CRSPs, existing resources constraints, and the information needs of the technical research programs.

Structure of the CRSPs. First, most CRSPs support collaborative research and training directed at relaxing constraints to increase the production and utilization of a single commodity (e.g., beans, cowpeas, sorghum, millet, peanuts, small ruminants, or fish). Since most CRSPs are directed at a specific commodity, we do not attempt to address the issue raised earlier about the possible greater potential for improving food security by focusing on another commodity or on nonfarm enterprises. However, we do stress the need to put the CRSP research in the context of the constraints posed by other elements of the households' food security strategies, a perspective similar to the systems approach of farming systems research. For example, farm households in a particular region may attempt to secure their food security by relying heavily on seasonal labor migration to diversify their income sources. Such migration reduces farm labor availability during certain periods of the year—a fact that scientists need to consider in developing new crop technologies.

Second, each CRSP is guided by its Global Plan, which specifies the major worldwide constraints for the respective commodities. In selecting collaborating countries, consideration is given to the potential of the research conducted in that specific country to generate new knowledge and technologies that will have a national, regional, and worldwide impact. Finally, research conducted under the CRSPs is expected to benefit not only developing countries, but U.S. farmers and consumers as well. Thus, social science research agenda must complement commodity-specific technical research agendas and seek to generate insights that have implications beyond the collaborating country.

Constraints to Conducting Social Science Research. There are two major constraints to implementing social science research in the CRSPs aimed at improving food security. First, financial resources available to the CRSPs are increasingly limited and social science data collection is often quite expensive. For example, it costs a minimum of $40,000 to implement a modest baseline survey and analyze the data generated (Bernsten and Ferguson, 1992). Second, many countries (including the U.S.) have a shortage of social scientists with the experience required to plan, implement, and analyze social science data in a way that generates insights that will contribute to a technical research agenda.

These constraints suggest that CRSP social scientists must place priority on developing cost-effective and replicable methods for implementing technology-generation-relevant social science research. In addition, to develop a cadre of appropriately trained social scientists, the CRSPs must allocate far greater resources to long-term and short-term in-service training of social scientists. Food insecurity is inherently an interdisciplinary problem, being affected by technical, institutional, and policy factors. Hence, the training of social scientists to deal with food security must equip them to work with those outside their own disciplines.

Information Needs of Technology—Generating Research Projects. Social scientists can contribute much more than they have in the past to developing appropriate technology that improves the food security of limited-resource farmers and consumers. To achieve this objective, rather than focusing on ex-post analysis, we must direct our attention to the more immediate needs of technical research projects (Knipscheer, 1989). This suggests that we must provide greater assistance in identifying appropriate technical research priorities, assessing (ex-ante) nascent technologies, and monitoring the initial impact of these technologies in their early stage of diffusion.[7] While social scientists can draw on existing methods to meet these needs, we must be the first to admit that, at best, we can anticipate the future only dimly. Serendipity plays a major role in technology development, and the impact (or lack of impact) of new technology is often influenced by exogenous, unanticipated events.

Important Agendas for Social Scientists

Social scientists can make their greatest contributions to improving food security via the CRSPs in three areas: by addressing commodity-specific constraints that threaten food security, by developing and implementing cost-effective and replicable methods designed to help establish research priorities and assess nascent technologies, and by monitoring the initial impacts of these technologies.

Setting Initial Research Priorities: The Subsector Approach. Establishing initial research priorities is particularly critical, since these decisions will largely determine the ultimate impact of the technical research program. The priority-setting process must consider the most important constraints to improving household food security,[8] assess alternative opportunities to relax these constraints, and identify specific research strategies.

Information Needs. Success in priority setting requires that the participants understand both the role of the commodity in the food system (especially its role in the food security strategies of the poor) and the linkages between interdependent components of the food system. In CRSP-sponsored projects, the target commodity is typically one of many crop-animal species in a cropping-livestock-farming system. The target commodity is linked to the national economy through input and output markets, influenced by local institutions, and affected by national and international policies. Thus, factors exogenous to the farm are likely to have a major impact on the commodity; and changes in farm-level factors will affect the rest of the economy.

For example, if population grows while forest resources do not, the price of fuel wood will rise, other factors held equal. This increase in the price of fuel wood (a change exogenous to the farm) will shift consumption towards staples such as rice that require less fuel to prepare compared to coarse grains, such as millet. If, as in much of the Sahel, rice is heavily imported while millet is locally grown, such a shift in demand can hurt the country's balance of payments, leading to broader macroeconomic problems. Understanding the links between fuel wood prices and international trade patterns is thus necessary for analyzing changes in the farm-level demand for these commodities.

The Process. Subsector analysis can guide scientists in setting in-country research priorities by helping researchers gain a view of the "big picture." Shaffer (1970:5) defines a *subsector* as a "meaningful grouping of economic activities related vertically and horizontally by market relationships." In the context of the CRSPs, the objective of a subsector study is to provide a "conceptual framework for organizing knowledge about the subsector, specify the nature of missing information and, thus, provide a basis for organizing future research." Component activities include describing the subsector, diagnosing problems constraining performance, projecting the consequences of specific alternative changes, and prescribing a research agenda (Shaffer, 1970; Témé and Boughton, 1992). Particular attention should be given to those elements of subsector performance that affect the access of the poor to the commodity. For example, understanding the factors affecting the seasonality of prices may be critical to developing policies to alleviate food insecurity during the "hungry season."

As originally conceptualized, subsector studies were typically implemented as a major research effort, extending a year or longer. In recent years, development-oriented economists have merged rapid appraisal techniques designed to assess village-level constraints (Chambers, 1981; Sarimin and Bernsten, 1984) with subsector analysis—thereby creating a rapid appraisal strategy for assessing the role of a commodity in a national economy (Abt Associates, 1988; Holtzman, 1986; Holtzman, Abbott, and Martin, 1989; Scott, 1990). Rapid-appraisal-subsector studies (RASS) are carried out by a multidisciplinary team of social and technical scientists, who focus on synthesizing data collected from secondary sources and key informants. The team generates an overview of the historical and current status of demand (domestic and foreign), supply (production and imports), institutional environment (e.g., research, extension, marketing system, land tenure), and government policies (e.g., prices, subsidies) as well as gains insights on gender, access, and equity dimensions of the subsector. From a food-security perspective, it is particularly important to identify which groups in the country are most involved in producing and consuming the commodity and what role the commodity plays in the food security strategies of poor households. For example, is the commodity a primary source of calories for the poor year-round, or is it consumed primarily during certain periods when other commodities are unavailable or very costly?

Simple analysis of existing price data can help identify topics to be further investigated during the RASS. For example, calculation of gross marketing margins and bivariate correlations of prices between markets may suggest areas where transport problems or lack of competition are hindering the movement of commodities. Similarly, simple graphing of prices over time may indicate seasonal price peaks that could be ameliorated through better storage technologies or the development of varieties with differing maturities. Such information is extremely useful in designing strategies for targeting food aid and other relief both seasonally and geographically (Staatz et al., 1989).

Retrospective interviews with household members carried out during a rapid assessment can also provide insights into how households have coped with food shortages in the past. Such interviews provide information on the role that the target commodity plays in the household's food strategy. This information may highlight how improvements in the production technology or marketing arrangements for that commodity may strengthen those coping strategies. For example, they may highlight the need for earlier maturing varieties to "break" the hungry season, thereby reducing the need for food-deficit households to go into debt during this time of the year. Such debts often have to be paid back with labor on others' fields during the planting season, thus putting the food-insecure household further at risk. Similarly, as mentioned earlier, certain coping strategies, such as seasonal migration, may create resource constraints at the household level that technical scientists need to consider when developing new technologies.

RASS techniques are useful to identify research priorities at the beginning of the project as well as to periodically monitor developments in the subsector that have important implications for technical research. For example, are export markets developing that offer remunerative new markets for farmers? Are farmers selling their work animals to cope with drought? If so, should technical research give greater focus in the short run to manual cultivation techniques? Subsector analysis is, thus, an iterative process that goes on throughout the life of the research (albeit at reduced intensity), not a one-shot affair.

Issues to Address. RASS analysis can provide considerable information relevant to establishing technical and social science research priorities to improve household food security. Some examples include the following.

- Who consumes the commodity, how important is it in their diet, and in what form it is consumed (type of processed products)?

- When does the commodity become available during the year, and how does it fit into the household's food strategy? How might its role in that strategy be modified? For example, in Mali, maize is currently grown primarily as a hungry-season crop for on-farm consumption. The breeding strategy to fine-tune this role may be very different from one that focuses on turning maize into a major cash crop (Témé and Boughton, 1992).

- What grain characteristics (e.g., size, color, cooking quality) do local consumers prefer? To what extent do households rely on other complementary or joint products, such as leaves for sauces and straw for animal fodder?

- Is there a potential for export or import substitution? If exports are a target market, what are the quality characteristics desired in the target market?

- What are current yields, types/levels of inputs used, costs of production, and major constraints that farmers, traders, and consumers face?

- Who grows the crop (men vs. women, small vs. large landholders, owners vs. tenants, irrigated vs. rainfed farmers) and how important is each group in terms of its share of total production and its share of total farmers producing the commodity?

- Do farmers (and, further, *which* farmers) have access to credit, input and output markets, and extension services?

- What government policies (such as controlled prices, tariffs, subsidies, and export taxes) create incentives/disincentives to farmers, traders, and consumers?

Potential Insights. Analysis of the data collected can help the project, for example, to identify major information gaps; recognize inappropriate technical options; highlight equity, access, and gender issues; refine technology options; specify desirable technology characteristics; and identify institutional and policy constraints that may limit adoption of new technologies. The following examples illustrate these potential contributions.

- *Identifying major information gaps.* The RASS analysis may clearly indicate that insects are a major production or storage constraint. Yet, the lack of detailed information may indicate that technical research is first needed to assess the relative economic importance of specific pests, before initiating a breeding program. Similarly, the RASS analysis may indicate the need to carry out a baseline survey to understand better the constraints faced by farmers, traders, and consumers. One of the advantages of the RASS is that it helps focus the baseline survey so it doesn't attempt to collect data on every conceivable topic, leading to long delays in data processing and analysis.

- *Recognizing inappropriate technical options.* Although the RASS may show that weeds are a major constraint, analysis of data on labor and herbicide costs may show that herbicides are too expensive, relative to the cost of hand weeding. Such results would suggest that herbicide trials are inappropriate, but research on cultural practices is an appropriate alternative strategy to relax this constraint.

- *Highlighting access, equity, sustainability and gender issues.* The RASS analysis may find that the commodity is produced by large, canal-irrigated, commercial male farmers with access to credit as well as by limited-resource, hillside, female farmers without access to credit. Research to address the constraints of the commercial sector would likely have far greater impact on national production, since this group is likely to rapidly adopt the new technologies. This, in turn, could benefit the many poor consumers dependant on the market for their food supply.[9] On the other hand, neglecting the research needs of the subsistence sector would exacerbate existing gender and income inequities—and promote environmental degradation by failing to generate technologies appropriate to the needs of, for example, hillside farmers. These results might suggest the need for a dual-focused research program, directed at addressing the differing constraints facing each group—with special attention paid to, for example, reducing soil erosion on hillside farms, which in turn will extend the useful life of the irrigation infrastructure.

- *Refining technical options.* A lack of processed products in the market may appear to indicate a potential to expand commodity demand by developing a new, highly nutritious processed products. Yet, analysis of data collected may show there is no effective demand for highly processed foods, since poor households have insufficient income to purchase the proposed product—a much more expensive source of calories/protein than the currently consumed unprocessed product. These results would suggest the need to refocus the technical research towards developing an equally nutritious, but less highly processed—and less expensive—substitute to enhance household food security of the poor.

- *Specifying technology characteristics.* In certain instances, the RASS analysis will indicate that sufficient information is available to initiate technical research to redress a major constraint, such as low yields due to insect damage. In this case, information gathered on consumer preferences and environmental constraints will suggest grain quality and varietal characteristics that need to be incorporated into the breeding program (e.g., drought tolerance, early maturity, insect-resistance, small-red-seed type, and rapid cooking time). On the other hand, if the RASS analysis identified exports as a major new market for surplus production, further analysis would be needed to identify consumer preferences in the target market.

- *Identifying institutional and policy constraints*. The RASS analysis may find that farmers growing the target commodity do not have access to credit or key inputs, or access is limited to owner-operators with land to offer as collateral—thereby limiting the potential impact of new technologies. Similarly, restrictions on grain movement within the country or on who may legally process it may substantially reduce the potential contribution of a crop to food security—as well as limit the demand for the crop from smallholders.[10] Given such situations, social scientists might develop a research initiative to document the negative impact of these policies. These results could then be used to initiate policy discussions with the government, directed to creating a more fertile institutional environment.

Benefits and Challenges. The key to the success of a RASS analysis is the active involvement of both technical and social scientists. The role of the technical scientist is primarily to provide insights about the technical aspects of the target commodity. The role of the social scientist is to put the commodity into a subsector context—highlighting farmer, farm-household, trader, consumer, gender, institutional, government policy, and international trade dimensions of the subsector. From a food security perspective, it is particularly important to highlight how the commodity fits into poor households' food-security strategies, both as a consumption good and as a source of revenue.

RASS analysis is particularly appropriate for setting initial in-country research priorities in the CRSPs, since it represents a strategy to generate rapidly (typically within one month) information needed to identify key constraints and research opportunities in the target subsector. In addition, when carried out at the beginning of a project, it provides an opportunity to establish rapport among in-country and U.S. scientists (often resident at different universities) from different disciplines. Finally, the jointly authored RASS report provides all participants a common understanding of the subsector, the role of the commodity in household and national food security, existing technical/socioeconomic constraints, and technical/policy options for increasing the contribution of the subsector to food security.

Implementing Field Research: Screening Nascent Technologies. Once research priorities are set, commodity research projects attempt to relax identified constraints by screening both promising technologies that performed well in other countries and nascent technologies developed by the project. Social scientists can contribute to this assessment by identifying the social factors that need to be considered in this assessment.

Information Needs. Agricultural research projects follow a sequence of stages. Initially, nascent technologies are assessed against technical criteria, under restricted conditions. For example, lines or varieties are evaluated in on-station trials for agronomic characteristics, pest resistance, yield performance, and so on. New ingredients (e.g., flour blends) are evaluated in the laboratory for nutrient content, storage and functional properties, and microbiological safety. Based on these tests, the most promising materials are advanced for broader evaluation. For example, preliminary lines and varieties are moved into on-farm trials to assess yield and yield stability under a wide range of environmental conditions. New ingredients may be supplied to commercial firms or expert sensory panels for further evaluation or formulated into products for evaluation by consumer taste panels.

While technical criteria measure many characteristics that determine their ultimate acceptability to farmers, traders, and consumers, these measures sometimes overlook factors that subsector participants feel are important. Such factors may include date of maturity, growth habits, storability, taste, grain size, and cooking characteristics (Ferguson, Millard, and Kahila, 1990). For example, households that face preharvest food shortages may be willing to trade off some increase in yield of a new variety for earlier maturity. Thus, the more effectively a research project can incorporate client preferences into the early stages of technology development, the more likely the finished technology will be acceptable to the target group(s).

The Process. Social scientists can help to increase the efficiency of screening by proposing methods to incorporate better the perspective of farmers, traders, and consumers as early as possible. Two approaches have been used to achieve this objective. First, anthropologists have assembled "representative farmer panels" to evaluate entries in on-station and on-farm trials. Participating farmers rank each line/variety against technical criteria (similar to those used by the breeders) and give their preferences about color, seed size, maturity dates, and so on (Ashby, Quiros, and Rivers, 1989; Sperling, 1989). Similarly, food scientists assemble consumer taste panels to assess preferences for both varieties and potential new consumer products.

Second, economists have developed models that seek to incorporate the farmers' perspectives into the evaluation of variety, herbicide, fertilizer, and insecticide trials (Perrin, et al., 1979). This is achieved by estimating the marginal rate of return (MRR) to the alternative treatments, using estimates of input cost and benefits that reflect farmers' actual circumstances.[11] For example, rather than using an average market price to value yield, the analysis would use the field price at harvest, which may be much less than the average market price.[12] By varying the assumptions about the parameter values (e.g., input and output prices, tenurial arrangements, distance to market, labor costs, credit costs), it is possible to estimate the marginal rate of return that different types of farmers would expect to earn on his or her investment. For example, the rate would differ between, on the one hand, land owners living near the market and having access to subsidized fertilizer and government credit and, on the other hand, share tenants living far from the market without access to subsidized inputs and who must borrow from money lenders at a high interest rate (Sumagaysay, 1990). Similarly, the marginal rate of return may be higher for food-insecure farmers who are net buyers of the commodity than for more food-secure net sellers.

Issues Addressed. Farmer participation in assessing experimental trials and ex ante MRR analysis can provide important insights about the likely acceptability of nascent technologies and their sensitivity to policy changes, such as the following.

- Do the varieties have characteristics preferred by farmers, traders and consumers? Here it is important to ask *which* farmers, traders, or consumers we are trying to help, as each of these groups have heterogeneous preferences. Food-insecure consumers may be willing to trade off taste for a significantly lower price, while more food-secure consumers are less likely to accept "substandard" staples.

- Do farmers, traders, and consumers use the same criteria in assessing varieties as technical scientists?

- What is the potential benefit to earlier-maturing varieties that allow farmers to capture a higher market price (if they are net sellers) or avoid paying a high market price (if they are net buyers)?

- Are farmers likely to adopt a variety that produces a high yield but must be sold below the market price for competing local varieties of superior quality? Or are they willing to eat this variety themselves, reserving the traditional varieties for the market?

- How much labor will farmers be willing to invest in carrying out a new crop management practice?

- Will a nascent technology be adopted by only owner-operators, or is it sufficiently profitable to also be adopted by share tenants?

- If the government eliminated input subsidies, would the technology still be profitable?

- If the government reduced or eliminated the guaranteed support price, would the technology still be profitable?

<u>Potential Insights</u>. Results of these analysis help to guide the research program by providing insights about the likely acceptability of nascent technologies in their early stage of development, as illustrated by the following examples.

- *Confirmation of appropriateness.* Where the "representative farmer panels"/MRR analysis indicate that the technology is sufficiently promising, scientists can proceed to test and fine-tune the technology, with greater confidence as to its ultimate acceptability. When considering appropriateness, scientists need to bear in mind the concept of "food security recommendation domain" discussed earlier. What is appropriate for one group of farmers, traders, or consumers may be inappropriate for others. For example, technologies acceptable to farmers who are net sellers of grain may be inappropriate for those who are net buyers. Hence, the RASS findings help to target technologies and institutional changes better to different groups.

- *Potential conflicts.* On the other hand, if these analyses suggest potential conflicts, the project should explore ways to modify the technology. Insights gained about the factors that reduced its acceptability can guide this process.

<u>Benefits and Challenges</u>. The success of strategies designed to incorporate clients' preferences and circumstances into early assessment of technology depends on the degree to which these analyses accurately reflect subsector participants' preferences and circumstances.

First, several issues arise in implementing "representative farmer panels." How should the participants be selected—randomly or purposely? Which types of farmers, traders, and consumers should be included? From a food-security perspective, one should include both food-secure and food-insecure households in order to contrast the role of the commodity in the food strategies of these two groups. How many participants should be included? How should these participants' evaluations be weighted, relative to technical scientists' criteria?

Similar issues must be resolved in structuring MRR analyses. For example, what are the most important types of farmers, traders, and consumers that should be simulated and how can their circumstances be best incorporated into the model? What values should be used to best reflect labor costs (e.g., zero opportunity cost, the wage rate of hired farm labor, or the nonfarm wage rate), input/output prices, tenurial arrangements, and so on that farmers, traders, and consumers actually face? (Here we must bear in mind the points raised earlier about how the household's food security strategy affects the opportunity cost of household resources.) What policy options are most important to simulate?

Resolution of these issues is needed to ensure that the proposed ex-ante analysis validly and reliably reflects clients' circumstances. Efforts to resolve these issues will require the participation of both technical and social scientists. Only through joint resolution will it be possible to convince technical scientists that the approaches proposed have "scientific merit" and can contribute to the assessment and redesign of nascent technologies.

Monitoring Impact: Initial Adoption Studies. Once tested under relatively controlled conditions, new technologies become available for extension to farmers, food processors, and consumers.

Information Needs. Scientists need to monitor the initial adoption of these technologies, since they are likely to have unanticipated impacts and may perform differently from the predictions of ex-ante analysis. Early evidence of performance is needed to establish priorities for critical future second-generation research.

The Process. Adoption studies to assess impact are typically carried out several years after technologies have been released.[13] While social scientists can draw on these ex-post methods, there is also a need to develop studies that track adoption during the initial diffusion period.

In response to this need, CIMMYT's Economics Program has drafted a manual for conducting studies to monitor the adoption of agricultural technology (CIMMYT, 1991). Adoption studies involve collecting data from a representative sample of farmers, traders, and consumers to estimate the rate (percent) of adoption, respondents' reasons for adoption/nonadoption, their evaluation of the performance of the technology, and constraints still faced. In addition, data are collected on the socioeconomic characteristics of the respondents. These data are used to analyze the distributional impacts of a new technology, by estimating, and then comparing, the level of benefits received by various types of beneficiaries (e.g., large vs. small farmers or traders, net sellers vs. net buyers of basic staples, female vs. male entrepreneurs, irrigated vs. rainfed farmers, and consumers at different income levels).

Issues Addressed. Analysis of data collected through adoption studies will increase our understanding about the initial performance of the technology and clarify who has benefited from the technology. Some examples are the following:

- Is the technology being adopted in all regions of the country or only in well-endowed environments?

- Is the technology being adopted by all types of farmers, or mainly by male/female, irrigated/rainfed, large/small farmers? Especially important from a food security perspective is the need to distinguish between farmers who are net buyers of the commodity and those who are net sellers. Resource constraints and the value of additional production are likely to differ substantially between these two groups (Jayne, Forthcoming).

- Has the technology performed as well as anticipated, or are improvements needed?

- Are there institutional or policy-related factors that explain a lack of or differential adoption, such as a lack of farmer access to extension services, credit, input/output markets?

Potential Insights. Answers to the questions outlined above can suggest initiatives that should be taken to improve the performance of the technology and identify opportunities to address better the needs of nonadopters, thereby accelerating adoption. Two examples follow.

- *Poor performance of technology.* Information generated about the initial performance of the technology under differing ecological condition and socioeconomic circumstances and the remaining technical constraints can be used to set priorities for future research.

- *Institutional and policy constraints.* Insights about the impact of access to input and output markets, extension services, credit, and so on will suggest opportunities to work with the private sector and government to redress the identified constraints. For example, if the analysis indicates that availability of seed was a limiting factor, the project could explore with private seed companies or nongovernmental organizations appropriate mechanisms for contracting for seed multiplication.

Benefits and Challenges. For adoption analysis to provide valid and reliable insights that can be used to strengthen the technical research program and identify interventions needed to diffuse the benefits of the new technology more widely, several methodological issues must be addressed. Social scientists, working closely with technical scientists, can contribute to strengthening survey design and analysis of the data by providing advice on the following critical issues.

- *Sampling.* Where should the survey be conducted? What sampling frames should be used to select a random, representative, and unbiased sample? How large a sample is necessary to achieve the desired level of precision? How large a sample is necessary to provide adequate representation of the various groups whose food security one wants to improve (e.g., adopters vs. nonadopters of new technologies; net buyers vs. net sellers of basic commodities)? What are the tradeoffs between purposive and random sampling to assure adequate coverage of these various groups?

- *Questionnaire design.* What information should be solicited to assess the performance of the technology and to understand the pattern of adoption? How should these needs be made operational through survey questions?

- *Analysis*. What types of insights are required to guide the assessment of the technology and identify unmet needs? What are the appropriate social, institutional, and policy interactions that should be explored in the analysis? Review of previous studies of household food security strategies provides some guidelines here.

Conclusion

Households in developing countries engage in a wide variety of activities to help assure their access to food. The diversity of their activities determines how they react to new technologies developed by agricultural researchers. We have argued that these diverse strategies and the heavy reliance many households place on the market for food have major implications for technology development under the CRSPs.

In particular, the diversity of strategies means that cropping activities must be viewed in a systems context, where the noncrop enterprises help determine the opportunity cost of household resources. These opportunity costs, in turn, affect the farmers' willingness to adopt new technologies. The heavy reliance of many rural as well as urban households on the market for food implies that a major focus of research should be on driving down the real cost of food through increased productivity in both the farm and off-farm elements of the food system.

This vision of food security places technology development in its broad context. But work under the CRSPs, by its very nature, is more narrowly defined. Such work can nonetheless make important contributions to household food security as long as that work bears in mind households' diverse strategies to assure their access to food and the importance of taking a subsector, as opposed to purely a farm-level, perspective.

A major need in the CRSPs is for greater collaboration between social scientists and technical scientists at critical points in technology design and implementation. In particular, we have described how social scientists can make important contributions to identifying research priorities, screening nascent technologies, and monitoring the impact of new agricultural technologies, all aimed at improving household food security.

These activities are not intended to be all-inclusive. But they represent a beginning—a way for social scientists to contribute more to successful technology development and build their credibility with technical scientists. This should, in the long-term, lead to a greater role for social scientists in the CRSPs. As a first step, each CRSP project should identify at least two social scientists to participate as full partners on the research team—one from the United States and one from the collaborating developing country.

Several actions could increase the productivity of social scientists working in the CRSPs. Among these, networking and training should have high priority. The development of a network among CRSP social scientists would provide a forum to develop, share, and refine research methods. Successful research approaches aimed at improving food security could be more rapidly diffused across CRSP commodities. Furthermore, such a network would allow CRSP social scientists to appreciate more fully how their individual commodities fit into various multicommodity household food strategies.

Finally, much more attention must be paid to training LDC social scientists in the skills needed to complement those of technical scientists. Without such an effort, the contributions of social scientists to national agricultural research systems will remain very limited.

We believe that the strategy outlined above will strongly contribute to the productivity of the CRSPs and the credibility of social scientists with technical scientists. This enhanced credibility will in turn lead to increased demand for social science research. We believe that such a "demand-led" strategy for increasing the social science contribution to the CRSPs is a more productive path than establishing guidelines that allocate a fixed percentage of CRSP budgets to social science research.

Notes

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[1] For a more detailed discussion of the various implications, see Eicher and Staatz, (1986).

[2] A germane question, which we don't address due to space limitations, is what is meant by the term "household" in this context. Once one begins to disaggregate by gender, the concept of household becomes blurred. What we are really dealing with are a whole range of overlapping managerial decisions and responsibilities taken by different individuals.

[3] A 10 percent decrease in unit costs of production is the equivalent of a 10 percent increase in total factor productivity (i.e., technical change that allows a farmer to get 10 percent more output for the same value of inputs). This reduction in unit costs is not equivalent to a 10 percent increase in yields. The impact of a 10 percent yield increase on consumer prices depends on the price elasticity of demand for the product.

Whether the decrease in marketing costs actually gets passed on to the consumer depends on how competitive the marketing and processing system is. If it less than perfectly competitive, some of the decrease in marketing costs will be captured by those in the least competitive segments of the marketing system. The degree of competition in the marketing system should itself be a subject of research, as it affects the level and distribution of payoffs to research on improving marketing and processing technologies.

In the short run, an increase in production of the commodity at the farm level may lead to an increase in the price of marketing services. The demand for marketing services would rise in response to the increased farm-level production. It will likely take time for the supply of those services to expand sufficiently to bring the price of marketing services back to their original level. A further important topic for research concerns factors that influence how quickly this adjustment takes place (or, to use the economist's jargon, the factors affecting the elasticity of supply of marketing services).

[4] The main losers from the introduction of the new technology were the approximately 12,000 small farmers who grew upland rice. They were not able to adopt the new technology but saw rice prices fall as a result of the expanded domestic pro-

duction. This example illustrates the importance of asking whose food security one is aiming to improve. But as Scobie and Posada (1990:412) note, "Under any plausible set of welfare weights, the . . . losses [of the 12,000 upland rice growers] would be more than offset by the gain to more than one million low-income consuming households, implying an overall gain (albeit uncompensated) in some measure of social welfare."

[5]The effect of cash cropping on household food security depends on many factors including, among others, the nature of the crops involved and the prevailing land tenure and marketing arrangements. For an introduction to the large literature on this topic, see Maxwell and Fernando (1989); the April 1988 issue of the *IDS Bulletin* devoted to this topic; Von Braun and Kennedy (1986); and Dioné (1989a).

[6]From a food-security perspective, this work needs to focus on stabilizing yields and reducing unit costs of production. Reducing unit costs of production may require increasing yields, but not all yield-increasing technologies reduce unit costs of production. For details, see Staatz (1989).

[7]Nascent technologies refer to early generation research outputs (lines/ingredients) that must undergo further development and evaluation before being released to farmers, processors, and consumers.

[8]As Jim Hooper, a former agronomist colleague at IRRI used to say, "Are we trying to find a solution to a problem that doesn't exist?"

[9]Whether increased domestic food production leads to lower consumer prices depends on, among other things, whether or not the country is a net importer of the commodity (if the country imports, increased domestic production may simply displace imports, with no change in price); and on how competitive the food marketing system is (Mellor, 1990).

[10]For an example from Zimbabwe, see Jayne and Chisvo (1991).

[11]The model actually estimates the marginal rate of return to a given increment in expenditures, That is, the marginal net benefit (gross field benefit minus total variable costs) divided by the marginal cost (increment in expenditure).

[12]The harvest price for a new variety could be close to or even above the season-average price if the new variety matured much earlier than the main crop.

[13]Often a baseline study is conducted following the subsector rapid appraisal to generate information as to farmers', traders', and consumers' before-project situation, including constraints faced. The information, collected in the baseline studies, can be used to assess changes that have occurred as a consequence of the project.

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Differences among Women Farmers: Implications for African Agricultural Research Programs

Anne E. Ferguson

Mainstream thinking in the agricultural sciences holds that new varieties, techniques and technologies are neutral, physical products of science and progress "stacked conveniently for ease of lifting" and transfer.[1] Issues like gender, class or ethnicity are typically regarded as social or political concerns lying beyond the scope of biological research.[2] At most, these issues are considered to have implications for technology transfer and adoption, but not for the process of problem identification in agricultural research or for technology development itself.

This paper presents a counter-perspective that draws largely from the women and development and feminist philosophy of science literatures. These literatures suggest, first, that the agricultural sciences and the technologies they produce are products of specific social circumstances and, thus, are themselves social constructs and practices (Stamp, 1989; Harding, 1991; Latour, 1987). As Steven J. Gould (1981:21–22) has summarized: "Science, since people must do it, is a socially embedded activity." Second, advocates of this counter-perspective contend that, depending on whose interests they serve, science and technology can transform social, economic, and political relations. They have the power to create new forces of production and new social relations (Stamp, 1989).

Consequently, far from being extraneous to the agricultural sciences, gender, ethnicity, class, and other forms of social differentiation are integral to the process of agricultural research and technology development.[3] They influence the problems identified for research and are used in the methodology. They also shape the characteristics of the new technologies and, once these products are put to use, they may bring about changes in social relationships, benefiting certain groups and disadvantaging others.

This alternative perspective challenges the largely supportive role allotted to social scientists in agricultural research programs and the beneficiary status assigned to those whom these programs are designed to impact. Social scientists involved in these programs are usually engaged to study policy and pricing-related issues or the dissemination, access, and impact of technologies. They seldom take part in problem identification or technology design itself, which remain the domain of the biological scientists. The perspective discussed here, in contrast, holds that social scientists and program beneficiaries have roles to play alongside biological scientists in the process of setting research agendas.

The Role of Social Differentiation in Agricultural Research and Development Paradigms

At least four coexisting research and development paradigms shape much of contemporary agricultural technology development. These paradigms include transfer of technology (TOT), farming systems research (FSR), appropriate technology and farmer participatory research (FPR). What roles have gender, class, and ethnicity played in problem identification and technology development associated with these different paradigms?[4]

Transfer of Technology (TOT)

The transfer of technology paradigm is the model of agricultural research familiar to most of us from our university educations, and it remains a dominant model today. In this approach, new techniques and technologies are developed by scientists at universities and research institutions based on their evaluations of the major constraints to production. After trials on research stations, these technologies are tested on farmers' fields under researcher-managed conditions. Technologies that are superior in the desired traits are then disseminated via the extension service to farmers for adoption.

TOT is closely associated with the modernization school of development and draws on a paradigm which views science as a socially and politically neutral, impartial endeavor. TOT researchers emphasize developing technologies that can be widely used across diverse environments. In this model, farmers are viewed as the beneficiaries of research designed and carried out by others. Social differentiation among them is not considered directly relevant in problem identification, technology design or, for that matter, in the dissemination process. Rather, it is expected that new innovations will be disseminated from the better-off, usually male farmers who researchers and extension agents often identify as most receptive to change, who are politically and economically well-positioned to adopt the proposed innovations, and with whom they are most comfortable working. Although appearing as value-free, socially-neutral research, in many cases, TOT agendas address the needs and advance the interests of relatively well-off male farmers. In this sense, agricultural scientists in these programs can be seen as the bearers of gender, class, and ethnic identities that influence their research agendas (Harding, 1991).

The TOT model has encountered greatest success in the industrialized West where farming is highly capitalized and relies heavily on inputs and subsidies, and where farmers and researchers most resemble one another in class, gender, and ethnic characteristics. It has also raised production in some developing country regions where reliable rainfall or irrigation exists.[5] TOT has been less successful in meeting the needs of small-scale farmers in low-input, resource-poor, rainfed areas. Here the farming systems are more complex, diverse, and risk prone, and there are likely to be class, gender, and other social differences between scientists and farmers as well as among farmers themselves (Lipton and Longhurst, 1989; Chambers, 1989:xviii).[6]

A rich corpus of literature exists on the differential impact of Green Revolution and other TOT technologies by gender, usually conducted by researchers not associated with the technology generation programs themselves. This literature includes numerous case studies describing how technological change is fed through existing sexual divisions of labor, family relations and wider class, power, and institutional structures in society (Whitehead, 1985; Agarwal, 1985; Palmer, 1978; Pearse, 1974; IRRI, 1985; Carney and Watts, 1991; Rubin, 1990). Many studies also show how technology development efforts have perpetuated and strengthened these existing gender, class, and ethnic hierarchies. Generally, these investigations indicate that TOT-style technological change has often had unanticipated and negative effects, especially on poor women (Whitehead, 1985; Stamp, 1989; Warren and Bourque, 1989).

Appropriate Technology (AP)

The appropriate technology paradigm represents an effort to physically and economically contextualize the technology development process. Advocates favor a decentralized, small-scale approach to development as a way of promoting the use of local resources and avoiding dependency on industrialized nations. Although involving a critique of centralization and capital-intensive economic strategies, AP places heavy emphasis on scientific rationality and technical efficiency as a means of increasing productivity. From this perspective, cultural variability and social differentiation may be considered as obstacles to "rational" technology design and use.

As with TOT, in many cases, local communities and people are treated as beneficiaries of AP products and techniques, and problem identification and problem-solving remain carried out by outsiders (Warren and Bourque, 1989). Although resource and financial dependency can be reduced using an appropriate technology strategy, social and scientific dependency may remain unchallenged.

Even in cases where the needs of different social groups, such the poor, are accurately identified, AP's focus on technological efficiency, combined with its neglect of the social context, may result in lack of widespread adoption of its products. In other cases, where AP technologies have been widely adopted, they frequently have had unanticipated, differential impacts, suggesting that researchers need to consider differences not only between genders and among classes but also within them. For example, technologies like grinding mills, which reduce middle-class women's drudgery and free them to engage in more "productive" tasks, can reduce poor women's employment opportunities (Dauber and Cain, 1981).

Farming Systems Research (FSR)

Farming systems research is an evolving paradigm which addresses rural sociocultural, economic, and gender differentiation in technology development. Multidisciplinary teams of researchers have developed a range of techniques to understand the farming systems in a specified area and to target technology development toward the circumstances of specific categories of farmers. A principal aim of the research is to identify and remove agronomic, economic, and other constraints faced by various groups of farmers so that they can successfully adopt new technologies and implement recommendations.

This research and development approach recognizes that there are differences among farming enterprises and takes them into account in developing technologies. This paradigm offers a number of advantages over the TOT paradigm. Farming systems teams are multidisciplinary and often involve social scientists so that sociocultural, political, and economic factors, in addition to environmental and agronomic ones, are more likely to be considered in problem identification and technology design.

Given these advantages, however, early FSR shared certain traits in common with TOT. In both approaches, defining problems; designing, implementing, and evaluating experiments; and disseminating technologies were typically carried out by researchers and extension agents. Although different farming systems were characterized, and farmers were consulted at various stages in the research process, they did not usually play central roles in setting research agendas or in evaluating technology (Chambers, Pacey, and Thrupp, 1989). Recently, however, FSR practitioners have adopted more participatory research strategies (Groenfeldt and Moock, 1989, also see the new *Farming Systems Research Journal*).

Thus, the farming systems paradigm has taken gender differences into account in the research process to a greater extent than have other paradigms. Major contributions of this literature, most of it carried out by women, include increased understanding of the differential allocation of decision-making and other responsibilities and resources within households by gender and age. Numerous excellent case studies document how gender differences, in particular, influence technology adoption, and what the implications of these differences are for project success (Poats, Schmink, and Spring, 1988; Dwyer and Bruce, 1988; Moock, 1986; Davison, 1988; Jiggins, 1986, 1989; Feldstein and Poats, 1989).

Closely related to these studies on intrahousehold dynamics are another group of investigations examining the nutritional impact of the intensification and commercialization of agriculture brought about, in part, through agricultural development projects (Kennedy and Cogill, 1987; Kennedy, 1989; von Braum, Puetz, and Webb, 1989; von Braum, Hotchkiss, and Immink, 1989; Pinstrup-Anderson, 1989; Peters and Herrera, 1989). This literature shows how the interaction among local systems of social and economic stratification, broad processes of capitalist incorporation, and agricultural development programs produces diverse nutritional impacts. Similar to the farming systems literature on the distribution of responsibilities and rights to resources within households, these studies indicate that the nutritional effects of agricultural change are not uniformly borne within households. In this light, the concept of "household food security," implying uniformity of interests within these units, needs reconsideration.

Farmer Participatory Research (FPR)

A number of more recent approaches to agricultural research involve active participation of farmers in the research and development process. While the names of these strategies vary (farmer participatory research, farmer first, farmer-back-to-farmer), they all involve farmer participation in setting research agendas, in carrying out experiments and trials, and in the technology dissemination process.

In farmer participatory strategies, analysis of problems is carried out by farmers assisted by researchers and by farmers themselves. Farmers' fields and conditions are the primary locus of research. The intent of FPR is to build on and to develop existing local knowledge and local capacities for innovation and experimentation. FPR advocates recognize that, in the face of rapidly changing social, economic, and environmental conditions found especially in risk prone areas, agricultural scientists do not have permanent solutions to offer farmers. In these circumstances, they suggest that researchers support farmers in their own continuing processes of agricultural experimentation (Chambers, Pacey, and Thrupp, 1989; Bunch, 1989; Richards, 1985). They advocate that genetic materials, cultural practices, and other technologies be developed in conjunction with farmers and be made available in such a way that farmers can select the materials that best suit their individual circumstances (Chambers, 1989). My discussion here is limited to how FPR practitioners accommodate social differentiation, because indigenous knowledge and participatory research are focused on elsewhere in these proceedings.

FPR sets out to democratize science. It represents an effort to remove the barriers between scientists and farmers and to empower local people and their knowledge. Many FPR practitioners recognize that knowledge is differentially distributed by gender, age, ethnicity, and class in local communities, and that farmers with differing resource bases require different types of technologies. The paradigm, thus, offers the potential to challenge existing local inequities in access to resources and power. In practice, however, much of the focus has been on breaking down existing barriers between outsider/scientists and local farmers. Relatively less attention has been paid to understanding local-level social differentiation or to examining its implications for implementing participatory research strategies. The extensive literature on the differential gender impacts of technology development, cited above, clearly indicates that the issue of social differentiation needs to be directly addressed if agricultural technologies are to realize their full potentials.

This review of how the major agricultural technology development paradigms incorporate concepts of gender and other forms of social differentiation indicates that significant differences exist among these paradigms. Farming systems and farmer participatory research have been the most receptive to social science perspectives on differentiation. Farming systems researchers have developed methodologies to include beneficiaries in problem identification, and they advocate on-farm research under farmer management. FPR practitioners have taken these efforts a step further by overtly challenging traditional roles and relationships between farmers and researchers embodied in the TOT paradigm. FPR advocates an egalitarian stance in which farmers and researchers together identify problems, carry out experiments, and disseminate technologies, as opposed to the scientist-dominated approach characteristic of TOT.

Although efforts to include farmers in technology development are increasing, the issues of social differentiation among farmers and the implications of this differentiation for research agendas still usually receive only limited attention in agricultural research programs. With the exception of some farming systems and farmer participatory researchers, social scientists working in these programs often treat gender, class, and ethnicity as static, descriptive variables rather than as dynamic, interactive relationships. In particular, the interrelationships among class, gender, and ethnicity and the significance of these interactions for agricultural research remain poorly understood.

Social Differentiation: Perspectives from the Women, Development, and Science Literatures

Different schools of thought exist in the social science literature regarding the nature of agricultural research and development. Many social scientists working in agricultural research programs ascribe to a developmentalist, western-scientific, technocratic orientation which regards technologies as socially neutral products of research. These scientists are not likely to question how social or cultural factors affect the research agenda or process and, instead, are apt to focus on how such factors among program "beneficiaries" influence technology adoption. Social scientists interested in questions of whose interests are being served by particular agricultural research agendas, in contrast, often are not directly associated with agricultural research programs and, in fact, may be critical of the objectives and effects of them (Escobar, 1991). These different approaches to social differentiation associated with different perspectives on the nature of agricultural development can be illustrated by a brief review of the literatures on women, development and science (Gallin, Aronoff, and Ferguson, 1989; Gallin and Ferguson, 1991; Harding, 1991; Longino, 1990).

Liberal Perspective

Many of the studies of women and agricultural technology grow out of a liberal orientation to development. Proponents of this perspective contend that women have been left out of the development process. They assert that policymakers, project planners, and technology developers have neglected women's productive roles and, as a result, development efforts generally have had an adverse effect on them (Tinker, 1976).[7] According to advocates of this view, the failure to recognize women' centrality to economic growth has resulted in wasted resources and diminished returns on investments, including investments in agricultural research. The solution, proponents hold, lies in the removal of the political, economic, and ideological obstacles that limit women's abilities to participate in, and benefit from, the development process.

Supporters of this orientation see the social and economic system they are enmeshed in as essentially sound and potentially equitable. They recommend changing the policies of established institutions and designing innovations so that they work in the best interests of women, and they concentrate on delivering resources to women which will allow them to share more equally in the benefits society makes available to its members. In this perspective, change is often initiated from the top and, although the negative effects of power relations on women are recognized, they are not a primary concern. A number of excellent guides for including women in development projects are the products of this liberal tradition (see for example, Overholt et al., 1985; Feldstein and Poats, 1989; Caye and Rollins, n.d. (GIF); Russo et al., 1989; Blumberg, 1989; Rockefeller Foundation/ISNAR, 1985).

This liberal approach to development shares much in common with liberal feminist critiques of science and technology. Advocates hold that women need to be provided increased access to scientific training and to decision-making positions within science, and they therefore endeavor to end sexist hiring and promotion practices. Proponents also work to eliminate sexist and androcentric biases in scientific inquiry by recognizing that research, which does not follow accepted and well-understood principles of method and theory, constitutes "bad science" and can produce sexist results. For example, they argue that generalizations about humans cannot be based on data obtained only from studying men (Harding, 1991).

Similar to their development-oriented counterparts, liberal feminist critics of science and technology assert that the scientific enterprise is sound, but that women have been excluded from decision-making positions and power within it. These feminists support the goals of value-free objectivity and impartiality for all scientific inquiry, but they suggest that these procedures have not always been followed (Harding, 1991).

Advocates of these liberal perspectives share much in common in their conceptualizations of women's subordination and exclusion from science and development. Both groups see existing institutions as essentially sound, requiring only that women be admitted as equal members. Both place primary emphasis on differences in access to resources and power between men and women. Accordingly, they consider women as a homogeneous group and are not likely to pay attention to differences among them stemming from class, ethnic, or other social factors (Gallin and Ferguson, 1992).

Structural Perspective

Structural views of women's positions in science and development contrast sharply with liberal perspectives. Proponents of the structural orientation to woman and development hold that women's disadvantage is not due to the mismanagement of otherwise sound social, economic, and political institutions. Rather, women's subordinate position, and those of subordinate classes and ethnic groups, result from fundamental contradictions within these institutions and the global economy (Gallin, Aronoff, and Ferguson, 1989).[8] From this perspective, more than ill-conceived development planning is involved in women's marginalization. Supporters contend that women have not been left out of the development process. Instead, they suggest that women's poorly compensated productive and reproductive labor has underwritten many development efforts.[9] Thus, from their standpoint, gender, class, ethnic, and other social differences, far from being extraneous, are integral to the development process.

Proponents of the structural perspective hold that broad systemic transformations in the relations between nations and among classes and genders are required for development to benefit women. In their research, most have focused on processes of capitalist penetration and transformation (Whitehead, 1985; Stamp, 1989; Warren and Bourque, 1989). They usually work outside of formal development-related structures which they see as maintaining and perpetuating inequality and exploitation. They often favor grassroots organizations and attempt to engage women themselves in the definition of problems and identification of solutions.

This structural perspective on women and development has a counterpart in feminist theories of science. Harding (1991:59) provides a succinct description of feminist standpoint theories. Advocates contend that knowledge is grounded in particular historical and social situations. In a society where power is organized hierarchically, a fully objective perspective—one that is disinterested, impartial, or value free—cannot exist. Each actor can achieve only a partial view of reality, and this view is distorted by the way relations of dominance are organized. Backers of this position contend that the perspectives of the dominant groups in society are more distorted than are those of the dominated because the powerful have more reason to obscure the unjust conditions that produce their privileges.

Harding suggests that science can approximate objectivity only by incorporating a diversity of perspectives, and that the scientific enterprise itself will be strengthened once the distinctive perspectives of women, the poor, and ethnic minorities inform problem identification and set research agendas. For standpoint theorists such as Harding, the subject of inquiry is not the abstract individual but, rather, the daily lives of social groups in particular historical situations.[10]

Advocates of these structural perspectives contend that admitting women as equal members of science and development institutions is not sufficient. Instead, they call for fundamental changes in existing institutions and power relations. In contrast to the supporters of the liberal perspectives who focus principally on variations between men and women, backers of this view also draw attention to differences within the genders stemming from class, ethnic, or other cross-cutting identities (Gallin and Ferguson, 1992). They regard gender differences and hierarchies as dynamic, interacting elements of wider economic and power systems.

A new body of feminist literature reflects this emphasis on diversity among women produced by interactions among class, gender, and other social factors (Gallin and Ferguson, 1992). These studies indicate that a focus on gender by itself may be of limited analytic value. Gender identities, instead, are cross-cut by class and ethnic affiliations, all of which are shaped in part by broad economic and political processes, including processes of agricultural intensification and capitalist incorporation.

This analytically more complex perspective on gender has rarely been adopted by social scientists working in agricultural research and technology development programs. It has the potential, however, to reorient these programs to better accommodate social diversity and, in doing so, to enhance scientific impartiality. A brief case study of a bean breeding program in Malawi illustrates how this nuanced view of social differentiation can inform agricultural research agendas.

Differences among Women: Implications for Bean Improvement in Malawi

Malawi is a small, densely populated country in southern Africa. The average per capita income is only $180 per year, and high rates of malnutrition and child mortality prevail. Beans are an important food and cash crop, and are a major source of protein for the population. Approximately 85 percent of the people live in rural areas where women perform a major share of the agricultural work. Nearly one-third of the households are female-headed; in another third, the men are working on estates in other parts of Malawi or are employed outside the country.

The Bean/Cowpea CRSP has an ongoing research project in Malawi that links the University of California-Davis, Michigan State University, and Bunda College of Agriculture in Malawi. Project researchers include plant breeders and geneticists, plant physiologists, agronomists, rural sociologists, and anthropologists. The initial purpose of the research, conducted between 1982 and 1989, was to study the biological, ecological, and social roots of diversity in Malawian beans. Once the diversity was characterized and its functions were better understood, researchers planned to develop a plant breeding and improvement strategy that would simultaneously maintain diversity and address farmers' production constraints.

Bean Improvement the "Gender Neutral" Way

Initial surveys of bean fields, conducted by project agronomists in the major bean production zones in Malawi, suggest that farmers grew undifferentiated mixtures of beans (Ayeh, 1986; Martin and Adams, 1987a, 1987b). These mixtures vary in complexity; depending on the region of the country, anywhere from two to thirty-six or more phenotypically different bean types can be found in farmers' mixtures. Discussions with male household heads suggest that relatively few distinctions are made among the individual bean types found in these mixtures. For example, men were often unable to identify bean varieties by name and knew relatively little about their individual characteristics.

Based on these surveys and discussions, project researchers initially proposed that all the beans grown on each farm taken together constituted a separate landrace. They hypothesized that the composition of these landraces changed over time due largely to physical factors such as out-crossing and to stresses caused by drought, disease, and pest pressures. Only very limited amounts of human intervention in these landraces were thought to occur (Martin and Adams, 1987a, 1987b). Project agronomists also conducted studies on research stations which demonstrated that growing such diverse mixtures of beans conveyed stability of production over seasons and locations and, therefore, reduced farmers' risks (Ayeh, 1988).

The information from these agronomic surveys of farmers' fields, from discussions with male farmers, and from these research trials was used to develop a bean-breeding strategy for use in the National Bean Improvement Program. Agronomists carried out a survey to determine the most common seed types found in bean mixtures throughout Malawi. They proposed that synthetic mixtures, varietal blends or multilines of these seed types that preformed well and produced high yields across several locations be developed and released to farmers as replacements for their existing landraces.

Further study by project social scientists, however, revealed a different, more nuanced picture of bean production in Malawi. Knowledge about crops and responsibilities for growing them are often differentially distributed by gender, age, ethnic affiliation, and class position. In many areas of Malawi, beans are predominantly a woman's crop. With the exception of land preparation, much of the agricultural work and decision-making are carried out by women. Women are usually the repositories of knowledge about beans as well as the custodians of the seed.

A combination of participatory research techniques, participant observation, and quantitative surveys of women farmers revealed that the beans grown on each farm did not constitute a single landrace as previously hypothesized. Rather, what appeared to be an undifferentiated mixture, based on interviews with male farmers, was instead revealed to be a carefully-crafted composition of different farmer-developed bean varieties, each one selected for its individual characteristics. When women were consulted, it became apparent that most local bean varieties were named and had specific traits associated with them. Some varieties were prized for their taste or fast-cooking characteristics. Others, although hard to cook, were high yielding. Some were early maturing and, thus, could provide food early in the season and escape late season droughts. Women usually actively chose which varieties to plant in the largest quantities, and their choices often varied over the seasons and years. These findings indicated that human selection, in addition to physical factors such as outcrossing, was a powerful force shaping the composition of farmers' bean mixtures (Ferguson and Sprecher, 1987, 1989; Barnes-McConnell, 1989).

While male bias played a role in shaping the initial research strategy, simply substituting a female perspective also proved inadequate. Participatory research revealed that the needs and interests of women farmers were not themselves homogeneous. Differences in bean production constraints and goals existed among women in the three regions of the country, and these regional distinctions were cross-cut by variations among women in different socioeconomic strata.

Differences among Women Bean Producers

Variations in women's bean production constraints and goals were reflected in differences in the average number of varieties found on farms in the three regions of Malawi. Social science and agronomic surveys revealed that bean diversity was greatest in the north and central regions and was smallest in the south.[11] The average number of bean varieties grown by women farmers in the north and central regions was well over ten, whereas the average number planted by women in the south was less than three. Strong regional preferences for certain varieties were also noted. Women in the south preferred large red kidneys while those in the central region favored red, white, and khaki kidneys and navy beans. Certain preferred bean varieties were grown in only one region and not found in the other regions (Ferguson and Sprecher, 1987; Ferguson, Kambewa, and Mkandawire, 1992).

In part, these regional variations reflected differences in small-scale farmers' relationships to the wider economy. These associations were shaped by the presence of large estates and relatively high population densities in the south, combinations of share-cropping/tenancy arrangements and large-scale estate production in the central region and more local, small-scale estate production in the north. In the south, for example, the presence of large urban populations and workers on estates provided women with opportunities to engage in market-oriented bean production, an opportunity which women in northern Malawi lacked.

Even within regions, the size and composition of bean planting stocks on farms varied significantly by socioeconomic stratum. Generally, poor households with little access to land, labor, or capital planted fewer bean varieties than did more affluent households. Further, poor women were more dependent on the market for bean seed, and their knowledge about beans was reduced compared to that of women from better of households who were able save their seeds from season to season. In addition, traits like fast-cooking time and early maturity were especially prized by poor women who had trouble obtaining fuel wood, and who ran out of food early in the growing season.

Although the data have not yet been fully analyzed, it is possible that differences in the size and composition of bean stocks on farms also reflect ethnic affiliations and their associated patterns of access to land and labor. These include differences in women's access to land through the matrilineal systems of the south and central regions and the patrilineal systems of the north as well as variations in patterns of postmarital residence and access to labor associated with the matrilineal and patrilineal systems.

Bean Breeding
Differences among Women

This brief description draws attention to how differences among women farmers in Malawi were reflected in their bean production practices and strategies. These insights were used to redesign the initial bean improvement strategy which had called for the development of a yield-focused, prepackaged composite or blend to be promoted throughout Malawi. The following changes were instituted.

First, a more flexible breeding strategy was devised, which recognized that women's production constraints and goals as bean producers were not homogeneous and that no single bean cultivar or blend could meet their diverse needs. This strategy, called "component breeding," maintains diversity and, at the same time, provides farmers with a greater range of varietal choice, thus permitting the interests of both commercially oriented producers and those who grow beans primarily for household consumption to be addressed (Ferguson and Sprecher, 1989). The component breeding strategy supports farmers in their efforts to tailor bean varieties and cultural practices to their individual circumstances by (1) improving and releasing a number of bean varieties with different characteristics, either simultaneously or in rapid succession, and (2) encouraging farmers to integrate these improved varieties into their existing seed stocks rather than replacing their existing varieties with new ones.[12]

Second, knowledge about the differences in bean production constraints and goals among farmers was used to select seed types for improvement purposes. In the initial breeding strategy, in contrast, the bean seed types proposed for inclusion in the blends or synthetic mixtures were identified on the basis of an agronomic field survey involving little farmer input. A number of varieties were originally selected for improvement which, although prevalent on farms, are not favored by Malawian consumers. These included small-seeded brown and black varieties that women often maintained as planting stock due to a shortage of more preferred varieties. The ChiChewa names of these varieties indicate their unpopularity: *Kachitosi* (chicken droppings), *Natsangala* (unwelcomed guest), and *Nankude* (unwashed).

Input from social scientists, biological scientists, and farmers resulted in identifying five cultivars for improvement in the component-breeding program. These local varieties represent seed classes and contain traits valued by women in different socioeconomic strata and regions of the county. Included in this program are two regionally preferred seed types which are early maturing, drought escaping, and fast cooking. While these characteristics are useful to all farmers, they are of critical significance for poor women. As noted, these women often depend on the early availability of bean leaves and seed to sustain them through the hungry season, and they lack the funds and time to procure fuel wood. Three other seed types with country-wide market appeal are also included in the improvement program. Breeding efforts will focus on introducing drought tolerance and incorporating disease resistance (such as angular leafspot and bean common mosaic virus) into these local varieties, both of which are important production constraints identified by women farmers (Ferguson, Kambewa, and Mkandawire, 1992).

Conclusion

This case study describes how a seemingly neutral research agenda to develop a plant improvement strategy that maintained genetic diversity and met small-scale farmers' needs began by incorporating androcentric views about farmers and their bean production constraints—assumptions which ultimately proved incorrect and were modified. Further, it suggests that we need to be more aware of how the gender, ethnic, and class identities of researchers themselves influence problem identification; play a role in setting research agendas; and shape the techniques, technologies, and varieties being developed.

This case study also illustrates that the bean production constraints and goals of women farmers themselves are not static or homogeneous but, rather, reflect complex and fluid regional, ethnic, and socioeconomic interactions. Theoretical insights drawn from the structurally oriented literature on women, development, and science, combined with social science and farmer participatory research, were used to develop a bean improvement strategy flexible enough to encompass variations in production constraints and goals among farmers. Thus, this case study demonstrates that the generation of social science theory and its application in programs of agricultural technology development are interrelated and mutually supportive processes. Consequently, CRSPs and other agricultural research programs may be best served when participating social scientists adopt dynamic, interactive approaches to social differentiation and when they link theory and practice.

Notes

[1]This is C. Achebe's characterization quoted in Stamp 1989:1.

[2]Except as their institutions require that they take affirmative action into account or their grants dictate some attention to women or the poor. (For example, see AID's Gender Information Framework, which contains the agency's guidelines for incorporating gender into AID development activities.)

[3]Social scientists usually conceptualize gender and ethnicity as social constructs. That is, these terms refer to socially and culturally determined differences among people as opposed to biologically derived ones (see Gallin and Ferguson, 1991, for a discussion of the concept of gender in the women and development literature).

[4]I draw on Chambers, Pacey, and Thrupp (1989) in discussing the agricul-

tural research and development paradigms and on my familiarity with the women and development literature in assessing how gender has been incorporated in these paradigms.

[5]These latter are the areas of Green Revolution success (Lipton and Longhurst, 1989; Chambers, Pacey, and Thrupp, 1989:xix). Although yields have increased using TOT, so too has environmental degradation. Many of these systems are now recognized as resource depleting and unsustainable (National Academy of Sciences, 1989).

[6]If we use adoption by farmers as the criteria for success, in India for example, it is estimated that 70 percent of the output of agricultural research in dryland areas is not adopted by farmers (Sanghi, 1989; Chambers, 1989). Although I have not found comparable figures for African countries, several recent reports suggest that here, also, the products of agricultural research may not be meeting the needs of small-scale farmers. These findings include reports of the downward trend in per capita food production in sub-Saharan Africa during the 1970s and 1980s (Amara, 1990; Eicher, 1988), and studies indicating that gains in agricultural output have come largely from increasing the area under production (Lele and Meyers, 1986; Lele and Stone, 1989).

[7]This is the perspective adopted by many farming systems researchers.

[8]This structural perspective has also been called "redistributionist" (Gallin, Aronoff, and Ferguson (1989), "feminist political economy," "socialist feminism" (Stamp, 1989), or "the new professionalism" (Chambers, 1986). Much of the literature cited above, which is critical of the TOT paradigm, draws on this theoretical orientation.

[9]See Whitehead (1985) for a perceptive analysis of how this takes place. Also some of the gender-related literature cited earlier, which critiques TOT approaches, reflects this orientation.

[10]In fact, these authors contend that the value-neutral, disinterested stance of western science usually guises the interests of white, middle-class men (Harding, 1991).

[11]See Ferguson (1992) for a discussion of factors underlying the small amount of bean diversity found on farms in southern Malawi.

[12]See Ferguson and Sprecher (1989) for a full description of this strategy.

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Session 3

Issues of Increased Production and Changing Consumer Demand

- Sociopsychological Aspects of Consumer Preferences
- Problems of Commodity Markets in Developing Countries: Implications for Technology Development

Session Chair: John H. Sanders

Speakers: Stephen G. Sapp
Bruce F. Johnston

Sociopsychological Aspects of Consumer Preferences

Stephen G. Sapp

The field of consumer behavior is multidisciplinary in scope, encompassing theories and methodologies from economics, psychology, and sociology (Robertson, Zielinski, and Ward, 1984). Economic theories focus primarily on the relationships of demand, supply, and price and consider attitudinal aspects of behavior as consumer preference; however, they will not be discussed here. Instead, this paper will focus on the various psychological (e.g., consumer information processing, cognitive processes, perception, and attitude formation and change) and sociological (e.g., demographics, social class, culture, reference group influences, and influences of significant others) aspects of consumer preference. Although these aspects cover a very broad range of potential factors influencing consumer preference, most of them can be incorporated within the Fishbein-Ajzen model, a well-established, social-psychological prediction model of rational expectations (Ajzen and Fishbein, 1980; Fishbein and Ajzen, 1975). This model has proved to be effective in integrating psychological and sociological determinants of intentions and behavior.

Theories of attitude formation and change provide the basis for understanding and predicting consumer preferences. Early attempts at understanding preferences were based on assumptions of the "rational person," that is, one who examines all available information about a product and selects the product with the best marginal utility. Studies of consumer preference later incorporated psychological concepts dealing with emotions, motivations, cognitive processes, and sociological concepts related to the influences of reference groups, experts, and significant others.

Whether to consume food is, of course, not an issue. What is of interest is what commodities will be consumed and, more specifically, what are the preferred forms, tastes, and styles of various commodities among different consumer audiences. For example, consumer preferences for protein generally shift from cereals and beans to animal products with increasing economic affluence. Similarly, aging populations that result from demographic transitions usually exhibit shifts in aggregate food demand, showing greater preferences for fresh fruit and vegetables than do younger populations. Further, more affluent populations or population segments prefer more manufactured products.

These generalizations, however, provide little guidance as to whether a population or population segment will favor the introduction of a particular food. Different cultures exhibit a wide variety of preferences among commodities (e.g., some choose to ignore entire commodities) and among tastes and styles within commodities (e.g., Japanese and American consumers differ greatly in their preference for fat in beef). Because consumer preferences vary widely from one culture to another, this paper will present consumer preference theories in abstract form and suggest a format to assess preferences for specific products within the constraints of time, money, and data collection procedures appropriate for less developed countries.

Psychological Theories of Consumer Preference

Psychological theories focus on the processes of cognitive awareness and decision-making among consumers. They address issues of consumers' knowledge and awareness and their evaluations of information about a product. Psychological theories emphasize the importance of attitudes and perception in consumer preference.

Hierarchy-of-Effects Theory

The hierarchy-of-effects theory underlies much of consumer behavior research, including such diverse areas as the diffusion of innovations model (Rogers, 1983). This theory describes preferences as resulting from a four-step cognitive process (Palda, 1966): the consumer becomes aware of the product, makes an evaluation of it, implements it on a trial basis, and then adopts or rejects it. Knowledge about the product can be obtained from favorable as well as unfavorable messages and transmitted over a variety of communication channels (mass media, change agent contact, interpersonal persuasion) in a variety of ways (both recursive and reciprocal between change agent and potential adopter). The consumer's evaluation of the product is then subject to persuasion in the form of educational and/or promotional messages.

Perception Theories

Perception theories emphasize the fact that information and persuasive messages are processed differently by different consumers (Zimbardo, 1979). Stimulus factors, such as information about a certain food or food consumption pattern, can be interpreted differently by persons of different background or predispositions. The credibility of the information provider and the similarity of informational messages with other types of information, for example, can influence the consumer's perception of a food product or habit.

Perception theories focus on the difference between objective facts about a food or food pattern and the subjective evaluation of the food or pattern by the consumer. Economic, psychological, religious, demographic, and other factors can influence consumer perceptions. In developing countries, for example, middle-class consumers may develop preferences for nontraditional exported foods, whereas lower-class consumers may continue to consume traditional foods. These differences in preference reflect the middle classes' desire to display wealth as well as their economic ability to enjoy a wider variety of foods. Perceptions can play an important role in maintaining traditional food consumption patterns or, alternatively, in influencing consumers to quickly abandon long-held patterns if perceptions (e.g., of safety) change rapidly.

Perception is reality for the consumer (Scherer, 1990). Changes in consumer preferences, therefore, can be driven more by perceptual factors than by objective traits of the food pattern itself. Consumers tend to simplify the characteristics of alternative food preference patterns by labeling its association with some well-known pattern that is perceived as favorable or unfavorable.

In general, consumer preferences resist change because they have been developed over many years of trial and error. A stable food consumption pattern, however, should not be confused with a favorable attitude toward that pattern. Consumers persist in some patterns out of economic necessity; changes in economic status may be rapidly followed by changing food preferences.

Communication Theory

Communication theory emphasizes the importance of both the message and the medium through which messages are transmitted (Bauer and Bauer, 1960). This theory recognizes that information alone is rarely sufficient to induce consumers to alter their preferences. Source credibility is an important factor influencing the ability of informational messages to change consumer preferences. For example, consumers' trust in government and industry is a key component affecting their acceptance of recommended changes in diet.

Cognitive Theories

Cognitive theories focus on the determinants of attitude formation and change, typically in relation to multiple attributes that can affect attitudes. An attitude is an evaluative component of information that can be acquired from a wide variety of sources with differing degrees of perceived credibility and competence. The structural approach (Krech, Crutchfield, and Ballachey, 1962) purports that attitudes result from favorable or unfavorable evaluations combined with multiplexity, or the number and variety of different elements comprising the attitude. High-involvement attitude formation and change, which are normally associated with significant changes in food preferences, generally have strong evaluations and high-multiplexity of input.

The cognitive, or knowledge, components that affect an attitudinal evaluation are usually quite consistent. That is, consumers tend to evaluate foods as either good or bad for them, but not both. Attitudes serve utilitarian functions, such as motivating consumers to include a certain amount of "healthful" foods in their diets. Attitudes also serve value-expressive functions; for example, consumers' preferences for certain types of foods reinforce cultural and family traditions and values.

Consumers tend to reduce dissonance in their food preferences (Festinger, 1957; Kassarjian and Cohen, 1967). Food preferences that contradict highly valued beliefs are subject to either behavioral or attitudinal adjustment, such as denying information, minimizing the degree of dissonance experienced, or bringing in additional, perhaps irrelevant, information to support existing behavior. Thus, if middle-class consumers are exposed to a new manufactured food that contradicts their pre-existing beliefs about what foods are appropriate, they may adjust their beliefs to fit the new food rather than reject it, depending on the strength of their belief system.

Attitudes can sometimes be poor predictors of behavior if factors that can intervene between attitudes and behavior are ignored. Economic opportunity, force of habit, religious proscriptions, social pressure, and so forth can either stimulate or hinder shifts in consumer preferences.

Motivation Theories

Motivation theories of consumer behavior are derived from psychoanalytic theories that emphasize the importance of pleasure and reality principles, defense mechanisms, identification with opinion leaders, projection of undesirable traits to others, displacement of blame for personal inadequacies, and rationalization of attitudes or behavior (Cohen, 1967). These theories stress the importance of emotion over rational judgments in consumer preferences.

Motivation theories focus on how food preferences satisfy the emotional needs of the consumer. These theories address such basic human needs as desires for achievement (accomplishing something difficult or surpassing others), affiliation (receiving affection), aggression (overcoming opposition), autonomy (being independent and free), deference (being admired and supported), dominance (controlling one's environment), exhibition (making an impression on others), nurturance (attending to the needs of others), play (seeking relaxation), and understanding (speculating, analyzing, and generalizing). Motivation theorists may classify consumers by their relative emphasis on these psychological needs. Thus, different consumer audiences may exhibit preferences for different foods based on their different gratification needs associated with these preferences.

Sociological Theories of Consumer Preferences

Sociological theories emphasize the importance of others' opinions on consumer preferences. Factors such as social class position, religious beliefs, residential location, age, race, ethnicity, gender, formal education, and opinions of significant others are considered to influence individual preferences because individuals seek to reinforce their affiliation with various collectivities. At the same time, collectivities develop and maintain distinct preference patterns as a means of reinforcing their cultural heritage and differences. Explanations for consumer preferences can be provided, therefore, by examining differences among various demographic categories or among social systems.

Consumer Demographics

Some consumer preferences can be explained by simple reference to biological needs. Men typically consume more food than women, for example, and elderly persons generally reduce their total caloric intake. However, consumer preferences based on other demographic categories, such as region of residence or social class, reflect complex cultural traditions designed to reinforce differences among human collectivities (Garreau, 1981). Preferences for certain foods or styles of food preparation not only reflect economic differences among members of different social classes, but also reinforce the unique nature of belonging to a specific social class.

Changing consumer demographics can affect aggregate preferences for certain foods. An aging population, for example, can be expected to consume less of some foods and more of others. Significant population trends, such as rapid expansion due to high in-migration can affect not only the total amount of food consumed, but also the types of food consumed. Changing family patterns, such as shifts toward fewer extended families and more nuclear families, can affect preferences, sometimes by accelerating new consumption trends favored by younger persons.

Social Beliefs

Social beliefs represent a relatively enduring set of opinions about the nature of humans and human interaction. Beliefs are essentially perceptions that are reinforced by values within social systems. Different societies and different collectivities within societies develop and maintain different beliefs both as a means of defining themselves and distinguishing themselves from others. Thus, adherence to certain beliefs reinforces individuals' association with different collectivities and differences among collectivities (Festinger, 1954).

Beliefs can affect consumer food preferences. Beliefs regarding the roles of women and men, for example, can affect food shopping and preparation decisions as well as decisions about what types of food to eat. Beliefs about diet and health relationships play a significant role in consumer food preferences. Changing beliefs about the role of fat in the diet, for example, have brought about significant differences in food preferences among American consumers.

Reference Group Influences

A reference group is any person or collectivity that serves as a focal point of interest for an individual (Hyman, 1942). Significant others (e.g., family and friends), special groups with which an individual closely associates (e.g., coworkers), and highly visible persons (e.g., celebrities) can serve as a reference group. An individual's food preferences will likely reflect the preferences of his or her reference others (Stafford and Cocanougher, 1977). Opinions of family and friends, therefore, are import aspects of an individual's food preferences. Reference groups influence an individual's food preferences because an individual desires to be associated with members of his or her reference group. "In-group" habits reinforce an individual's association with others and, thereby, satisfy the human need to belong.

Reference groups influence individual food preferences in three ways. "Informational influence" refers to the fact that reference groups are viewed by the individual as highly credible sources of information. In cases where government or industry credibility regarding food preferences is suspect, the opinion of the reference group can be crucial in determining the individual's food choice. "Utilitarian influence" refers to the ability of the reference group to exert normative pressure on the individual to comply with existing food preference patterns. Reference groups, therefore, often provide a source of stability for food preferences. However, individuals generally have multiple reference groups and, therefore, may experience contradictory messages about food preferences. "Value-expressive influence" refers to the fact that individuals have self-interest in complying with reference group norms because compliance satisfies their need for association.

The Fishbein-Ajzen Model of Rational Expectations

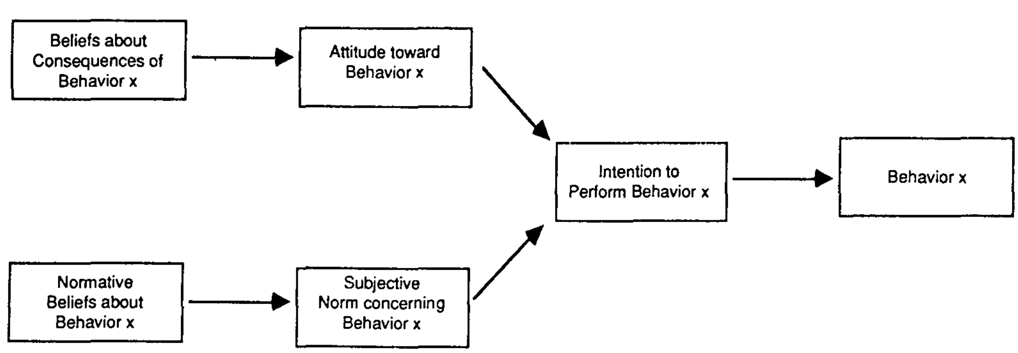
Psychological and sociological theories provide many concepts that can be applied to understanding and predicting consumer food preferences. No theoretical perspective can provide a complete explanation of consumer preferences. Pragmatic considerations thereby require researchers to select certain approaches to understand and predict consumer preferences. The Fishbein-Ajzen model of rational expectations (Ajzen and Fishbein, 1980; Fishbein and Ajzen, 1975) has received much empirical support over the past two decades and currently predominates model selection in consumer behavior research. This model, however, is only one approach to examining both psychological and sociological aspects of consumer preferences.

In the Fishbein-Ajzen model (Figure 1), behavior results from intentions or commitments to act. Intentions are influenced by psychological attitudes which, in turn, are affected by beliefs and subjective norms which, in turn, are affected by the opinions of referent others. Thus, the model incorporates both psychological and sociological theory within a single prediction model. The Fishbein-Ajzen model incorporates a multiattribute approach to measuring consumer preferences. Beliefs, attitudes, and opinions of significant others are considered to result from multiple influences, each with different degrees of influence on an individual's choices.

Intention to act is expressed in relation to a specific behavior. This construct is measured, as are all other constructs in the model, using a seven-point Likert scale. Thus, an individual is asked to elicit a response, ranging from "strongly agree" to "strongly disagree," to a statement such as, "I intend to eat food x."

Attitudes are considered to be predispositions to act. In the Fishbein-Ajzen model, attitudes are evaluations directed toward a specific object (food preference). Limiting evaluations to a specific object improves the ability of the model to predict

Figure 1.The Fishbein-Ajzen model of rational expectations.



behavior. Attitudes are composites of multiple beliefs. Thus, an attitude would be measured from responses to items such as, "For me, eating food x is a good thing to do." or "For me, eating food x is a healthful thing to do."

Beliefs are considered to be an individual's opinions about the nature of the behavior under study and, as such, are considered to be the fundamental building blocks of the model. An individual's beliefs originate from varied experiences and are affected by many different sources. Beliefs may be either objectively correct or incorrect. The Fishbein-Ajzen model is not concerned with the accuracy of a belief but, rather, with the fact that an individual holds the belief.

A central element of measuring beliefs is that they have different weights depending on an individual's perception of the consequences of performing some behavior. This consequence is usually expressed in terms of how important some aspect of the belief is to an individual. Thus, a belief might be measured as, "Eating food x will provide me with essential vitamins." And this belief would be weighted by (the response would be multiplied by the response to) a statement regarding the importance of the central aspect of the belief such as, "Consuming essential vitamins is important to me."

Beliefs, like attitudes, are considered as multiattribute items. Thus, a belief set regarding some behavior would be measured by asking an individual about multiple items associated with the behavior. Thus, consuming food x might be associated with receiving essential vitamins, minerals, protein, and other nutrients, as well as with avoiding unfavorable consequences, such as contracting cancer from eating carcinogenic foods or heart disease from eating foods high in saturated fat. The summation of belief statements, weighted by their respective association with consequences, provides an index of an individual's belief system toward the performing of the behavior under investigation.

A significant contribution of the Fishbein-Ajzen approach to measuring consumer preferences and anticipating changes in consumer preferences is that it combines sociological concepts with psychological concepts within a single model. In the Fishbein-Ajzen model intentions are influenced not only by attitudes, but also by subjective norms. Subjective norms represent an individual's overall perception of the opinions of his or her referent others. It represents an assessment of the predominate opinion of persons who are the most important to the individual. Thus, a subjective norm is measured, usually with a single indicator, as agreement or disagreement with a statement such as, "The persons who are most important to me think that I should eat food x."

An individual's perception of subjective norms results from his or her perception of the opinions of the various referent others to whom he or she turns for advice and council. Friends, family, and experts comprise some of the significant others who influence an individual's conception of subjective norms. Motivation to comply with different referent others varies across different types of behavior and in different circumstances. Thus, the opinion of a referent other is weighted by an individual's motivation to comply with a specific referent other. The opinion of the referent other is usually measured by agreement or disagreement with a statement such as, "[Referent other] thinks that I should eat food x." The response to this statement is multiplied by the response to an accompanying statement such as, "I do what behavior. Attitudes are composites of multiple beliefs. Thus, an attitude would be measured from responses to items such as, "For me, eating food x is a good thing to do." or "For me, eating food x is a healthful thing to do."

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A significant contribution of the Fishbein-Ajzen approach to measuring consumer preferences and anticipating changes in consumer preferences is that it combines sociological concepts with psychological concepts within a single model. In the Fishbein-Ajzen model intentions are influenced not only by attitudes, but also by subjective norms. Subjective norms represent an individual's overall perception of the opinions of his or her referent others. It represents an assessment of the predominate opinion of persons who are the most important to the individual. Thus, a subjective norm is measured, usually with a single indicator, as agreement or disagreement with a statement such as, "The persons who are most important to me think that I should eat food x."

An individual's perception of subjective norms results from his or her perception of the opinions of the various referent others to whom he or she turns for advice and council. Friends, family, and experts comprise some of the significant others who influence an individual's conception of subjective norms. Motivation to comply with different referent others varies across different types of behavior and in different circumstances. Thus, the opinion of a referent other is weighted by an individual's motivation to comply with a specific referent other. The opinion of the referent other is usually measured by agreement or disagreement with a statement such as, "[Referent other] thinks that I should eat food x." The response to this statement is multiplied by the response to an accompanying statement such as, "I do what larger groups do not always allow for input by all members. Focus groups can last from one to two hours, depending on the number of questions that are generated and on the amount controversy that arises about the new product. The moderator plays a key role during the meeting, directing the discussion to the issue at hand (accepting or rejecting the product) while at the same time creating sufficient interaction among the focus group members.

The key philosophy underlying focus group techniques is that consumers do not necessarily know whether they will accept or reject a new food product after hearing information about it, tasting it, and so forth. Rather, the focus group technique assumes that consumer preferences are formed in the presence of the preferences of other consumers. That is, consumer preferences are socially constructed. The decision to adopt or reject a product or idea is social rather than individualistic because persons decide to adopt or reject (or modify) their opinions in relation to those of others. Survey methodologies do not take advantage of this aspect of consumer preference formation. Instead, they assume that information about the new product, by itself, is sufficient to form a lasting opinion of the product.

Focus groups should be composed of persons who will feel comfortable expressing their opinions to other members in the group. A focus group should not be dominated by one or two persons, neither because these persons outrank the other members in status or prestige nor because they are especially forceful in their opinions. Therefore, the moderator has an obligation to select members who talk openly to each other and then to guide the discussion in such a manner that all persons have an opportunity to talk.

Conclusion

This paper addresses sociopsychological aspects of consumer *preferences*, where preferences are broadly defined as both consumption preferences and acceptance of agricultural technology. Consumer food choices are subject to a vast array of economic, social, and psychological aspects, and they can change rapidly with even subtle shifts in production and distribution characteristics, social conditions, or psychological understandings of the safety, wholesomeness, or social acceptability of foods or food consumption patterns.

Psychological and sociological theories of consumer preferences have been reviewed as a means of presenting important aspects of consumer choice. Different aspects may be important to understand preferences at different points in time or in different locations. The Fishbein-Ajzen model of rational expectations was presented as one example of a prediction model that incorporates both psychological and sociological concepts.

Understanding consumer acceptance of new food products, therefore, requires the social scientist to incorporate both psychological and sociological concepts into prediction models. In some instances, this task involves both predicting consumer food preferences and understanding risk assessments associated with a proposed change in food preferences. That is, proposed changes in food habits for health reasons, for example, involve understanding food preferences and risk assessments regarding alternative dietary patterns. One approach that can be considered as a means of integrating prediction models and diffusion models is to expand the Fishbein-Ajzen model to include assessments of the social acceptability of a food or food pattern. The expanded model would thereby incorporate psychological beliefs, subjective norms, and perceived social acceptability (as a measure of constructed risk assessment) to predict consumer preferences for the alternative food or food pattern.

Focus group techniques are advised for cases where time and/or funds are limited and in cases where the researcher is not fully familiar with the nature of belief systems that guide food choice behavior. Focus group techniques can be as accurate as survey methodologies and can also provide invaluable information about consumers first impressions of the new food product and their suggestions for improving the product. Most importantly, focus group techniques allow for social interaction among group members, which can sometimes be the most important factor in creating the overall opinion of a new product.

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Problems of Commodity Markets in Developing Countries: Implications for Technology Development

Bruce F. Johnston

The Importance of Markets and Specialization

The key mechanism of economic progress in farming, as in other sectors, is specialization, as well as the accelerated technological progress which it fosters and facilitates. Much more important than farmers' specialization in specific crop or livestock enterprises is the transfer of a host of functions to specialist producers. Specialization not only makes possible the introduction of capital equipment, but it also facilitates changes to more effective organizational arrangements as well as generates and adopts more productive technologies. As a result of these interrelated processes, farm households shift along the continuum from self-sufficiency to dependence on markets for disposal of their produce, for purchases of inputs and other goods and services, and for opportunities to borrow and invest.

Specialization and increased market participation at the producer level lead to sectoral interdependence and the process of structural transformation, whereby predominantly agrarian economies are transformed into diversified, highly productive economies that are mainly industrial. This industrialization process involves much more than the expansion of a country's manufacturing sector. Coordinated growth of transport, communications, financial and other services, and international trade is accompanied by greatly expanding small sectors such as education and health. In addition, agricultural and other research activities are greatly enlarged and bring together specialists in universities, experiment stations, research and development (R&D) divisions, and similar institutions. The institutionalization of activities such as education and research is a distinct dimension of specialization, often aptly described as *functional differentiation.*

Thus, specialization and technological and institutional change, the driving forces of the development process, are intimately linked with structural transformation. Economic progress, including the increase in labor productivity that makes possible rising per capita incomes, is also linked to the demographic transition in which traditional societies with very high levels of fertility and mortality enter a period of rapid population growth (because of sharply reduced mortality) before entering a phase of declining fertility, which reestablishes a sustainable balance between birth rates and death rates.

The implications of those structural/demographic characteristics are especially important for about 55 countries where 50 percent or more of the population and labor force still depends on agriculture for employment and income. For virtually all of these countries, the heavy weight of agriculture in their labor force, in combination with the rapid growth of their population of working age, means that the absolute size of their agricultural labor force will not decline for many years. These countries are referred to as

CARLs—countries with abundant rural labor (Tomich, Kilby, and Johnston, Forthcoming). This paper focuses mainly on the distinctive problems of CARLs, a subset of developing countries which accounts for approximately half of the world's population.

The intimate link between a country's structural/demographic characteristics and increases in agricultural productivity are epitomized by the huge contrast between the productivity changes in Bangladesh and the United States between 1960 and 1980. Changes in labor productivity can be partitioned into changes in output per hectare and changes in the number of hectares cultivated per worker. A close approximation is that the rate of change in labor productivity is the sum of the rates of change in output per hectare and hectares cultivated per worker. Hayami and Ruttan (1985:120) estimate that, for 44 countries, the enormous gap in agricultural labor productivity between rich and poor countries substantially widened between 1960 and 1980. In sharp contrast, agricultural labor productivity in the United States increased threefold, whereas output per worker in Bangladesh declined from 2.0 to 1.8 "wheat units" between 1960 and 1980.[1] As a result, the differential in farm labor productivity rose from an already huge 47-fold differential in 1960 to an astounding 158-fold differential in 1980. In both countries, output per hectare increased about 40 percent during the 20-year period. However, because of their sharply contrasting structural/demographic characteristics, the male farm work force in Bangladesh increased 57 percent from 12.1 to 19.1 million, whereas in the United States the male farm work force declined from 3.8 to 1.7 million between 1960 and 1980.

Two Types of Commodity Problems in CARLs

It is generally recognized that efforts to foster increased agricultural production in less developed countries (LDCs) are likely to be frustrated because of marketing problems. Less commonly, however, the problem is perceived to be related to a more fundamental problem of the country's existing economic structure rather than a faulty performance of the local marketing system. By focusing exclusively on performance problems of commodity markets, the important problems stemming from the limited extent of domestic commercial markets, which are inevitable in CARLs, are likely to be obscured.

The limited adoption of modern farming practices are commonly attributed to the subsistence-mindedness of local farmers. Historical accounts of American agriculture provide a useful reminder that farmers in this country were also "subsistence-minded" when our agricultural economy had the structural characteristics of today's CARLs. A century and a half ago when some 70 percent of the U.S. labor force was dependent on agriculture for livelihood, farmers were praised if they were jacks-of-all-trades and produced virtually everything required within the circle of their own family.[2] By the middle of the nineteenth century, the growth of grain exports to Europe and the expansion of domestic commercial markets led to increases in farm cash income that transformed American agriculture from a semisubsistence to a commercial orientation. Specialization in agriculture was resisted initially because Americans overwhelmingly disapproved of purchasing anything that could be produced on the farm.

This paper will focus on the forces that limit the extent to which domestic commercial markets for farm commodities provide an outlet for a marketable surplus. Export markets can also provide an outlet for a significant fraction of a country's farm output. It is noteworthy that in tropical Africa, where the domestic commercial market is exceptionally small relative to the number of farm households, the terms "export crops" and "cash crops" are often used synonymously. It should not be surprising that both external aid and domestic programs often emphasize expanded production for export. For most CARLs, agricultural exports represent the principal option for expanding foreign exchange earnings. Furthermore, rapid growth of a country's exports will have relatively little effect on world prices unless it already accounts for a substantial share of a commodity's world exports. Thus, the possibility of expanding export production is likely to be seen as an attractive means of increasing farm cash incomes. Because of the well-known disadvantages of relying on a few agricultural products such as coffee or cocoa, subject as they are to sharp price fluctuations, the export option modifies but definitely does not eliminate the problems that stem from the limited extent of the domestic commercial market.

Problems Related to the Faulty Performance of Commodity Markets

Much can and should be done to improve the performance of commodity markets in LDCs. But, especially in CARLs, faulty diagnosis of the reasons for poor performance is likely to lead to policies that do more harm than good. An important lesson derived from the success stories of agricultural development is that emphasis should be on government interventions to improve the functioning of markets and promote the development of markets over time rather than on efforts to replace markets with bureaucratic organizations such as a grain marketing board. The role of private firms or independent cooperatives and price and market mechanisms are extremely important to the performance of commodity markets. Assertions about the "magic of the market place" do not generally presume that private firms are superior to public agencies.

In a classic work, which integrates their insights from political science and economics, Robert Dahl and C. E. Lindblom provide a basis for making informed and specific judgments about the relative advantages of public agencies and private enterprises. Four decades ago they began their analysis by declaring that the "great issues" such as capitalism versus socialism, top-down versus bottom-up management, and other ideological wrangles over organizational alternatives "are no longer the great issues, if ever they were" (Dahl and Lindblom, 1953:3). They emphasized, instead, that "the possibilities for rational social action, for planning, for reform—in short, for solving problems—depend not upon our choice among mythical grand alternatives but largely upon choices among particular social techniques" (Dahl and Lindblom, 1953:6). These "social techniques" are essential elements of the institutional framework for rationally calculating and achieving the control that enables groups of individuals to determine what should be done and how to ensure it is done.

Dahl and Lindblom identify four categories in which the basic organizational techniques of calculation and control fall: hierarchies directed by leaders, price and market mechanisms (and other exchange techniques), use of voting or other political mechanisms of control over leaders, and exertion of control among leaders through bargaining processes. The choices that are made between hierarchical techniques and reliance on market-determined prices give rise to crucial policy decisions.

Bureaucratic organizations, whether a government agency or a large private corporation, rely mainly on hierarchical techniques and are unilateral in the control relationships they seek to impose. The difficulty public agencies have in achieving efficiency is compounded by the fact that they have to satisfy diverse objectives and clientele. Private enterprises or cooperatives (which are independent and not merely creatures of government) can be expected to be more efficient than public agencies in responding to the cues of the price system and in holding down costs. Individual proprietorships and other small enterprises differ from both public agencies and large private enterprises by not having the distinctive characteristics of a bureaucracy. When individuals own the firm and its resources, they respond more directly to price and profit signals and have little need for hierarchical techniques of calculation and control. Such individuals often become effective entrepreneurs even though they are totally lacking in bureaucratic skills and may even be illiterate. "Entrepreneurial and trading skills are acquired in the market place 'school of hard knocks' rather than in formal education" (Hopcraft, 1986).[3]

Markets are not the only form of exchange relationship, but they become critically important as an agrarian economy is transformed into a modern, diversified, and productive economy based on specialization among individuals, firms, and a complex array of private and public institutions. Conversely, the disadvantages of reliance on hierarchical techniques for guiding resource allocation and for performing marketing and production functions become increasingly serious as an economy reaches higher levels of income and complexity.

Clearly, the key policy issue is the choice between organizations that rely on hierarchical techniques versus those that rely on market mechanisms. There is no one "right" answer. The challenge is to strike a balance between reliance on the public and private sectors that maximizes the comparative advantage of each. Essential public goods such as education, public health programs (e.g., immunizations), and family planning programs will obviously not be provided at socially optimal levels if their provision is dependent on private firms responding to private demands. Agricultural research, which is such a critical element in strategies for agricultural development, exemplifies the essential attributes of public goods—nonrivalness and nonexcludability (in the jargon of economics). "Nonrivalness" is derived from the fact that the use of new information, such as the practice of planting on the contour, does not hinder the adoption of that practice by other farmers. "Nonexcludability" depends on institutional arrangements and historical circumstances. But apart from hybrid seeds that require annual replacement, biological research has not been profitable for private firms because they have not been able to capture the investment returns in breeding improved varieties or in identifying improved agronomic practices.

The role of private firms and price-and-market mechanisms merit special attention in relation to agricultural commodity marketing. In his recent book on environmental issues, Senator Al Gore provides this succinct explanation of the "design advantage" of an economic system made up of numerous independent decision-makers who can process the mass of information that is generated and disseminated with great efficiency by market-determined prices. Gore (1992:359) states, "Under capitalism people free to buy and sell products or services according to their individual calculations of the costs and benefits of each choice are actually processing a relatively limited amount of information—but doing it quickly. And when millions process information simultaneously, the result is incredibly efficient decisions about supply and demand for the economy as a whole."

The efficiency advantages of decentralized decision-making for CARLs is most apparent in farm-level decision-making, where important on-the-spot decisions are often a consequence of the variability and uncertainty of agricultural production (a biological process spread out in space and in time). Similarly, commercial decisions on which efficient marketing depends are characterized by rapid and unpredictable changes in the supply/demand relationships that determine agricultural prices. Hierarchical decision-making by bureaucrats in a government agency, however, cannot match the efficiency of private traders with their greater flexibility, capacity for quick decisions, and strong incentive to gather and process available information in order to make profit-maximizing decisions.

This is not to suggest that markets in CARLs are free of problems. Indeed, imperfect or incomplete markets are almost a defining characteristic of their economies. There are a variety of ways in which government action can promote improvements in the functioning of markets. Selective interventions are likely to include public investments in roads and other types of transport infrastructure, in communication facilities, and in storage or other market infrastructure. Providing market information as a public good and action to encourage the use of standard grades can also facilitate increased marketing efficiency. Furthermore, it may be advantageous for government agencies to perform certain roles during transitional periods, for example, undertaking long-distance trade to move supplies between major marketing centers at a time when transport infrastructure is not well established.

An Indonesian Agency for Management of Food Logistics (BULOG) acted to support a floor price for yellow maize in one of the Outer Islands where farmers previously grew only white maize for their own consumption. After a number of years, sufficient maize was marketed to attract private traders. The traders offered farmers lower prices but still managed to cut into BULOG's share because they offered better payment terms and greater convenience. This example is unusual because the marketing agency resisted the usual bureaucratic urge to maintain its market share by obtaining increased subsidies or, alternatively, by securing a ban on private trade in order to eliminate the competition (Tomich, Kilby, and Johnston, Forthcoming).

A more typical example is a marketing initiative by CONASUPO, the Mexican government corporation responsible for purchasing, importing, and distributing grain and certain other food products. This initiative was prepared in 1972 by a team of economists and agronomists in a new department of this powerful agency. The "theoretical explanation for the growing marginalization of the subsistence sector . . . began with the assumption that in order for a traditional farmer to pass to the modern agricultural sector, it is necessary for him to produce a surplus, to retain the use of the surplus, and finally to invest it productively; [but] the problem is that any surplus produced by the Mexican peasant is extracted by individuals and groups who make their livings by exploiting him" (Grindle, 1977:84).

This analysis led to a policy statement calling for a "transformation of subsistence agriculture in Mexico" and a key role for a CONASUPO initiative in the rural economy: "The federal government, by means of deliberate and programmed activity, should intervene more decisively in rural areas to provide a change in the impact of market forces on the peasants" (as quoted in Grindle, 1977:89). This initiative resulted in a large expansion in CONASUPO's marketing and distribution activities in rural areas. The number of grain reception centers more than doubled between 1973 and 1975, reaching nearly 2,500. Some 1,500 of the analysts from those centers, who receive, weigh, analyze, and pay for grain received from farmers, were trained in a program that included "extensive efforts to promote their 'social conscience' . . . to prevent a reoccurrence of corrupt practices" (Grindle, 1977:115).

There is no evidence that the impact of this CONASUPO initiative brought about the desired change on the peasants. In fact, it seems likely that the CONASUPO diagnosis was simplistic and based more on casual observation than on careful analysis of the performance of the rural marketing system. A number of studies of food-marketing systems in developing countries have concluded that most of the alleged deficiencies are not supported by the evidence, although serious imperfections are likely in remote areas where there is little competition among traders. (See, for example, Jones, 1972; Lele, 1974.)[4]

Avoiding inappropriate marketing interventions is especially important in CARLs. The case for government action will likely be strong because of numerous market imperfections. Many of those imperfections are, however, inherent consequences of the economic structure of CARLs with their "thin" markets which shift sharply from scarcity and very high prices to glut and very low prices because consumer demand is so price inelastic. Allocating the scarce resource of administrative capacity to essentially commercial activities has a high opportunity cost because of the critical need for government involvement in activities such as education, agricultural research, and public health and family planning programs for which a public sector role is indispensable. A well-nigh universal feature of CARLs is an imbalance between the responsibilities assumed by government and the resources available for fulfilling those responsibilities. That harsh fact underscores the importance of making good decisions about priorities and the time sequencing of activities that depend on the scarce resources of government funds and administrative and professional staff.

Structural and Demographic Features of CARLs: Their Implications for Research Priorities

Assertions regarding the importance of making good decisions about priorities are easy to make. However, it is difficult to make such decisions and still more difficult to achieve a workable consensus with respect to priorities and the time sequencing of government allocations of funds and administrative resources. The interactions among the long-term consequences of the policy choices shape a country's pattern of agricultural development (Johnston and Clark, 1982).

The objective of "good policy analysis," according to an eminent practitioner of the art and craft of policy analysis,

> is to evaluate, order, and structure incomplete knowledge so as to allow decisions to be made with as complete an understanding as possible of the current state of knowledge, its limitations, and its implications. Like good science, good policy analysis does not draw hard conclusions unless they are warranted by unambiguous data or well-founded theoretical insight. Unlike good science, good policy analysis must deal with opinions, preferences, and values. (Morgan, 1978:971)

The structural and demographic characteristics of CARLs are stressed because they provide a basis for some hard conclusions with respect to the design of agricultural strategies that have important implications for research priorities. Furthermore, the perspective of structural transformation—the extent to which a traditional economy has moved along the road toward becoming a diversified and predominantly industrial economy—proves to be of great value in assessing the relevance of the historical experience of various countries. A country at an early stage of development has many possible "growth paths" or "patterns" of agricultural development from which to choose. To be sure, the choice is often made by default. It is a cliché, but nonetheless true, that "not to choose is to choose."

Comparative analysis of agricultural development experience in Japan and the United States directs our attention to some important contrasts and similarities. The most significant contrasts are related to the fact that the pattern of technological change in Japan was labor-using and land- and capital-saving. Divisible innovations, notably high-yield varieties and increased use of commercial fertilizers, that increased output per hectare were of great importance, whereas mechanical innovations leading to an increase in the number of acres cultivated per worker were of slight importance.

For the United States, it was not until the 1930s that yield increases became a significant source of expanded output. But long before the advent of tractors and combine-harvesters, a sequence of mechanical innovations made it possible to dramatically reduce labor requirements. For example, the labor requirements in wheat production are estimated to have been reduced from 43 to 13 man-hours per acre between 1850 and 1880, first with the introduction of the horse-drawn reaper and then with the reaper-binder. The latter accounted for much of that reduction in labor requirements (Danhoff, 1944:137).

Surprisingly, the rates of increase in farm output and even in agricultural labor productivity over the period from 1880 to 1960 were quite similar in the two countries. It is by no means obvious which pattern is more relevant for contemporary developing countries as they make the strategic decisions that will determine their pattern of agricultural development. There is now a considerable consensus, however, that historical experience in Japan and, still more, Taiwan is especially pertinent to today's CARLs in demonstrating the importance of establishing a broad-based pattern of agricultural development that involves a large, growing percentage of the small-scale farm units that predominate in CARLs as well as fosters positive interactions between agricultural and industrial development.

Both of these lessons have important implications for agricultural research, including the role of the CRSPs in strengthening national agricultural research systems. A country's pattern of agricultural development will be determined in large measure by the technical innovations that are generated by agricultural scientists, promoted by government policies, and adopted by farmers.

The Advantages of Broad-Based, Small-Farm Strategies[5]

During the 1960s and 1970s, when there was great optimism that independence would permit a rapid acceleration in economic growth in sub-Saharan Africa, many agricultural specialists advocated policies intended to permit a rapid shift from hand-hoes to tractor mechanization. The argument was that with a relative abundance of land, the adoption of tractors by farmers (or state farms) establishing large, mechanized farm units would not have the adverse effect of displacing cultivators that was to be expected in a land-scarce economy.

The principal consequences of that faulty diagnosis have been a waste of capital and foreign exchange and delay in focusing research priorities on innovations adapted to the needs of small-scale farmers subject to a severe purchasing power constraint. That costly error was basically the result of a failure to recognize that research objectives and priorities need to take account of local socio-economic as well as agroclimatic conditions.

Although there is considerable variation in the extent to which producers in different areas have been able to enlarge their farm cash receipts, the reality is that throughout sub-Saharan Africa (and CARLs generally) the average farm unit is subject to a severe cash income or purchasing power constraint because of the limited extent of the commercial market for farm products relative to the large number of farm households dependent on agriculture for employment and income. A subsector of large-scale farm units can, to a considerable extent, escape that purchasing power constraint if it accounts for the lion's share of commercial sales. However, the inevitable consequence is that, for the great majority of farm households, the purchasing power constraint is intensified. Thus, CARLs face a choice between "crash modernization" of a subsector of atypically large, capital- and cash-intensive farm enterprises versus "progressive modernization" of the small-scale farm units with limited cash income that predominate in CARLs.

There has, in my opinion, been an unfortunate tendency for advocacy of small-farm strategies to be based on equity considerations. This emphasis has reinforced the assumption that only large farms can be efficient. The phrase "small is beautiful" is absurd, at least if it is interpreted literally. What is true and important is that because of their structural and demographic characteristics, small is inevitable for a great majority of farm units in CARLs. Furthermore, a wealth of evidence has shown that as long as farm labor is relatively abundant and cheap, small farms generally have an economic advantage over large farms (e.g., see Berry and Cline, 1979.) An important qualification must be noted. If a country's macroeconomic policies and government programs (e.g., an overvalued exchange rate together with administrative rationing of foreign exchange, import licenses, and cheap, subsidized credit) give preferential treatment to large farmers, a dualistic pattern of agricultural development will emerge because of these policy distortions.

For most of the 55 CARLs, it will be at least several decades before they reach the structural transformation turning point when the absolute size of their farm labor force begins to decline. Only then will an emerging scarcity of farm labor give rise to an increase in its price or opportunity cost so that investments in capital-using, labor-saving innovations such as tractors and tractor-drawn implements become socially as well as privately profitable. Meanwhile, four factors are particularly important in making it economically and socially advantageous for CARLs to pursue broad-based, small-farm strategies.

1. Small farms are usually superior to large farms in economic efficiency because resources of land, labor, and capital are combined in proportions more appropriate to the relative factor endowments and relative factor prices that prevail in CARLS (or should prevail if "scarcity prices" are not distorted by ill-advised policies).

2. Decentralized decision-making and the exercise of initiative and judgment by farm workers are especially important because of the nature of the agricultural production process. Because of unpredictable variations in weather and microvariability in the quality of land and other resources, even routine chores often involve "on-the-spot supervisory decisions."

3. Family members have a claim on the residual output of a farm rather than on a fixed wage. Therefore, they have a direct incentive to maximize farm profits by working hard and exercising initiative and judgment. Thus, labor costs will normally be lower on small farms than on large farms dependent on hired labor until it becomes socially and privately profitable to invest in labor-displacing mechanization. Although the price of farm labor will be higher for those working on large-scale farms, returns to labor in the agricultural sector will be lower, with a dualistic pattern of agricultural development. The diseconomies that occur, when large farms rely on large gangs of hired labor along with other factors, encourage large farms to substitute machines for labor, thereby reducing the income-earning opportunities of the farm labor force.

4. A small-farm strategy facilitates structural transformation by fostering more rapid expansion of manufacturing and other nonfarm activities. By relying on capital-saving, labor-using technologies, small-farm strategies make it possible to increase farm output by fuller and more efficient utilization of a CARL's large and growing farm work force, thereby minimizing the agricultural sector's requirements for scarce capital and foreign exchange. Moreover, the pattern of effective demand in rural areas generated by broad-based agricultural development maximizes the positive interactions between agricultural development and the growth of output and employment in the rural and urban nonfarm economies. The dispersed pattern of demand as well as its commodity composition also encourages growth of small and medium enterprises that are less constrained by shortages of capital and foreign exchange than are large-scale urban enterprises.

Broad-Based Strategies and Research Priorities

The structural/demographic characteristics of CARLs generally imply that priority needs to be given to generating a sequence of divisible innovations that are labor-using and capital-saving and can be adopted in increments. Two major lessons can be derived from the Asian experience: (1) innovations and associated inputs should be divisible items such as high-yield varieties and chemical fertilizers that are neutral to scale, and (2) investments in irrigation and drainage facilities are often complementary to those yield-increasing innovations and, therefore, have very favorable benefit/cost ratios.

These are powerful empirical generalizations, but good decisions with respect to research and development priorities depend on local socioeconomic and agroclimatic conditions. Particularly significant for the CARLs in sub-Saharan Africa is the great variation in which different countries, and areas within countries, have moved from being "land surplus" to "land scarce" agricultural economies as a result of rapid population growth during the past four decades.

In areas that still have a relative abundance of land, farmers have little incentive to invest scarce resources in yield-increasing innovations because the return to such investments is related directly to the scarcity value of land. Binswanger (1986) argues persuasively that the limited success of research on food crops in Africa, and the limited political and financial support for such research, has been influenced strongly by the failure of agricultural scientists and administrators to take account of locality-specific conditions related to the scarcity or abundance of land and the availability of cash income in determining research priorities. The fact that many farmers have shown little interest in fertilizer-responsive varieties and in husbandry techniques, such as the precise placement of fertilizers or intensive manuring, has often been explained as an irrational rejection of "improved farming" by "tradition-bound" farmers. In fact, the farmers were being rational; it was the extension advice that was irrational. Even in remote, land-abundant areas, farmers readily adopted disease-resistant varieties of cotton and new crops that provided more food or income per unit of labor (i.e., a worthwhile return on a scarce resource).

Also, there is probably considerably more scope in African than in Asian CARLs for "selective" investments in mechanical innovations. Conversely, because of Africa's resource endowment for agriculture, there is most certainly much less scope for reliance on irrigation (see Moris and Thom, 1987). These important and complex issues will not be discussed here. However, it should be emphasized that there is a strong presumption that agricultural research and development programs in Africa need to be concerned with both biological/chemical innovations and mechanical innovations. Because of the rapid increase in rural population densities, farmers in an increasing number of areas have found it profitable to invest in yield-increasing and land-saving innovations. However, the yield increases will not likely be as great as those in Asia, because the scope for irrigation to avoid stress caused by inadequate moisture is limited.

On the other hand, many areas in Africa will continue to have considerable scope for expanding cultivated areas as well as developing better tillage practices to improve the use of available moisture and reduce soil erosion. Clearly, in the longer term, as structural transformation leads to the growth of domestic commercial demand, an increase in cash income per farm household, and the creation of a more effective marketing system, it will become attractive for a large, growing number of farmers to invest in land improvements and to adopt an increasing number, albeit gradually, of improved farm implements. Rising farm cash incomes and rural population growth creating increased pressure and opportunities for intensification will, of course, lead to expanded use of high-yield varieties and fertilizers. But even in the short run, there appear to be opportunities for identifying simple, relatively inexpensive mechanical innovations for alleviating seasonal labor bottlenecks, for expanding the area cultivated per worker, and for implementing soil- and moisture-conserving tillage methods. Thus, in the African context, intensification can be expected to encourage investments in animal-powered farm equipment. As population pressure increases, producer preference for cropping land shifts from lighter soils, which are easy to cultivate with hand hoes but risky, to heavier soils. That shift encourages the adoption of animal draft power. Those heavier soils require more power for cultivation, but they have the advantage of retaining moisture better, and they make possible higher and more reliable yields because they respond to better management (Pingali, Bigot, and Binswanger, 1987).[6]

Finally, it is worth noting that expanded use of a gradually widening range of simple, affordable farm equipment represents a potentially significant backward linkage to the manufacturing and trade sectors. Agricultural implements constitute a large part of the output of the metal-working industry in developing countries. Therefore, the kinds of organizational and technological developments experienced in the production of farm implements can have a significant impact on the growth of an indigenous capacity to produce capital goods which are adapted to the country's relative factor prices and stage of technological development. Thus, expanded use of a widening range of simple but well-designed farm implements can contribute to increases in farm productivity and incomes. It can also stimulate growth of rural enterprises capable of facilitating structural transformation by fostering dispersed growth of small- and medium-scale manufacturing firms that employ relatively labor-using, capital-saving technologies.

The Misleading Dichotomy between Growth-Oriented and Poverty-Oriented Strategies

A common justification for intervening in commodity markets in developing countries is to achieve results that are supposedly more equitable than those resulting from outcomes determined by market forces. Clearly, this raises issues on which there is only limited agreement among social scientists.

In these concluding remarks, I make no claim to offer "hard conclusions." Rather, I will briefly state why I believe that the often-made distinction between "poverty-oriented" and "growth-oriented" strategies is misleading. The crucial question is, What is the best type of growth-oriented strategy for the CARLs? Given the pervasiveness of poverty and very low incomes, there is no realistic hope of eradicating poverty without growth. A broad-based agricultural strategy—characterized by strong, positive linkages with decentralized industrial development and major reliance on labor-using, capital-saving technologies—can lead to rapid growth and reduction of poverty. Taiwan's experience is especially interesting because it demonstrates that achieving a rate of growth in demand for labor that exceeds the growth rate of the working population seeking employment is an extremely powerful means of increasing the return to labor and realizing widespread reduction in malnutrition and other serious manifestations of poverty.

Although "production-oriented" activities are crucial to achieving economic growth, certain "consumption-oriented" activities also need to be given priority. A notable contribution of the "basic needs" approach, which became popular in the 1970s, was to remind us that some needs are more basic than others.[7] The most significant implication of this recognition is that policymakers should focus on the composition of goods and services produced and consumed in a country as well as on the growth and distribution of output. An interesting illustration depicting the significance of the composition (or content) of the goods and services that make up a country's GNP is provided by Preston (1978). His comparative analysis of factors associated with declines in mortality demonstrates that "unstructured" economic development is generally less efficient in lowering death rates than is more "structured" development in which a larger fraction of a country's GNP is devoted to expenditures on education and public health activities.

There is now wide-spread agreement that education and health programs should not be viewed simply as welfare activities to be subordinated to the goal of expanding production until a country has reached some threshold level of per capita income. That is, the educational level, nutritional status, and health of a country's population represent "human capital" that has an important impact on economic growth as well as on the level of well-being of individuals. But difficult questions with respect to priorities remain: What levels of expenditure for what types of educational, nutrition-related, or health activities should be funded in CARLs with their severe lack of financial and administrative resources? A balance must be struck between public and private sector activities. Social services, such as education and certain highly cost-effective public health and family planning activities, appear to merit priority even when resource constraints are severe. But direct action to increase food consumption by food subsidies or similar measures can probably be justified only at higher income levels when budget and personnel constraints are less binding. However, the evidence that broad-based development strategies can lead to rapid and widespread improvements in food consumption and nutritional status represents an additional important advantage of small farm development strategies and related policies that foster development, both farm and nonfarm, based on labor-using, capital-saving technologies.

Notes

This paper draws heavily on a forthcoming book, Transforming American Economies: Opportunities Seized, Opportunities Missed (Tomich, Kilby, and Johnston), and especially on Kilby's treatment of the central role of specialization and markets in the structural transformation process.

[1]Hayami and Ruttan (1985) obtain their common denominator of "wheat units" by converting the output of other crops and livestock products into tons of wheat based on their value relative to the price

of wheat. Their calculations are based on a country's male farm labor force to improve the cross-country comparability of their estimates. There is great variation in the definitions used to determine whether women members of farm households should be included in the farm labor force and even greater variation in the actual coverage of women in labor force surveys. Although those are valid reasons for limiting cross-country comparisons to estimates of the male farm work force, it may have the unfortunate consequence of reinforcing the tendency to ignore the extremely important role of women in the agricultural economy of most LDCs.

[2]Monetary expenditures were held to a minimum because opportunities to sell produce for cash were limited. Danhof (1969:16–17) puts it aptly, money "was difficult to come by [so] necessity was converted into a virtue."

[3]Although the knowledge and skills of a country's traders represent a valuable resource, it is also important to emphasize that marketing systems need to evolve as an important component of the process of structural transformation. In an article that remains timely after three decades, Drucker (1958) emphasizes that marketing is the business discipline that is most advanced and is both learnable and teachable.

[4]Conclusions from studies in Asia and in tropical Africa may have to be qualified to some extent in the Mexican context. Allegations that local bosses (*caciques*) forcefully prevent the entry of potential competitors to preserve the market power of privileged merchants seem plausible given the frequency with which *caciques* resort to violence and other coercive measures. It should not be overlooked, however, that a government-operated channel for buying and selling commodities has considerable market power, and some officials are likely to seize opportunities for underpaying farmers or overcharging consumers. It is not easy to inculcate a social conscience that will dissuade officials from collecting monopoly rents if the opportunity exists. Satisfactory performance by private traders is not a reflection of a social conscience but is a result of the spur of competition when customers and potential customers are free to exercise the "exit" option. During the past decade, Mexico's economic policies have moved away from the interventionist bias illustrated by the CONASUPO initiative and that agency's involvement in essentially commercial activities has been reduced substantially.

[5]This section draws liberally on an assessment of AID (Agency for International Development) activities to promote agricultural and rural development in sub-Saharan Africa carried out in conjunction with the World Bank's MADIA (Managing Agricultural Development in Africa) study directed by Uma Lele (see Johnston et al., 1988).

[6]This outstanding study of agricultural mechanization and the evolution of farming systems in sub-Saharan Africa includes a concise analysis of how the design of animal-traction projects might be improved so as to avoid the pitfalls that account for the poor performance of past projects (see Chapter 8 in Pingali, Bigot, and Binswanger, 1987).

[7]A 1976 ILO (International Labour Office) report was soon followed by a rash of publications arguing for a "basic needs" approach or strategy.

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Session 4

Food Policy and Sustained Development

- Socioeconomic Implications of Biotechnology for Developing Countries
- Impact of Food Policies on the Development of Agricultural Technologies

Session Chair: Billie R. DeWalt

Speakers: Lawrence Busch
George W. Norton

Socioeconomic Implications of Biotechnology for Developing Countries

Lawrence Busch

he age of scientific and technological optimism is coming to an end. No longer are new technologies accepted at face value in the way they once were. Gradually—indeed, painfully—we are coming to the realization that scientific and technical change is not the result of some immutable force but of the concerted actions of human beings organized to achieve certain ends. Congressman George Brown (1992), Chair of the House Science, Space, and Technology Committee recently noted that science often raises fundamental questions of ethics and values but that it fails to answer those questions. Moreover, the Office of Technology Assessment of the U.S. Congress (OTA, 1991) recently called for a coherent science policy that would ensure that national objectives and goals were served. Science may be, as Vannevar Bush (1945) once put it, "the endless frontier," but its very endlessness that has forced us to call it into question.

The New Biotechnologies: An Overview

It is essential to remember that biotechnology is not a single *technique*, a way of doing things, or a *technic*, the various material objects that are used, but an ensemble of techniques and technics, each of which is capable of transforming some aspect of living nature. What these techniques have in common is their origin in molecular biology and, more specifically, in the programs of the Rockefeller Foundation in the 1930s (see Busch et al., 1991; Abir-Am, 1982; and Kohler, 1978, 1980). Among the myriad techniques and technics are the following:

Recombinant DNA (rDNA). Fragments of genetic material are moved from one organism to another across species lines. In principle, this technique is the most precise of the molecular techniques, permitting the scientist to move a single gene or a complex of genes that code for a particular trait from one organism to another. Thus, insect resistance may be moved from a microorganism to a plant, conferring resistance on the plant. In practice, use of this technique is often hampered by the lack of knowledge of the function of particular genes, lack of knowledge of the location of genes on the genome of most organisms, lack of understanding of the mechanisms of gene expression in the host organism, and the difficulty of inserting the foreign material in the "right place" in the host genome.

Cell Culture. Individual cells are made to grow and divide in a nutrient medium. This technique has been well-established for some time and is considered by some to predate the new biotechnologies. However, what is relatively new is the ability to scale up the division and growth of various cells in vats known as bioreactors. In principle, any cell from any organism may be grown in vitro in this manner, eliminating the need for the rest of the organism.

Tissue Culture. Individual cells are made to differentiate within a nutrient medium. This technique is essential for cloning organisms that appear to have characteristics that are of interest. Thus, in principle, a single cell of a plant or animal might be made to differentiate such that eventually an entire organism is reproduced. Tissue culture techniques have been particularly successful in developing high-yielding oil palm clones—clones which moved the palm oil industry from West Africa to Malaysia.

The Old Biotechnologies Take Over. That is to say, once plants or animals are cloned, more conventional whole organism techniques are used to pursue agronomic, horticultural, or livestock-raising goals. The process as a whole, as it applies to plants, is displayed in Figure1.

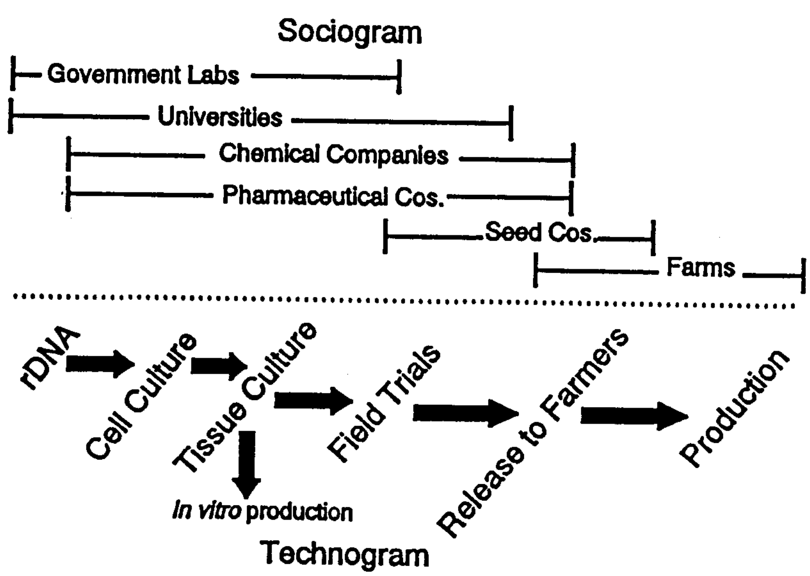
Of particular import for the Third World, or at least for parts of it (see Busch and Gunter, 1991), are four particular applications of the new technologies: (1) in-vitro production of food and fiber, (2) transgenic plants and animals, including (3) functional attribute or identity-preserved crops, and (4) fabricated foods.[1]

In-Vitro Production

In their recent book, Busch et al. (1991) argue that in-vitro production of tropical commodities has already started. The basic idea behind this technology is to treat plant (or animal) cells as if they were single-celled organisms. In so doing, it becomes possible to focus solely on that part of the crop that is of interest as food, fiber, pharmaceutical,[2] or industrial compound.

The early work on in-vitro production focused almost entirely on very-high-

Figure 1. Social and technical aspects of the improvements of plants using biotechnological and conventional techniques.



value pharmaceuticals and spices. Perhaps the first success was the in-vitro production of *shokin*, a dye and astringent grown in China and Korea (Fujita, 1988). Soon afterwards, Imperial Chemical Industries (ICI) developed an in-vitro production system for vanilla. However, this latter system is still not in widespread use as it is more costly than artificial vanilla and the FDA refuses to allow it to be labeled "natural vanilla" (Fowler, 1988).

More recently, work has begun on more common crops such as cocoa. A recent report of the Dutch government noted that Nestlé and Hershey (with Cornell University) researchers have synthesized cocoa butter in this manner, but that the cost still remains at $220 per kilogram, far above the $9 per kilogram that cocoa butter brings on the world market (van Roozendaal, 1992). Barring a major breakthrough, cheap in-vitro production of bulk commodities is still a decade or more away. Nevertheless, such methods will continue to pick away at conventional approaches to production. Moreover, the methods for engaging in this type of production are moving beyond the trial and error stage; as they do so, progress will undoubtedly be more rapid. It is also likely that in-vitro production techniques will become corporate secrets as this will be a major means for maintaining an edge in the market.

Transgenic Plants and Animals

As little as three years ago it appeared that transgenic plants and animals would have relatively little effect on agriculture for some time to come. However, most observers—including this one—are now being proved wrong. A wide variety of transgenic plants is nearing the marketing stage, including tomatoes, tobacco, cotton, potatoes, soybeans, alfalfa, rice, canola, and sunflowers.[3] Many of these plants have been modified to resist certain herbicides, especially glyphosate.[4] However, there is considerable controversy over the claims of chemical companies. These companies assert that herbicide tolerance will result in the use of less herbicides while public interest group scientists argue that herbicide use will increase as a result of these products (e.g., Goldburg et al., 1990).

In addition, many companies are also developing plants with the toxin from Bt (*Bacillus thuringiensis*), a naturally occurring insecticide, incorporated into the plant. Company officials claim that in so doing they can cut deeply into the use of insecticides and create a more permanent form of control. Critics argue that the effect will be to select for insects that are resistant to the toxin, thereby making Bt in its common form as a spray useless in insect control.

Another area of rapid advance is the creation of transgenic fish. Such fish grow faster and are more efficient convertors of feed into protein. However, the creation of such fish has raised serious concerns about accidental release into the environment. Relatively little progress, by contrast, has yet been made with respect to animals, although the use of dairy animals for pharmaceutical production is being explored.

Functional Attribute (or Identity-Preserved) Crops[5]

These crops have been genetically altered to make a major modification to the harvested portion of the crop. In a 1990 article, Pioneer HyBred President

Thomas Urban (1990) argued that as much as 20 percent of American maize land would be planted in identity-preserved crops by the turn of the century. From his perspective, the advantage of such crops will be that they will permit brand identification and will permit farmers to know what price they can expect before the crop is planted. Urban further asserts that such crops would be grown almost entirely under contract as they would deteriorate if passed through the bulk commodity system. To date, much of the most rapid development has been in the area of industrial crops, where FDA regulations do not slow the speed of transfer from lab to field. Among the identity-preserved crops is a high-lauric-acid canola that will be grown under contract using seed provided by Calgene. The crop will be used for soapstocks which currently have to be imported from developing countries.

Fabricated Foods

Finally, food manufacturers are working hard to expand and accelerate the development of fabricated foods. Such products permit the manufacturer to go beyond the current situation in which most foods are made of ingredients. Instead, each of the agricultural commodities is broken down into starches, sugars, fibers, etc. Then, the various components are reconstituted into a new food product. Some foods of this type (e.g., margarine) have already been in use for some time. However, new technologies permit the speeding up of the process. The result might be exotic such as high-protein potato chips. Already, one Brazilian company is selling citrus fiber under the brand "Citro-Suco."

Consequences for the Third World

Market Instability

Perhaps the most immediate consequence of all the new biotechnologies is to create greater market instability than ever. The case of sugar is instructive (Clairmonte and Cavanaugh, 1986). For hundreds of years sugar was produced entirely from cane, a tropical crop. Indeed, it is not too far fetched to argue that the search for sugar was among the many reasons for the rise of colonial empires. However, sugar beets—a temperate crop—began to make inroads into cane markets about a century ago. More recently, with the development of high-fructose corn syrup (HFCS), major market segments were shifted from cane and beets to corn. In particular, the production of soft drinks in the United States and even in some developing nations, shifted to the exclusive use of corn syrup. For example, Pakistan is producing a similar isoglucose product from broken rice to supply its soft drink industry (Crott, 1986).

By 1982, 50 percent of the sugar marketed in the world came from HFCS (Byé and Mounier, 1984). The chemical synthesis of aspartame (Nutrasweet™) has also eaten into the cane sugar market as the middle classes worldwide have found that they could satisfy their cravings for sweetness without the accompanying calories.

Finally, the large sugar companies have identified several new sources of sweeteners from plants. One, thaumatin, is several hundred times sweeter than cane sugar and can be produced in vitro. Today, the world is awash in sugar and there is no end in sight. Van den Doel and Junne (1986) estimate that between 8 and

10 million people in the Third World have seen their livelihood destroyed by the collapse of the sugar market.[6]

The edible oil situation is not too different. It was not too many years ago that the Philippines was the world leader in edible oil production as a result of its smallholder-owned coconut plantations. However, the development of high-yielding oil palm clones by Unilever led to the shift in production from West African smallholders to large plantations in Malaysia as noted above. Moreover, as a result of research on substitutability, it led the food industry in the western world to substitute palm for coconut oil in their recipes. Still later, as a result of dietary concerns, soy, sunflower, and canola were substituted for the "tropical oils" which contain considerably more saturated fats.[7] As Barker and Plucknett (1991:115) argue, "These examples suggest that widespread application of biotechnology could increase the volatility of world markets and lead to dislocations in agriculture in both the developed and developing countries."

Continued Secular Decline in Commodity Prices

The new biotechnologies combined with the heavy subsidies to agricultural production in both the United States and the European Economic Community are likely to continue, if not speed up, the secular decline in commodity prices. A recent article in the *Québecois* magazine *L'Actualité* (Bois, 1992) outlined the effect of declining commodity prices on the global traffic in illegal drugs. It noted that Bolivian smallholders are faced with declining income for all the crops they can grow except coca leaves. For example, a sack of coffee that sold for $240 in 1986 only brings $80 today. Under these conditions, only coca can provide even a meager income.

The same applies to the production of foodstuffs and export crops in the less developed countries (LDCs). In Senegal, the foodgrain of preference is wheat, despite the fact that it is extraordinarily difficult to grow in that nation. The most modern flour mills are located in the ports of Nigeria, Sri Lanka, and Indonesia to handle the huge imports of wheat into those nations (CIMMYT, 1985). In the current free trade negotiations, Mexico has been very clear that it will not free imports of maize for fear of overwhelming smallholders with massive imports of cheap, subsidized American maize.

Prices for cash crops as well have been falling. Cocoa, coffee, tea, rubber, oilseeds, and sugar have declined rapidly over the last several decades. This, combined with massive national debt and the general economic instability of the world economy leaves millions of smallholders with far less income than before. The new biotechnologies will only speed up this decline by increasing supply faster than effective demand.

Greater Competition from the West

At the same time, biotechnology will increase competition from the West. On the one hand, multinational corporations will attempt to transform existing crops so as to produce needed food and feedstocks closer to the point of consumption. On the other hand, the same companies will step up their activities in LDCs so as to capture local markets previously off limits. In so doing they have already altered the research agenda. For example, Barker and Plucknett (1991) report that China signed agreements with Occidental Petroleum and Cargill in 1980 giving those companies exclusive rights to hybrid rice technology in certain parts of the world. As a result, the same companies have pressured China not to release certain information to the International Rice Research Institute.

Furthermore, the United States and Japan have both shown their reluctance to support the International Centre for Genetic Engineering and Biotechnology (with laboratories in Trieste and New Delhi) (Hobbelink, 1987) as they are seen as being in direct competition with U.S. and Japanese companies. In contrast, the United States has been willing to engage in joint public-private ventures with the international agricultural research centers (IARCs) and national agricultural research systems (NARS) (Cohen, 1989). The words of the director-general of the International Potato Center, Richard L. Sawyer (1989:17), are indicative of the overall mood:

> With the rapid movement of fast-food into the developing world, major food processors need local potato varieties that will grow well and provide the accepted standard of processed quality in warm tropical areas. Otherwise, the fast-food industry has to depend on imported frozen products, that elevate the cost of the fast-food service and do not provide the income needed by resource-poor farmers of the tropics. Through a collaborative arrangement with some major food processors, we are helping develop potential varieties that will grow well in the warm tropics and meet rigid quality standards of the fast-food industry.

In the aftermath of the Green Revolution, critics often argued that the IARCs merely made the LDCs dependent on continued supplies of fertilizer and pesticides, most of which were (and still are) produced in industrialized nations or by multinational corporations. Sawyer appears ready to go much further by transforming the entire food system of developing nations so as to suit the desires of a segment of multinational capital. Moreover, he conflates the standards of the fast-food industry with the needs of smallholders.

Loss of Genetic Diversity

Finally, the new biotechnologies may be linked to a further decline in genetic diversity. In particular, the fine tuning that the new technologies provide, makes it possible—although not necessary—to attain levels of uniformity in the field that were undreamed of before. The creation of millions of true clones through tissue culture, the use of a handful of gene loci for pest resistance, the spread of high-yielding varieties with identical or similar parentage, eliminate the genetic diversity that lends stability to agroecosystems.

Admittedly, Duvick (1981) is right in suggesting the seed industry compensates for diversity in space by providing diversity in time. For this reason, despite the havoc it wrought, seed companies were able to respond rapidly to the Southern Corn Leaf Blight epidemic of 1970. But such a response demands a modern NARS, a modern seed production system, and the institutions of credit, input delivery, and output processing that are the hallmark of a developed nation. It also requires political and economic stability, a goal that remains elusive despite the end of the Cold War.

Conclusion: Research Directions for the CRSPs

Where does this all leave the CRSPs? After more than a decade of existence, these novel institutions, which link scientists in American universities with those in developing nations, are still a mere drop in the bucket when compared to other assistance programs. Yet, despite my critical and seemingly pessimistic remarks, I do believe that the CRSPs can make some difference if they change certain of their basic operating principles.

First, the CRSPs need to take a subsector approach to their work.[8] The CRSPs were established along commodity lines. Nearly all of them are responsible for one or more commodities and the emphasis has been largely on the production of that commodity. As a result, plant and animal breeders have been the dominant actors in the development of the CRSPs. Recently, molecular biologists have challenged their dominance, as they have in domestic research programs. This is likely to move the CRSPs further toward a reductionist view at precisely the moment when a constructionist view (i.e., one that views agriculture as a socially constructed system) is needed. In short, the CRSPs need to begin to consider, at the very least, the entire commodity subsector described in their mission. If they do not, they risk the possibility that what they have accomplished through breeding will remain on the shelf, unavailable to potential users.

Since commodity subsectors are organized in a linear sequence, the weakest link in the chain can cause the entire chain to collapse. In some cases, this means that more attention needs to be paid to seed multiplication. In others, it means more attention to processing and marketing activities. Whatever the particulars, the CRSPs will need to bring in competencies that they have not had (too much of) in the past. In particular, CRSPs will need to integrate the special skills of social scientists into their planning and programming as full partners. This will be a painful process at best, but if it is not accomplished, much of the research of the past decade will have been for naught.

Second, the CRSPs need to continue and even to increase their training of LDC scientists. One of the major contributions of the CRSPs has been their provision of graduate education for LDC scientists. The CRSPs need to continue this aspect of their mission and perhaps even to increase the number of scientists trained. Moreover, the CRSPs need to develop training plans with NARS that will permit the creation of effective interdisciplinary teams in developing nations. Such teams must include both natural and social scientists.

Third, the CRSPs need to move from a focus that is multidisciplinary to one that is interdisciplinary. At their inception, most of the CRSPs were mere agglomerations of scientists from a variety of disciplines. Indeed, when I was associated with a CRSP at its early stages, I was struck by the fact that whoever happened to be there at the inception was written into the agreement. Balance among disciplines or even a global plan only came later. Even now, the CRSPs too often consist of disconnected pieces that are run by individual principal investigators (PIs). And, the budgets of too many CRSP projects are viewed as sinecures that arrive each year to support the interests of the PI. The CRSPs need to be restructured so as to foster interdisciplinary collaboration to solve problems of concern to developing nation farmers.

Fourth, the CRSPs need to take a strategic approach to the problems they face. Too often, the research undertaken by CRSP scientists is uncoupled from either other research or post-research activities. Some scientists might even argue that the CRSPs were established to do research and not to engage in extension or technology transfer activities. In some sense, this is true. Nevertheless, the ultimate success of the CRSPs will be judged on the impact that the technologies and approaches they develop have on developing nations. Well-designed technologies that sit on the shelf will not be defensible to either AID administrators or developing nation officials.

During much of the first decade of the CRSPs, this was of little consequence, as there were few new technologies or approaches. However, as the CRSPs come to maturity, there will be a continuous flow of new technologies and approaches ready to be employed in the field. Therefore, CRSP scientists and administrators need to develop strategies for enrolling other actors in the implementation of the results of research by showing them how their organizations can benefit from linkages with the CRSPs. These actors may be extension services, international and local development agencies, or nongovernmental organizations. In different locations, different agencies will be the vehicles that will demonstrate the successes of the CRSPs as well as their own success. But this will only occur if the CRSPs begin to think strategically and to allocate resources to the encouragement of these activities.

If given the opportunity, social scientists are likely to take to lead in developing a more strategic approach, if only because such an approach puts human actors and social structure at the center of the research process. Social scientists have a major task to perform in educating technical scientists on these issues. On the other hand, unless social scientists begin to take the content of the technical sciences seriously, it is unlikely that much progress will be made.[9]

Fifth, the CRSPs must begin to consider ethical and value considerations as a fundamental part of their work. To date, the CRSPs, like most scientific projects, have tended to sidestep ethical and value issues. They have assumed that such concerns are beyond the scope of scientific research. Yet, as the new biotechnologies amply demonstrate, technical change is also *always* social change (Latour, 1987). There is no way to change technologies without also changing institutions, policies, and the distribution of income, wealth, status, power, and prestige. This is the case in part because science is a value-laden activity. Scientists—of whatever stripe or persuasion—strive for the realization of certain scientific values: objectivity, parsimony, simplicity, precision. These values may clash with other nonscientific values, especially ethical values such as equity and justice.

Some scientists who have discovered this connection have determined that science must prevail at whatever expense. For example, Boysie Day (1978) has asserted that agronomists are revolutionaries and those who oppose what they find are likely to be trampled. In contrast, Martha Crouch (1990) has argued that it is science which has gotten us into the mess we are in today and, therefore, it is not the proper vehicle to get us out. She has left her field of molecular biology because of her concern for ethical issues. Yet, it appears to me that neither Day's cavalier attitude nor Crouch's despair are likely to resolve our present dilemma. We must recognize that science is value-laden and ethically engaged and begin to construct a science that is truly responsible. We must abandon Vannevar Bush's "endless frontier" and decide for whom and for what knowledge is to be produced. This will also require an interdisciplinary, strategic approach. Furthermore, it will require the participation of farmers, farm laborers, and other actors in agriculture in defining what is to be the good.[10]

The above recommendations say very little about biotechnology. This is not because of its irrelevance; indeed, the new biotechnologies offer a considerable number of new pathways to improving tropical crops. However, my concern lies not in that inadequate resources will be devoted to these techniques, but in that they will receive too much funding. The very expense of these new techniques can easily devour the entire budget of the CRSPs. As important as some of them may prove to be for the future development of agriculture in the Third World, I want to close by putting in a plea for paying more attention to the post-production aspects of each of the CRSP commodities, for it is here that (arguably) the biggest gains in income for the rural poor are to be had.

Lipton and Longhurst (1989) have noted that the problem of the next decade even in Africa will be an increase in the number of landless laborers. While land reform might be a solution in some areas, in most areas farms are already of relatively small size. Further subdivision will result in the creation of nonviable entities. Therefore, some thought must be given to the creation of off-farm jobs. The industrial sector will not be able to provide such jobs as manufacturing is already too automated to require large amounts of labor. In contrast, small-scale food processing and related agricultural activities at the village level are often possible. These activities have the capacity to employ large numbers of people where they currently live and to create development from the bottom up. The CRSPs need to pay more attention to these nonfarm agricultural activities including seed production, contract services, grain milling, food preparation and preservation, and preparation of animal feed. In so doing the CRSPs can ensure that the on-farm technologies they have developed are fully utilized. That is the challenge of the next decade.

Notes

1. Other technologies such as animal vaccines and diagnostic kits will not be discussed here, as they are unlikely to have a direct effect on most of the Third World in the near future.

2. Over 25 percent of the pharmaceuticals sold in the United States are derived from plants (Balandrin et al., 1985).

3. Release information is summarized in a quarterly publication of the National Wildlife Federation, *The Gene Exchange*.

4. Technically, engineering for herbicide resistance does not constitute a transgenic plant unless genes from other organisms have been inserted. This is usually not the case.

5. The term "functional attribute" appears to be used by the food manufacturers (Moshy, 1986), while "identity-preserved" appears to be favored by the seed companies.

6. Research of this type is encouraged by the protectionist policies of the developed nations which elevate prices for sugar and other commodities far above the world market price. Put differently,

new technology is a convenient way to skirt tariff barriers.

7. However, it should be noted that the minor amounts of palm and coconut oils in bakery products are likely to have had little impact on the saturated fat intake of Americans or Europeans.

8. For a domestic view of the subsector approach, see Marion (1986). For a view that specifically focuses on the tropics, see Griffon (1990).

9. For an example of how that might be done, see the paper by Anne Ferguson in this volume.

10. Boltanski and Thévenot (1991) have recently argued that the public good can only be seen as a compromise between competing notions of the good held by different groups in a society. Their position is well worth pondering.

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Impact of Food Policies on the Development of Agricultural Technologies

George W. Norton

Economic and social benefits of agricultural research depend both on the quantity and quality of research and extension efforts and on the policy environment that surrounds the affected commodities. Social scientists have played an important role in improving the design and testing of new technologies and in predicting and evaluating impacts of agricultural research. They have devoted less effort to improving our understanding of the influence of food policies on the development of new technologies. This paper examines whether the CRSP social science agenda should be expanded to include the latter topic.

Many governments in developing countries distort product and factor markets through output price ceilings, input and credit subsidies, export taxes and quotas, overvalued exchange rates, and other policies. The combined effect of these policies is often to discriminate against agriculture (Krueger, Schiff, and Valdes, 1988). At the same time, low productivity in agriculture, low rates of productivity growth, and high estimated rates of return to agricultural research signal an underinvestment in research in many developing countries. The reasons for this underinvestment are unclear, but one possibility is that price policy distortions have reduced the incentives for producers to press for new technologies.

Demands for the development of particular types of new technologies are influenced by relative product and factor prices (Hayami and Ruttan, 1985). Therefore the nature of technologies generated also may be affected by policies that distort relative prices. CRSP social scientists could play a role in improving our understanding of the linkages between food-policy distortions and investments in the creation of new technologies.

Public research spending to increase the supply of new technologies may be jointly determined with spending or taxation associated with price policies (Gardner, 1988; de Gorter, Nielson, and Rausser, 1992; Rausser, 1982; Rausser and Foster, 1990; de Gorter and Zilberman, 1990). Hence, analysis of the effects of price policies on the development of agricultural technologies may require a framework that allows for joint determination of both types of government spending decisions. However, the fact that effects of price policies are felt almost immediately while effects of research spending occur over several years may help in isolating the effects of price policies on research spending (Alston and Pardey, 1991).

This paper is organized as follows. The first section describes the nature of food policies in developing countries. It summarizes methods that CRSP social scientists might use to assess levels of price support or taxation. The second section summarizes evidence on the rates of return to agricultural research and the effects of food policies on those returns. The studies summarized have treated research spending as independent of these policies. The third section focuses on determinants of the level and direction of research investment. Induced innovation and political economy models are considered. Implications are drawn for the research agenda of CRSP social scientists.

The Nature of Food Policies in Developing Countries

Developing countries tend to tax agriculture relative to other sectors. They often proclaim food self-sufficiency as an objective, yet subsidize consumers through price ceilings, export taxes, overvalued exchange rates, and other means of keeping food prices artificially low. Direct interventions in the food sector frequently are implemented through public marketing agencies that control marketing margins. Overvalued exchange rates result from fiscal and monetary policies that lead to higher inflation at home than that prevailing abroad. When the government fails to adjust the official exchange rate downward, the currency becomes overvalued. An overvalued currency makes exports from the country more expensive and imports into it cheaper. The additional supply of products in the domestic market reduces farm and consumer prices.

Summary measures of direct (or sectoral), indirect (or economywide), and total price interventions for 18 countries are presented in Table 1 from a paper by

Table 1. Direct, indirect, and total nominal protection rates for agriculture (average, percent)*.

County	Period	Indirect Nominal Protection Rate	Direct Nominal Protection Rate: Importable Commodities	Direct Nominal Protection Rate: Exportable Commodities	Direct Nominal Protection Rate: All Commodities	Total Nominal Protection Rate
Cote d'Ivoire	1960-82	-23.3	-26.2	-28.7	-25.7	-49.0
Ghana	1958-76	-32.6	42.9	-29.8	-26.9	-59.5
Zambia	1966-84	-29.9	-16.4	- 3.1	-16.1	-46.2
Egypt	1964-84	-19.6	- 5.1	-32.8	-24.8	-44.4
Morocco	1963-84	-17.4	- 8.2	-18.5	-15.0	-32.4
Pakistan	1960-86	-33.1	- 6.9	- 5.6	- 6.4	-39.5
Sri Lanka	1960-85	-31.1	39.0	-18.4	- 9.0	-40.1
Malaysia	1960-83	- 8.2	23.6	-12.7	- 9.4	-17.6
Philippines	1960-86	-23.3	17.9	-11.2	- 4.1	-27.4
Thailand	1962-84	-15.0	n.a.	-25.1	-25.1	-40.1
Argentina	1960-84	-21.3	n.a.	-17.8	-17.8	-39.1
Brazil	1969-83	-18.4	20.2	5.4	10.1	- 8.3
Chile	1960-83	-20.4	- 1.2	13.5	- 1.2	-21.6
Colombia	1960-83	-25.2	14.5	- 8.5	- 4.8	-30.0
Dominican Republic	1966-85	-21.3	19.0	-24.8	-18.6	-39.9
Total Average		-22.5	14.4	-12.6	- 7.9	-30.3

n.a. = not available

*The direct nominal protection rate reflects the degree of price support, on a percentage basis, compared to a situation with no direct price interventions. A negative value indicates taxation or negative protection. The indirect nominal protection rate reflects the degree of price support (taxation), on a percentage basis, that results from indirect government intervention. The total nominal protection rate is the sum of the direct and indirect interventions.

Source: Alberto Valdes (1991).

Valdes (1991). Price interventions are measured as the percentage departure from the price of agricultural goods that would have prevailed without sectoral price interventions, as well as in the absence of trade interventions in the nonfarm sector, corrected for exchange rate misalignment. For most of the countries, these nominal rates of protection (NPRs) are negative, implying net taxation of agriculture, and the indirect taxation is greater than the direct taxation. Details on procedures for calculating NPRs are found in Krueger, Schiff, and Valdes (1988).

Unfortunately, relatively few measures of price intervention are available for the major commodities and countries targeted by the CRSPs. Some estimates of producer subsidy equivalents (PSEs) are available for peanuts, soybeans, and small ruminants in certain countries. Examples of PSEs are provided in Table 2 together with a description of how they were calculated. Calculation of PSEs is a little simpler than the procedures for calculating NPRs.[1] Social scientists working on CRSPs may wish to calculate PSEs (or NPRs) to obtain rough estimates of the degree of price intervention. The purpose would be to provide measures of price distortions that could then be used to predict or explain levels and directions of research funding as discussed later in the paper.

Returns to Research and the Influence of Food Policies

A large number of studies have provided estimates of the rates of return to agricultural research. Most of the studies completed in developing countries have measured changes in economic surplus resulting from a research-induced shift in

Table 2. Producer subsidy equivalents for selected commodities and countries for 1987 (percentage)[1].

	Commodity		
Country	Peanuts	Soybeans	Mutton and Lamb
Argentina		-42	
India	-29	-10	
Mexico		59	
Taiwan		83	
China	-95		-17
Senegal	39		
Colombia		25	
Venezuela		59	

Sources: A.J. Webb, M. Lopez, and R. Penn (1990) and D. Roberts and P. Trapido (1991).

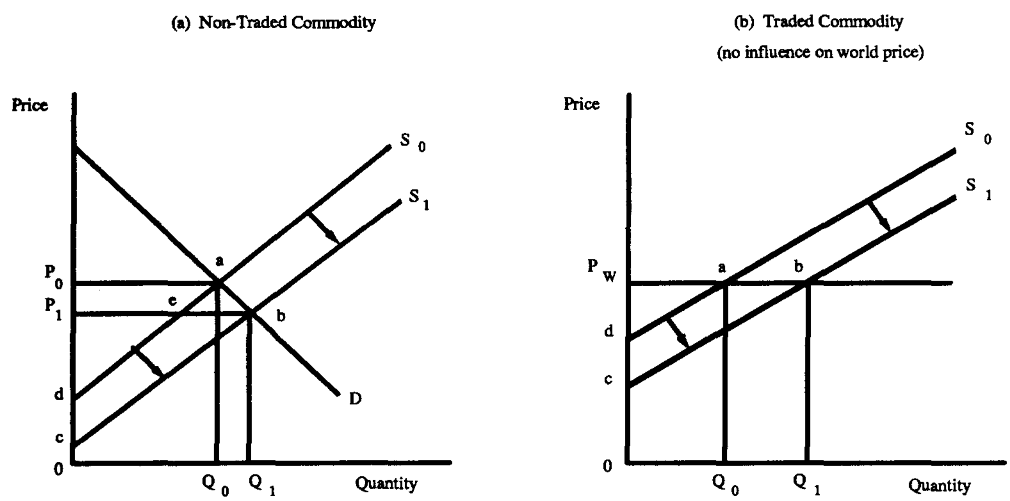
[1] The percentage producer subsidy equivalent (PSE) is defined as 100 times the total transfers to producers from government intervention divided by the commodity's value to producers.

$$Percentage\ PSE = 100\ x \frac{Total\ Transfers}{Value\ to\ Producers} = \frac{100\ x\ Q\ x\ (P_d - (P_w\ x\ E)) + D + I}{Q\ x\ P_d + D}$$

Where: Q = quantity produced,
P_d = producer price in domestic currency units,
P_w = world price in world currency units,
E = the exchange rate conversion factor,
D = direct government payments
I = indirect government transfers through policies such as input subsidies and exchange rate distortions.

Source for above formula: Webb, Lopez, and Penn (1990).

Figure 1. Changes in economic surplus resulting from research investment. Adoption of new technologies generated by research can shift the supply curve from S_0 to S_1. In panel a, price falls from P_0 to P_1 and quantity increases from Q_0 to Q_1. Consumers gain P_0abP_1 and producers receive ebcd - P_0aeP_1. In panel b, an exported or imported good for which the country cannot influence world price, the world price remains at P_w, producers receive abcd, and consumers do not benefit from the research. For a traded commodity for which the country has some influence on world price, there would be a price reduction and benefits to consumers.



the supply curve for a commodity (see Figure 1).[2] Echeverria (1990) has summarized the results of these studies, the vast majority of which have found annual rates of return in excess of 20 percent. Relatively few studies have incorporated food policies into the analysis. Norton, Ganoza, and Pomareda (1987) did consider the effects of alternative rice policies on research benefits in Peru. Other studies have measured the effects of price policies on research benefits in developed countries (Zachariah, Fox, and Brinkman, 1988; Fox, Roberts, and Brinkman, 1989).

Alston, Edwards, and Freebairn (1988) analyzed the qualitative implications of a range of commodity price policies for the size and distribution of research benefits under a range of market conditions (closed economy; small or large country importer or exporter). They found that omission of price policies when calculating the benefits of research might lead to either an over- or understatement of research benefits and the rate of return. Oehmke (1988) estimates that ignoring price policies can lead to a sizable overinvestment in returns to research. However, de Gorter and Norton (1988) estimate small total effects on returns to research but potentially large distributional effects when price distortions are omitted.

Most research-evaluation studies have not adjusted for the excess burden of taxation on the measure of costs (primarily administrative costs associated with collecting taxes). Fox (1985) and Dalrymple (1990) illustrate how this omission can lead to an overestimate of the rate of return to research. Even allowing for this cost and for the potential negative effects of price distortion on calculated benefits, the estimated rates of return would still be high in most cases, pointing to some underinvestment in research. This underinvestment may be highest in developing countries. These countries tend to have a lower research intensity, as measured by the ratio of public agricultural research expenditures to the value of gross agricultural output. Alston and Pardey (1991) found that developing countries, in general, had research-intensity ratios of less than 0.5 percent compared to an average of 1.5 percent in more-developed countries.

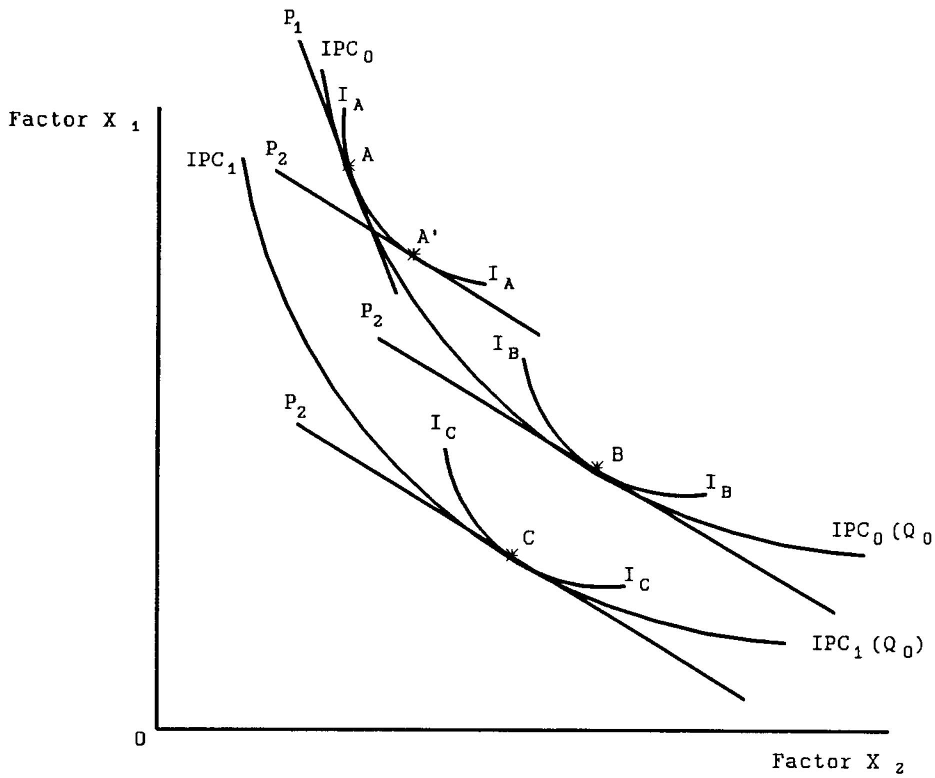
All previous studies of rates of return to agricultural research have treated food policies as exogenous to research funding and agricultural productivity. Any effects of food policies on rates of return were due to inefficient allocation of resources. Thus, we do not know if these policies have contributed to the research underinvestment. The fact that developing countries tend to discriminate against agriculture and also spend a relatively small amount on agricultural research is suggestive but little more.

Determinants of the Level and Direction of Agricultural Research Investment

The theory of induced innovation, first elaborated by Hicks (1932) and later applied to agriculture by Hayami and Ruttan (1970, 1985), suggests that market signals of abundance and scarcity of factors of production and of products are likely to induce the creation and adoption of technologies that favor particular factors and products. An example of the effects of changes in relative factor prices is illustrated in Figure 2. The output produced initially is Q_0 and the curves in the figure are isoquants for this quantity. Isoquants I_A and I_B represent different technology choices from the initial available set defined by the innovation possibility curve IPC_0.[3] Assume the initial equilibrium is at point A with the factor price ratio P_1. Now suppose the factor price ratio changes to P_2, perhaps as a result of factor X_2 becoming more abundant relative to factor X_1. In the short run, farms could change their factor mix and move to point A′ while still using the same basic technologies. In the intermediate run, however, they would have an incentive to adopt the new technology choice I_B and move to B as this move would minimize total factor costs given the available set of technologies. In the long run, the price change could induce the development of new technology so that the farms could move to a lower-cost technology choice I_C at point C on a new IPC, such as IPC_1.

In summary, there are short-run and intermediate-run changes in factor use and technology choices that involve changes in the *demand* for factors and technologies. An empirical analysis of the effects of price policies on the demand for agricultural technologies is provided by Miller and Tolley (1989). In the long run, research investments can be induced to alter the available *supply* of technologies. It is these long-run effects that are of concern to us in this paper. There is little question that changes in relative factor prices cause farmers to alter their input mix or to change technologies within the existing set available to them. The question is the extent to which changes in relative prices affect the development of new technologies and, more specifically, how changes in relative prices that are

Figure 2. Induced changes in technology in response to a change in relative factor prices.



due to food policies, such as price supports, export taxes, and so on, affect technology development.

The above graphical example focused on expected changes due to shifts in relative factor prices. Shifts in relative output to input prices and in relative output to output prices can also induce changes in output mix and in adoption of new technologies that favor particular commodities and that increase agricultural productivity. It is also possible that these output to output price shifts might induce development of new technologies that favor particular commodities. Furthermore, as the price of agricultural products increases (or decreases) relative to the price of nonagricultural products, it is possible for the change to induce additional (or reduced) support for agricultural research. Binswanger (1974) tested the induced-innovation model for U.S. agriculture and one of his conclusions was that a rise in the value of output (due to greater output at a higher price) will increase the research budget and hence the rate of productivity growth.

There has been relatively little empirical work to analyze the effects of policy-induced price changes on development of new technologies. Alston and Pardey (1991) regressed agricultural research-intensity ratios on a series of economic variables, on regional and temporal intercept-dummy variables, and on nominal rates of protection.[4] They estimated their model for a small set of countries for which they had data on nominal protection rates from Krueger, Schiff, and Valdes (1988) and from Tyers and Anderson (1986). The purpose was to test for a positive relationship between price supports and public research support. They did not find this result however, but instead found a negative relationship. Their results, that run counter to theory, may have been due to poor-quality data, a limited number of observations, or questionable model specification. However, they also may be due to an incomplete theory. Alston and Pardey explain their results by noting that price policies may be symptoms of a set of underlying forces rather than a basic determinant of research funding.

If agricultural research were private so that private firms were responding to price signals and directly changing research budgets, then there would be reason to expect a direct causal relationship between price policies and research spending. Levels and directions of public research spending, however, are determined in a political-economic environment in which (a) governments may respond to a diverse set of interest groups, (b) all interest groups may not be weighted equally, and (c) research funding is not the only instrument available to achieve a set of objectives. Given a particular political-economic environment, price policies and public-sector research investments may be jointly determined in a process in which policy instruments are chosen to maximize a weighted sum (rather than a simple sum) of benefits to producers, consumers, and taxpayers (Gardner, 1988; Oehmke and Yao, 1990; de Gorter, Nielson, and Rausser, 1992). This public-choice explanation of research funding suggests that the differential political power of different interest groups may account for both price-distorting policies and research policies.

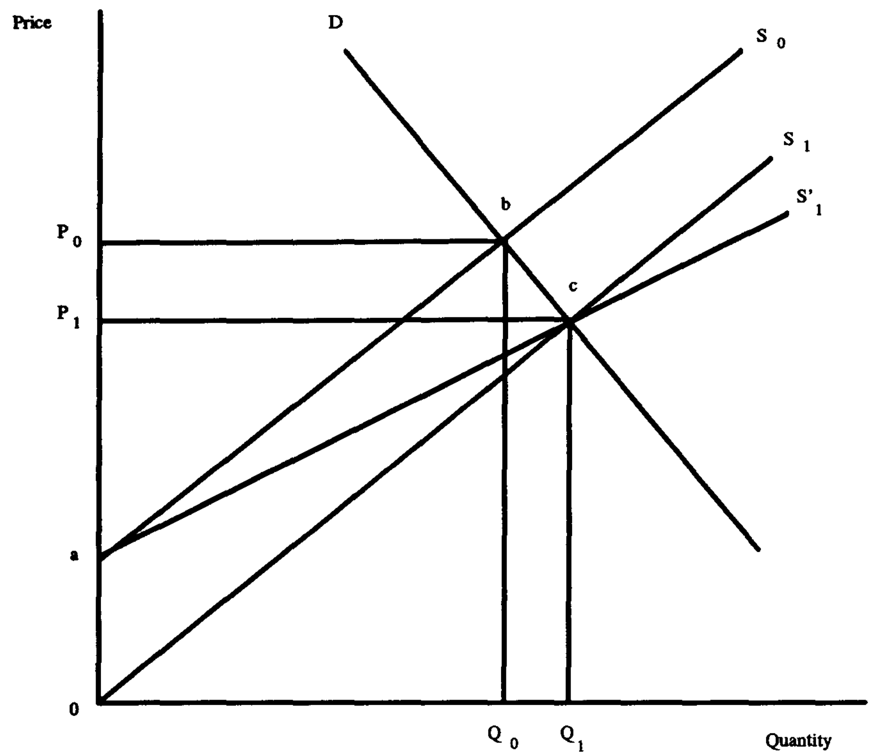
The results of political-economy models depend on the nature of the preference function that determines the government's response to the relationships between policies and welfare. These relationships depend on the functional forms of supply and demand functions, elasticities of supply and demand, the nature of the research-induced shift in the supply curve, and on the types of protectionist policies (Alston and Pardey, 1991). For example, a vertically-parallel shift in supply compared to a pivotal (divergent) shift almost doubles producer benefits from research (Figure 3). The more elastic the demand curve, the more research benefits accrue to producers rather than consumers, other things being equal. The more elastic the supply and demand schedules, the greater the output impact of a price subsidy and the less the price impact.

de Gorter, Nielson, and Rausser (1992) derive an expression that summarizes when producers benefit from changes in research expenditures (E):

$$\Pi_E \underset{<}{\geq} \text{ as } \frac{d(C_E)}{dQ}\frac{Q}{C_E}\left(\frac{\eta^s}{\eta^s - \eta^d}\right) \underset{>}{\leq} 1.$$

The change in producer profits with an increase in research expenditures ($\Pi_E > 0$) is positive when the expression is less than 1. The expression is the product of the elasticity of the marginal research-induced cost saving ($C_E = \partial C/\partial E$) with respect to output and the ratio of the supply elasticity to the difference between the supply elasticity and the absolute value of the demand elasticity. de Gorter, Nielson, and Rausser use the ratio of marginal to average cost to approximate the elasticity of the marginal research-induced cost

Figure 3. Research-induced supply shift. Research benefits (abc0) under a parallel supply shift are roughly double the benefits (abc) under a pivotal supply shift.



savings with respect to output. Basically, when this elasticity is greater than one, marginal cost falls more than average cost as research increases, resulting in a pivotal supply shift due to research. When the elasticity is equal to one, the supply shift is vertically parallel.

The above expression implies that, in most cases, producers will benefit from the agricultural research conducted in a particular country. The relevant demand is elastic for most products because they are internationally traded or potentially tradeable. Few countries trade sufficient amounts to have a major influence on price. Therefore, even if the supply shift is pivotal, producers will generally benefit. In addition, it is not unreasonable to assume that the supply shift is roughly parallel (Rose, 1980). Producers may lose from research that goes on elsewhere in the world as the demand for many food products for the world as a whole is inelastic, but they seldom lose from research programs that provide new technologies directly for them. Consumers also benefit from research that takes place elsewhere, but may receive limited economic benefits from their own country's research (except for nontradeable commodities) unless the benefits are distributed to them through price policies.

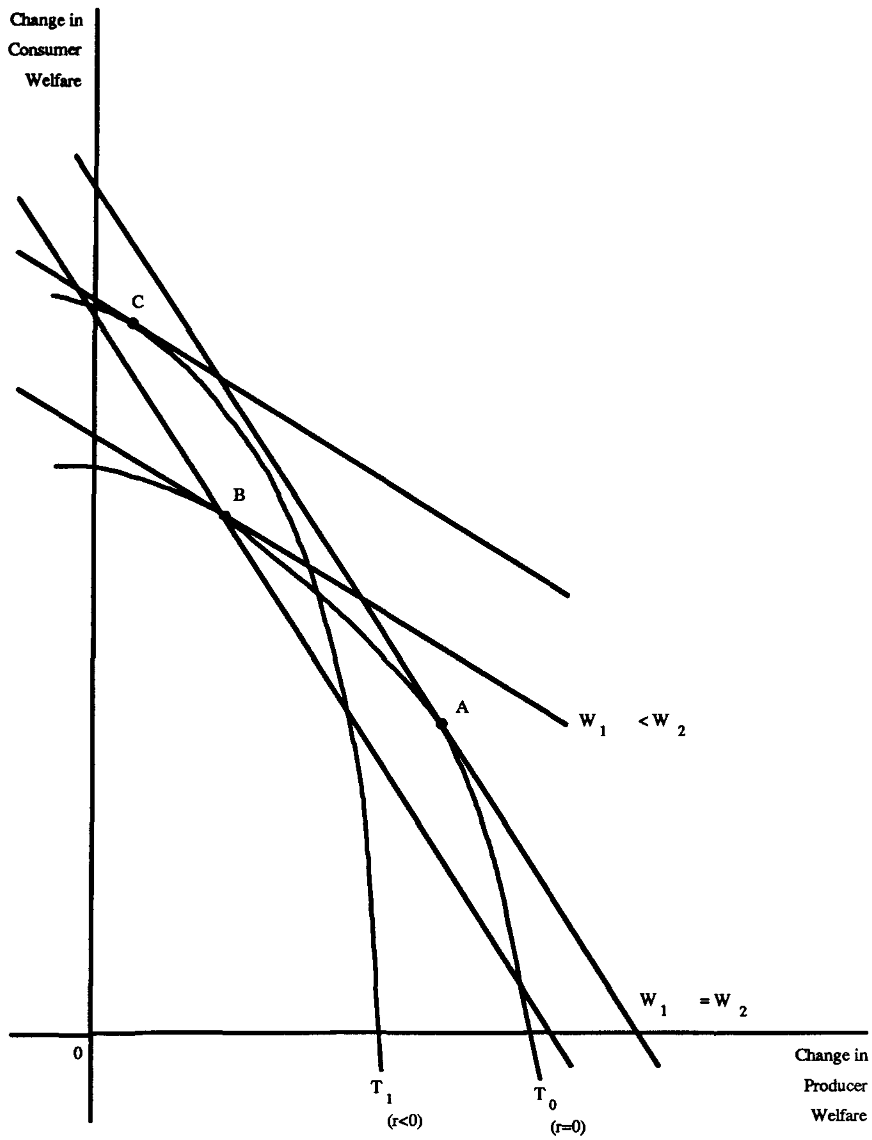
But price policies often do just that in developing countries, at least for key food commodities. Price ceilings are put in place to reduce prices to consumers and food is procured by government marketing agencies at below market prices. Exchange rates are overvalued to encourage imports to meet the extra demand. Producer benefits from research are reduced by such policies. Export crops are often directly taxed. These taxes generate revenues, reduce producer benefits from research, but have little effect on consumers. Therefore, while research in the absence of price policies tends to favor producers, these benefits tend to be reduced in developing countries by the price policies that are concurrently imposed. This reduction in benefits suggests that producer incentives to press for research funding may be reduced in those countries. However, the level of research funding may also be affected by the fact that producer and consumer weights in the government's objective function may not be equal. Also governments may try to use research investments to help offset losses to producers caused by price policies.

Gardner (1988) and de Gorter, Nielson, and Rausser (1992) present models that incorporate government objective functions and derive results that illustrate that the effects of price policies on incentives for funding agricultural research depend on the form of the objective function (specifically the weights on producer, consumer, and taxpayer benefits and costs), on market conditions (elasticities and trade status), the nature of the research-induced supply shift, and the nature of the price-policy instruments.[5] Curiously, they draw conclusions for agricultural research funding based on a choice of market conditions that are implausible for most commodities. Hence the relevance of the conclusions that they draw from their specific examples are limited. However, their analytical approaches are potentially useful to CRSP scientists interested in examining the influence of food policies on development on new technologies.

A review of the mathematical derivations in Gardner and in de Gorter, Nielson, and Rausser is beyond the scope of this paper, but Figure 4 provides a graphical illustration of the significance of unequal welfare weights on producers and consumers when combined with the existence of both research and price-policy instruments. The transformation frontier T_0 ($r = 0$) describes the change in producer and consumer welfare generated by the optimal level of research under various weights on producer welfare (W_1) and consumer welfare (W_2) in the absence of a consumer price subsidy ($r < 0$) or tax ($r > 0$) policy. The graph assumes that market conditions and the research-induced supply shift are such that both producers and consumers benefit from research. Hence, the transformation frontier lies in the northeast quadrant. If producers and consumers have equal welfare weights ($W_1 = W_2$), the change in total net economic surplus is maximized at point A.

If consumers are favored politically but governments are not allowed to use consumer subsidies, the outcome would be at point B and underinvestment in research would result if measured by an unweighted rate of return analysis. The movement to point B could be accomplished by choosing a different mix of commodities or types of research. Introducing the possibility of a consumer subsidy would allow the country to move to point C on a new transformation frontier T_1, ($r < 0$). With both policy instruments available, the country could increase its research benefits (as measured by an unweighted rate of return analysis) compared to point B. However, because of deadweight losses from consumer subsi-

Figure 4. Political equilibrium with research and consumer subsidies.



dies, point A would continue to represent an efficiency improvement over point C.

The above analysis illustrates the fundamental point that in a world of political interest groups, it may be the unequal welfare weights attached to those groups rather than price policies that accounts for the measured underinvestment in agricultural research. In fact, cheap-food policies may be reducing the underinvestment rather than increasing it. Another factor also may come into play for commodities that are exported in the presence of export taxes. These tax revenues, which may come at a lower opportunity cost than other sources of government revenue, may provide revenues both to meet distributional objectives and to fund research.

In summary, previous theoretical and empirical studies are ambiguous about the relationship between price distortions and research investments. While the induced-innovation model predicts that negative price distortions for agricultural products will discourage research, the political-economy model illustrates that the negative protection and low research funding may both be due to more fundamental underlying causes related to welfare weights on interest groups and to market situations. Previous studies show conflicting theoretical results because economists disagree over the nature of the research-induced supply shift, trade status, and elasticities of supply and demand. All these factors influence producers' benefits from research. Theoretical results also vary with the form of the tradeoff assumed among interest groups. Finally, as Alston and Pardey (1991) point out, complications arise when allowance is made for other objectives of government such as food security and environmental protection.

Implications for CRSP Social Scientists

What are the implications for the research agenda of CRSP social scientists? Two fundamental decisions must be made by or for CRSP social scientists. The first decision is whether to devote part of the CRSP social science research agenda to work on improving our understanding of the influence of food policies on the development of the new technologies. The second is how to conduct the research if the first issue it resolved in the affirmative.

The first decision should hinge on (1) the relative importance of the topic compared to other topics that CRSP social scientists might tackle, and (2) the comparative advantage of CRSP social scientists compared to other researchers in addressing the topic. The CRSP social science research agenda to date has been directed at increasing our understanding of the social environments that influence CRSP commodities in order to help improve the design and testing of new technologies or programs. Relatively little effort has been devoted to the political and more macro-economic "food policy" environments that also influence the development of new technologies and the benefits of agricultural research. Clearly the food-policy environment can influence the social and economic benefits of research. This paper has illustrated the need to understand both political (i.e., weights placed on different interest groups) and economic (i.e., market situations that affect the potential beneficiaries of research) forces if research system directors, donors, or others are to interact meaningfully in the policy-making process. There is little question, for example, that negative producer-price distortions generally discourage technology adoption. But it is less clear whether negative protection reduces government support for research. While it is difficult to say how much effort should be devoted to improving our understanding of the influence of food policies on technology development, the issue would seem important.

CRSP social scientists represent several disciplines including sociology, anthropology, and economics. At a minimum, economists and political scientists would have key roles to play in extending the CRSP social science agenda to the topic discussed in this paper. The complexity of the topic would require scientists interested in mixing interdisciplinary problem-solving research with disciplinary research. CRSP social scientists, to the extent that they have existed in CRSPs, have typically emphasized a problem-solving orientation more heavily than a disciplinary orientation. Whether the nature of a CRSP will allow for a different balance may determine the comparative advantage of CRSP social scientists on this topic.

Assuming that a decision is made to focus part of the CRSP research agenda on examining the impacts of food policies on the development of new technologies, the second decision that has to be made is how to conduct the research. The following suggestions are offered for consideration. First, the need for a political-economy approach means that researchers must identify the relevant interest groups for the CRSP commodity (or other CRSP focus). Second, particular policies influencing the nature and level of protection must be identified and the degree of positive or negative protection calculated. Third, information is needed on research support to the commodity and to different types of technologies. Fourth, information is needed on key economic or market variables. Finally, theoretical and empirical models, perhaps along the lines of Gardner (1988), of de Gorter, Nielson, and Rausser (1992), and of Alston and Pardey (1991) could be developed. Although Alston and Pardey had little success with their regression analysis, it is possible that a recursively structured model focused on an individual commodity (or set of commodities) would provide useful insights. Their model for aggregate agriculture for several countries may have obscured the offsetting effects of different policies on individual commodities.

The type of political-economy research proposed here is not simple. For many countries, the data may not be adequate for substantive empirical analysis. Nevertheless, CRSP social scientists can potentially improve our understanding of the interactions between pricing and research policies and thereby help research directors argue for research budgets and set research priorities and help donors understand the linkages among the various policies affecting agriculture.

Notes

1. The primary simplification is the more approximate manner in which exchange rate distortions are handled.

2. Norton, Pardey, and Alston (Forthcoming) provide a description of methods for evaluating the benefits of agricultural research.

3. This graphical representation is based on Hayami and Ruttan (1985:91).

4. These economic variables included agricultural income, per capita income, agricultural exports as a share of total income, agricultural exports as a share of agricultural output, and public spending

on agriculture as a share of agricultural output.

5. Oehmke and Yao (1990) suggest a means for approximating the weights in the government objective function and provide an example for wheat in the United States. Alston and Pardey (1991) provide a qualitative model for deducing these weights.

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Session 5

Increasing Productivity and Sustaining Natural Resources

- Sustainability: The Challenge for International Agricultural Research
- Using Local-Level Knowledge to Improve Agriculture and Natural Resource Management

Session Chair: Jere Lee Gilles

Speakers: John K. Lynam
Billie R. DeWalt

Sustainability: The Challenges for International Agricultural Research

John K. Lynam

Agriculture's contribution to sustainable development in the Third World dictates the use of the land resources which, in turn, determines much of the quality and quantity of the water resources as well. Apart from the small amount of land devoted to urban settlement, crop and livestock activities dominate the landscape. However, with an increasing demand for agricultural products, these activities compete strongly with other claimants for land use, particularly forests and other natural ecosystems. The sustainability agenda in agriculture thus revolves around the problem of how to preserve and enhance the natural capital embodied in land and water resources. This agenda has two dominant features. The first is how to ensure that increased cropping intensity and increased productivity do not deteriorate the quality of the land and water resource base. The second is to ensure that adequate safeguards are put in place to preserve some of the natural plant and animal communities at a time when demand for agricultural products is still increasing and managers of those land resources are seeking increased incomes. The first issue deals with the design of technology; the second, with the social institutions that regulate access and use of natural ecosystems.

Challenge 1: Making Sustainable Agriculture Compatible with Economic Growth

In economic history and development theory, a dynamic agricultural sector has been seen as an initial determinant of economic growth (Mellor and Johnston, 1984). The agricultural sector, especially during early stages of development, supplies the labor (including financing the education of many urban migrants) and a significant part of the savings and marketable food surpluses at declining prices. It also provides the demand for agricultural inputs and cheap manufactures that comes from the incipient industrial sector. This scenario has characterized the growth patterns of much of East and Southeast Asia and Latin America and forms the basis for much of Africa's future economic growth. Underlying such structural transformation is the evolution of agricultural systems from diversified subsistence producers to systems that are increasingly integrated (i.e., increasingly specialized and dependent on external inputs) into the market. Underlying agricultural systems that are increasingly extractive is a rising percentage of agricultural production that must leave the farm as the economy industrializes. Commercialization and increased population, then, can put added pressure on the land resource base. Sustainable development now requires that mechanisms are put in place to ensure sufficient investment in the natural resource stock so that its quality does not deteriorate.

Rapid population growth within largely subsistence-oriented agrarian economies (as in much of Africa and where lack of growth in the secondary and tertiary sectors limits migration) can lead to degradation of land and water resources (Clay and Lewis, 1990; Overseas Development

Group, 1991). Under these conditions, to meet short-term food security needs society may have to accept some long-term costs such as loss of soil nutrients and erosion of the land resource base. This is a very difficult problem to solve, especially if improved management of farmer-owned resources is solely relied on. In general, resolution must eventually rely on access to income- generating activities, either within the farm or, more often, external to the farm. Commercialization, and the associated improvement both in financial intermediation and market integration, introduces more options or flexibility to ensure reinvestment in the natural resource base, but it does not guarantee such investment. Initial reactions to new commercial opportunities often result in a short-term mining of soil capital (Fresco, 1986), but the accumulation of financial capital and the development of input markets may then allow, with some lag, the investment in the techniques needed to maintain soil fertility. Binswanger and von Braun (1991) posit major complimentarities between commercialization and adoption of new technologies, both in the cash crop and in the associated subsistence crops. However, Byerlee (1992) shows a major lag in the small-farm, rainfed systems of Africa between the adoption of improved maize varieties and the associated adoption of fertilizer. This is confirmed more generally by the work of Stoorvogel and Smaling (1990), who show alarming rates of nutrient depletion across Africa.

Under a dynamic-growth scenario, the sustainability question then shifts to whether the high-external-input model leads to declines in quality of the soil resource base. The division of labor and the economies of scale (although usually external to the farm) that arise from increasing integration into the market economy often lead to a loss of diversity in the farming system and increasing dependence on external inputs.[1] The farming system reorganization imposed by market integration runs counter to many of the attributes of sustainable agricultural systems embodied in LEISA (low-external-input sustainable agriculture). This reorganization certainly seemed to be responsible for China's remarkable agricultural growth in the 1980s, as the country became the largest user of inorganic fertilizers in the world. However, Xu, Chunru, and Taylor (1992) show that a hybrid model combining modern external inputs and China's traditional organic practices is not only possible but more productive and profitable. This hybridization appears to be necessary for productivity growth in Africa. Boserupian intensification involving crop residue recycling, agroforestry, and legumes must be combined with efficient fertilizer use. Moreover, farmers, in shifting to cash crops, tend to maintain a subsistence food component—due to high transactions costs in the market—and therefore can exploit crop diversity (von Braun, de Haen, and Blanken, 1991). The main point is that there is no single model for sustainable exploitation of the land resource base; it is conditional on changing relationships of the farmer to the market.

Commercialization and technological change within agriculture are dynamic as well as uneven processes, which introduces a potential link between equity and sustainability considerations. As indicated above, developing sustainable land-use practices is most difficult where poverty arising from marginal agricultural conditions, lack of market opportunities, and population pressure is widespread. This situation can apply to whole countries, such as Haiti, Rwanda, or Burundi, but is more of a product of regional disparities within a country, such as the Brazilian northeast, the Peruvian sierra, or the East African semi-arid zones. Technological change and commercialization can reinforce and widen these regional disparities through the agricultural treadmill (Binswanger and von Braun, 1991); this situation is only partially resolved through migration. The agricultural sustainability problem is, therefore, usually diverse and spatially patterned within Third World countries and arises from both agroclimatic as well as market phenomenon. Research and policy interventions to address these problems must reflect this diversity.

One further distinction is useful to further discriminate the sustainability research agenda and to draw links to the agricultural development process. This distinction may be referred to as "agricultural sustainability at the intensive frontier" versus "agricultural sustainability at the extensive frontier." The former focuses on preserving or enhancing the land and water resource base as farmers search for increasing levels of productivity. The problem is now most apparent in the Asian irrigated sector. There is mounting evidence that increasing inputs, especially fertilizer, are needed just to maintain yield levels (Pingali, 1991) or, rather, to avert a decline in yields. The problem is compounded by an increasing rate of salinization in irrigated lands. Additionally, greater dependence on high inputs and high costs increases the risk and, therefore, the tendency to use risk-reducing inputs such as pesticides. This trend was very clear in Southeast Asia and is only recently being reversed by a major FAO/IPM program in the rice sector. Intensification through crop shifts, most notably to horticulture, also exacerbates the pesticide problem. Finally, in Africa, needed increases in food production must come through improved crop yields. As stressed above, improved husbandry of the soil resource is essential to achieve such yield gains. At the intensive margin, meeting the sustainability challenge is absolutely critical to meeting the world's food needs in the next millennium.

On the other hand, a far different sustainability agenda has emerged at the extensive margin or agricultural frontier. The focus here is on converting natural ecosystems, such as tropical forest, savannah, or wetlands, to arable agricultural systems. Moreover, the property relations are much more diverse in such situations; land is held in gazetted reserves as state property or as common property. These natural ecosystems have not been converted to arable agricultural systems either because the transport infrastructure is limited. For example, the tropical forests in the Amazon basin have been too costly to develop and the wetlands have a soil or climate that is too marginal for agricultural purposes. Transport infrastructure development; population growth; and growing land intensification, credit policies, or demand for fuel or forage may increase the exploitation of these resources or their conversion to pasture or cropping activities. Key public policy issues focus on the social value of these natural land-use systems, the degree they differ from the private benefits derived from exploitation or conversion, and the way these social values might be better reflected in land-use decisions (Ehui and Hertel, 1989). The issue of valuation is complex because land-use change is permanent, particularly for tropical forests and wetlands. An even more perplexing issue deals with the different values of the land-use systems at different levels of development (i.e., whether there is an income effect in the demand for natural ecosystems) (Antle and Heidebrink, 1991) and, further, whether national social valuation differs from international social valuation, given the international externalities now evident in global warming and climate change.

Global warming, loss of genetic diversity, and concerns over local and regional water cycles are sustainability issues surrounding the expansion of the agricultural frontier, where migrants convert rain forest, savannah, or semi-arid bush into cropland. Nevertheless, these areas account for little of the food that is produced in the agricultural economy. This lack of coincidence between this component of the sustainability agenda and food production raises important questions about the amount of research and development resources that should be shifted into conservation and natural ecosystem activities. The issue is further complicated by the debate on the types of interventions that will stabilize expansion of the agricultural frontier. The first argument posits that major expansion at the intensive frontier—increased productivity in existing agricultural areas—will both relieve the pressure to migrate and diminish the profitability of agriculture at the extensive margin. Second, many international agricultural research centers (IARCs) argue that technological change at the extensive margin will stabilize farming systems and replace current shifting agricultural systems. The technology challenge in such areas is difficult because transport costs make inputs expensive and a short labor supply makes the cost of labor relatively expensive; yet stabilizing farming systems requires improved nutrient flows and reduced weed growth in crop production. However, a counter-argument can be made that increased profitability of agriculture at the extensive margin with new technology will cause the agricultural frontier to shift even faster. A final argument suggests that reducing deforestation will require changes in land tenure and rules of access to such lands, as well as methods of economic exploitation that still maintain the integrity of the natural ecosystem. These three hypotheses are not necessarily inconsistent, but each implies a very different commitment of research resources.

Challenge 2: Sustainability as an Organizing Framework for Agricultural Research

Commodity programs have provided the logical framework for organizing agricultural research in both the IARCs and the national agricultural research systems (NARS) over the past three decades. These multidisciplinary commodity teams have proven to be quite successful in generating scientific results and appropriate agricultural technology. The organizational paradigm was so strong after the success of the IRRI rice and CIMMYT wheat programs that newer IARCs formed with very explicit agroecological mandates (such as CIAT, IITA, ICRISAT, and ICARDA) and organized most of their research around commodities important within the target zone. The reasons for the success of this model are multiple. First, varietal improvement provided a central focus around which to organize a number of disciplines into a functional team that could develop an integrated research strategy. Second, the research program could easily incorporate postharvest research and market development strategies in what could be called a subsector approach (Lynam and Janssen, 1992). Third, given the focus on economic yield, there was a clear correspondence between farmer and researcher evaluation criteria. Fourth, research priority setting along commodity lines could be easily linked to pricing and marketing policy formulation, which is also developed along commodity lines (Lynam, Janssen, and Sanint, 1989). Fifth, recent developments in plant biotechnology have served to reinforce the central role of varietal improvement within overall management of the cropping system and, to be effective, has required strong links to plant breeding programs. Finally, commodity research programs could accommodate a spectrum of basic, applied and adaptive research, all strategically focused on technology generation. The longer established commodity programs have been able to extend further "upstream" into biotechnology and further "downstream" into crop management research, allowing interaction between basic and adaptive research in the technology design process.

The weakness of the commodity approach is that IARCs have found it difficult to extend the basic and applied research from the cropping system to include other elements of the farming system or the natural resource base. Some examples include IRRI's inability to deal with irrigation management; most centers, although recognizing the importance, could not systematically handle soil management research, especially soil erosion; and, the linkages to animal agriculture were problematic. The agroecological centers struggled with farming systems research programs (applied research programs as distinct from the much more successful adaptive research programs) that would link the commodity research to other major structural features of the farming system. CIAT abolished its farming systems program completely, while IITA, ICRISAT, and ICARDA continued to tinker with the organization of their programs. Unlike the cropping or commodity system, the IARCs found it difficult to organize basic or applied research around the farming system. One problem was defining exactly which farming systems would be researched (particularly a problem at CIAT), and the other problem was that systems research methodologies were not well developed. Thus, more narrowly defined research problems were lumped together under these farming systems research programs and included such elements as vertisol management, improvements in oxen-drawn equipment, alley cropping, and water harvesting. Adaptive farming systems research was also a made part of these programs and, in many cases (such as at IITA and ICARDA), most of the social science research was placed in these programs as well. Probably the only example of a research program organized within a farming systems framework was CIAT's tropical pasture program, which integrated pasture development and livestock performance within the framework of ranching systems in the Latin America savannah. In this program, the target farming system could be defined in significant detail, and the research could be organized around that structure.

CGIAR, over the last few years, has been struggling with the problem of how to accommodate sustainability issues within its research programs. The problem has two components: first, defining the expansion of research areas to accommodate the principal sustainability issues, and second, organizing that research at the system level, the center level, and at the level of individual research programs. CGIAR's expanded research program to accommodate sustainability has emphasized research on natural resource management (NRM)(TAC/CGIAR, 1991). The number of centers in the system have been expanded to include those working on various aspects of NRM. These include ICRAF and CIFAD, which focus on land management systems involving forestry, and IIMI and ICLARM, which focus on water resource and fisheries management. In the process, the concept of global mandates for research on commodities has been extended to global mandates for different areas of NRM. This definition of global mandates was never applied to the research within the farming systems programs. Surprisingly, not one center has been created for global research on soils management, which is probably the most important sustainability challenge facing Third World tropical agriculture. The argument here is that soils research underlies the research already performed by most of the centers. Strategic and applied research that cuts across programs in a number of centers can be organized as collaborative research. However, intercenter research planning has not worked for commodity research where there have been multicenter efforts as, for example, in rice, maize, and cassava. Nor has it been easy to accomplish in emergent research areas such as geographical information systems. Thus, there is a rationale for assigning different aspects of NRM as global mandates to individual centers.

Yet, the soils area encapsulates the organizational challenges facing sustainability research in three ways. First, the research agenda has been the provenance of one discipline, soil science, and yet the disciplinary boundary has been too restrictive to deal with the underlying problems of soil management (as is also the case with forestry). Second, strategic research in this area requires a finer focus, which has led to an explosion in the number of organizations working on different dimensions of the soil management problem. Thus, IFDC deals with fertilizer, TSBF with organic matter management, NIFTAL with biological nitrogen fixation, ISRIC with soil pedology, and ICRAF with nutrient cycling under agroforestry. Other aspects such as vertisols, management of acid soils, and soil erosion are found in a number of other research organizations. Third, given this institutional proliferation in strategic research, how are these components integrated at the applied and adaptive research levels? The concept of integrated soil or nutrient management has been bandied about, but there is not one good example of its application within an applied or adaptive research program. Particularly at the farm level, a farmer's soil management depends on such factors as topography, soil type, climate, cropping systems, farming system integration of ruminants, fertilizer availability and prices, and tillage methods; this is by no means a complete list. The question, however, is how are applied and adaptive research programs organized to bring the multiplicity of strategic research elements together to bear on particular farmers' soil management problems? CGIAR has adopted another organizational innovation to deal with this set of problems, the ecoregional mechanism.

CGIAR recognizes that applied research on natural resource management and the integration of NRM with commodity research will have to adopt a more decentralized approach than the global centers. In many ways, the ecoregional mechanism is another attempt to incorporate higher system levels into the organization of research. Not only are the subsystems inherent in the NRM complex (such as soils, hydrology, or forestry), but they have to be embedded in the farming system or, a concept which is seen more often in relation to NRM, in the land-use system. System diversity is, in turn, dealt with by decentralizing the *ecoregions*, that is, the agroecological zones defined within a contiguous geographical area (McCalla, 1991). There is a significant overlap in this idea with the agroecological mandate of many of the IARCs. In practice, agroecology is a key parameter in organizing crop improvement programs, since it combines the soil and climatic, as well as many of the insect and disease, constraints on crop productivity. The concept only partially aids in organizing natural resource management research, in that it differentiates natural plant ecologies and, thus, helps organize forestry or agroforestry research or pasture/forage research. The key question of how soil and water resources are managed, however, is essentially determined by the farming system, soil type, and terrain variables. Thus, centers define their agroecologies in terms of a combination of climatic or vegetation zones, land-use systems, and production systems. Unlike crop ecologies, such definitions do not give an idea of the principal constraints on the sustainable management of soil and water resources. There is an implicit assumption in the ecoregional concept that a correspondence between agroecology and a set of principal farming systems exists. Thus, for example, agroecology defines the type of animal production system in Africa, the focus of ILCA's research. Agroecology defines many of the principal disease constraints, the availability of forage resources, the adaptation of improved breeds, and the grazing systems by which those forage resources are exploited. This overlay of agroecology and the animal production system allows a framework for constraint identification, priority setting, and structuring of research programs. This correspondence between agroecology and the production system is not as well defined for other centers.

The ecoregional mechanism sets research priorities within contiguous agroclimatic zones. A principal research focus is NRM, but since NRM is usually a function of crop and livestock management, the main thrust is to integrate the two research areas. In addition, the mechanism is designed to coordinate collaborative research and training activities with NARS (TAC/CGIAR, 1991). Given these functions, there is a current question of what organizational form this ecoregional mechanism will assume. The dominant approach, to date, is the ecoregional center in which an IARC assumes responsibility for organizing research in a particular ecoregion. All centers with agroecological mandates are reorganizing along such lines; some global commodity responsibilities are retained while others are reduced. Even global commodity centers such as IRRI and CIP are defining research activities within the ecoregional structure. The second approach is a consortium model, in which different IARCs collaborate around an agreed-upon ecoregional plan but with no one center assuming the overall coordinating function. Such an idea is currently being discussed for the East African highlands ecoregion. A final alternative would to be to house such a planning and coordinating role within existing regional institutes such as SACCAR in Southern Africa and CATIE in Central America. However, to date, this last model has not been discussed and is somewhat more radical because it shares decision-making with these regional organizations.

The transformation of IARCs with an agroclimatic mandate into ecoregional centers raises the issue of what changes in the research program during the process. The main shift is that the farming systems research programs are being recast as natural resource management programs. Most critically, however, NRM leads in the organization of the overall research program rather than the commodity programs. That is, priorities are set first by natural resource criteria. Applied research in the commodity programs is organized around the NRM framework and the global responsibilities are met by scaling back and focusing on more basic research, usually in the biotechnology and germ plasm maintenance areas. CIAT, a leading example of this trend, introduced sustainability as a dominant objective in how it sets research priorities for Latin American agriculture in its last strategic plan. The plan significantly scales back the four traditional commodity programs to germ plasm activities and creates four major programs in resource management. These four resource management programs were developed on the basis of a priority assessment across land-use systems/ecologies, particularly taking into account the social costs of resource degradation problems. The resulting target ecologies are the savannahs, hillside agriculture, and forest margins, as well as a land-use policy and characterization program. The organizational logic is to structure resource management research around ecologies and then link this research to crop research within each ecology. This particular hierarchy in organization, however, results in major shifts in the priorities of the rice and cassava programs, some shifts in the bean program, and little change in the tropical pasture program.[2] This organizational structure shifts the focus outside the large-farm and small-farm commercial areas, as well as the small-farm population in the semiarid areas, and onto the agricultural frontier and small-farm agriculture in sloping lands. Recognizing that centers such as CIAT have multiattribute objective functions, the weighting given to agricultural production (as well as to food prices and consumption by the urban poor) has been reduced compared to that given to sustainable resource management. CIAT would argue that this is where the comparative advantage of an IARC in Latin America is presently, especially given the relative strength of NARS. ICARDA sets its priorities in much the same hierarchial pattern and, yet, by focusing on crop and resource management in the more marginal areas of the Middle East and North Africa, ICARDA can have direct impact on less than 10 percent of the region's food production (Michael Collinson, personal communication).

In Africa, the locus of productivity and sustainability issues more closely coincide. In most of Africa, except for the Zaire basin, rapid population growth over the last 40 years has closed the agricultural frontier. The central issue is how to get sustainable increases in productivity, while recognizing the purchasing power constraints on agrochemicals and the increased demands that are being placed on the underlying soil resources from rapidly increasing population and expanding commercialization. The focus under such conditions has been on managing soil resources through efficient nutrient use, increased cycling of nutrients within the agroecosystem (e.g., alley cropping), and better conservation of the physical structure. IITA, like CIAT, has until just recently separated research into two basic divisions: crop improvement and resource management. Because ecologies are defined in very broad bands in West and Central Africa, IITA has been able to set priorities from a matrix of the seven crops in its research portfolio and the four ecologies it defines (IITA, 1988). IITA can quite easily combine crop and resource management research priorities. However, what it has failed to achieve is an effective mechanism for integrating the commodity improvement research with the resource management research and even a means of integrating its commodity improvement work with the very successful biological control research. The latter has led to the creation of a third division called "plant health."

The current planning of research within the ecoregional framework has led the IARCs to confront a number of organizational issues that permeate research on agricultural sustainability as a whole. Only four of these issues will be outlined here:

structuring NRM research programs, integrating NRM and commodity research, rationalizing coordination costs in NRM research, and linking IARC and NARS research in NRM. The IARCs have had to move away from commodity systems as the basis for organizing research in order to address sustainability, but the process of defining an alternative organizational logic to accommodate NRM research is still in an experimental phase.

Given the experience of CIAT and IITA, IARCs are searching for a structure around which to organize NRM research. CIAT has used the land-use systems' concept (the other dominant framework is ecological zones) to create at least one of its NRM programs (the hillside program), the SANREM CRSP has used it to organize a program called "agroecological landscape," and ICRAF has used it to diagnosis and design activities. FAO works with a land-utilization typology in their framework for land evaluation (FAO, 1990). The advantages of this conceptualization are that it integrates the production or farming system more systematically into the management of the underlying resource base; it allows for interaction between farming systems across a landscape, watershed, or ecological variation; it broadens competition for land beyond agricultural uses; and it introduces variability in the landscape as an explicit variable. There is much value in such an integrative framework, but there are also problems. First, the concept leads the analysis very quickly into land-use planning, which has very little practical use in rural sectors of developing countries. Second, the variability inherent in a concept such as a land-use system allows little scope for discriminating dominant land-use types within the research target area, diagnosing and prioritizing research problems, and targeting technology. These problems have led most NRM programs to organize research around benchmark research sites, where strategic, applied, and adaptive research are combined around the particular structural features of the site. This approach needs to address the challenge of the extent to which research results can be extrapolated and whether, in studying a site so intensively, research leads to the development of niche technologies with little application outside the site. Finally, farmers do not make decisions in terms of optimizing a land-use system. How to obtain better correspondence between farmer decision-making and NRM research remains a challenge for social scientists. This challenge includes the issues of integrating decision-making at the crop management and farming systems level with the management of the resource base and, even more difficult, joint decision-making to exploit benefits or reduce externalities across the landscape.

In planning and organizing their research, the ecoregional centers have created separate programs for commodity/germ plasm research and NRM research. Commodity programs are being scaled back to germ plasm and breeding functions to accommodate expanded NRM programs and to foster better integration with the NRM programs. Pure breeding programs are relatively ineffective and need to be structured within a broader systems structure. The question is, what will substitute for the commodity system and at the same time integrate with NRM research? The experience, as outlined above, suggests that this integration will take place either in benchmark research sites (which is very constraining for a breeding program) or in adaptive research programs. In the latter guise, sustainability is cast as a reformulation of farming systems research with much more focus on integrating soil and water management interventions with the cropping system adaptations. Nevertheless, a salient characteristic of sustainable systems is the exploitation of complementarity in the interaction of diverse germ plasm, crop management, and resource management components. This concept is expressed in such evolving paradigms as integrated pest management, integrated soils management, and low-external-input sustainable agriculture (LEISA). Neither IARCs nor any other institution have been able to organize their strategic and applied research around such an integrated systems framework. LEISA probably remains the largest challenge of all in this respect. Doing applied research where component interactions are critical to technology design will require the techniques and methodologies of systems research. Agricultural research, apart from biotechnology, has still not moved much beyond factorial trials. Although there has been significant progress in computer-based modeling of biological systems, it has not been well integrated with experimental research to exploit its true potential. If the bridge between crop improvement and NRM research is to be achieved at the adaptive research stage, then the issue of coordination needs to be considered.

Truly interdisciplinary research programs will generally involve between five and fifteen scientists. Research programs larger than this will tend to break into subprograms of manageable size. On the other hand, once research program lines are defined within an institution, achieving across-program integration on common research problems is usually difficult. The problem is much greater if the scientists are cooperating across different institutions. Yet, the sustainability problem structure demands such collaboration between crop and NRM programs, sometimes within the same institution, but often between different institutions. The ecoregional mechanism engenders the idea that the center integrate applied and adaptive research on all important crops in the ecoregion with research on the principal NRM problems. No ecoregional center works on all the important crops in their ecoregion, which implies that mechanisms will have to be worked out for research cooperation between centers. It is telling that none of the ecoregional centers has really addressed this issue, and the East African consortium is struggling with it. The SANREM CRSP relies heavily on such interinstitutional cooperation in its research plan. The main factor underlying the problem is that cooperation entails both financial and personnel costs that are usually not budgeted within the research program. Moreover, joint planning, allocation of responsibilities, and apportionment of costs in benchmark research sites raise questions of where and how incentives and rewards are determined between the cooperating institutions. One of the real tests of conducting sustainability research will be the flexibility different institutions bring to research cooperation, especially given the past history of collaboration between the IARCs.

Probably the most critical issues that underlie the restructuring of research to address sustainability are the implications for the NARS and the relationship between the NARS and IARCs. The NARS have largely adopted the commodity program model but have overlaid it on a network of stations distributed across the agroecological variation in the country. To a substantive degree, the IARC strategy for strengthening national programs has been to replicate IARC programs within the NARS. The development of varietal pipelines, in essence, required this. The question then, is whether the same model is followed for NRM programs, especially at a point when most NARS already face major resource constraints and donors are recommending cutting back the number of research programs to those that can be effectively operated within budget constraints. This is an especially critical issue for those IARCs focusing on research problems at the extensive margin. One strategy is to adopt a division of labor between the NARS and the IARCs, whereby the NARS concentrate their resources on commodity research and the IARCs shift their relative focus to NRM. The danger here (and also in the biotechnology area) is that the IARCs will lose their mission for strengthening national programs, a mission in which real progress has been made only in the last decade. The IARCs could focus on the integration of NRM and commodity research in their training and networking activities, but this will require attention to NARS research priorities. Alternatively, the IARCs could focus on a selective strengthening of NRM capacity in stronger NARS, organized mainly around benchmark sites. Nevertheless, these sites have not been selected with that consideration in mind. In sum, in restructuring many of its research programs, CGIAR faces a real challenge in how it will also restructure its cooperative links with NARS.

Challenge 3: Sustainability and Technology Adoption

Crop research has been successful when there has been a direct correspondence between researchers' objectives and evaluation criteria and farmers' objectives and evaluation criteria. Crop improvement focuses on yield increases moderated by risk and consumer quality considerations. Economists have often cautioned biological scientists that yield maximization does not necessarily imply profit or income maximization but, more importantly, farmers and researchers can both make decisions based on the production frontier, even though they may choose different points at which to operate. The closer that breeder objectives are to farmer objectives, the closer researchers are to producing adoptable technologies—which has implications for level of decentralization and stratification of the breeding program. This process has evolved to include farmers in the evaluation and selection processes of breeding programs (Ashby, 1987).

Agricultural researchers in the IARCs do not yet have clear correspondence between sustainability research and farmers' objectives and decision-making. This lack of correspondence occurs between farmers and researchers at various levels, from problem recognition (e.g., externalities in pesticide use or productivity impact of soil erosion), to research evaluation criteria, to relative priority assessment. This is partly a problem of how to achieve a better coincidence between social and private welfare assessment; partly a reflection of a disfunction between technical evaluation methodology and actual farmer decision-making; and partly, the farmer's sustainability or resource management strategies or objectives that are usually embedded in a set of higher level objectives. All three issues create potential for a dysfunction between research and the production of adoptable technology.

One factor separating the farmer from the researcher is the multidimensional nature of the resource management problem. Thus, improved soil management involves managing external nutrient flows into the system, managing the organic matter fraction, controlling soil erosion, selecting appropriate tillage systems, and managing soil toxicity problems (such as acidity and aluminum). Agricultural research breaks these down into research components, each with its own monitoring and evaluation criteria. Yet, the farmer is only interested in an improved management system for his soils and farming system. Research in resource management does not yet work in a unidimensional (and integrative) framework such as the yield dimension in crops research. As Stocking (1992) points out in the case of soil erosion in Africa, this leads to a top-down, technical-fix approach to the problem, with little integration of farmer management constraints.

Sustainability also adds a greatly expanded time dimension to agricultural research. This dimension expands beyond the annual cropping year that conditions much of the crop research as well as farmer planning. The time dimension introduces two major problems underlying technologies flowing from the sustainability research agenda. The first is farmers' time preferences and decision-making underlying an investment decision, where the return will not be captured for a significant time. Crop technologies rely on a yield response in the current cropping year and, therefore, have not had to address the issue. The second problem revolves around the costs and certainty of information in managing resource management technologies. The discrete time between the investment in improved resource management (e.g., agroforestry or bench terraces) and the impact on output and revenues requires that the farmer has information about the future benefits of the technology. Moreover, these technologies, such as agroforestry or improved organic matter management, require significant changes in the farmer's management of his or her farming system. Crop research tends to embody research "information" in the seed or the input, while sustainability research must translate the research information directly to the farmer in terms of improved management practices. In sum, three questions need to be answered: How much information does the researcher need about the performance of a technology over time to make a recommendation? How much information does the farmer need to adopt the technology? and, What is the cost of that information?

Better correspondence between farmer and researcher evaluation criteria in resource management research contributes to a higher probability of producing adoptable technology. Several issues need to be addressed in improving this correspondence. First, there is often little link between evaluation and modeling of biophysical processes and economic behavioral modeling. Antle and Capalbo (1991) describe these problems for the case of externalities in agricultural chemical use, and Pagiola (1990) analyzes these issues for soil erosion. The basic problem, again, is how to match evaluation criteria for the physical processes to decision criteria for farmers. Farmers do not make decisions on the basis of soil erosion rates but, rather, on the effect these rates have on crop productivity. The latter turns out to be a difficult relationship to establish.

The second component of this issue, how close these models approximate actual farmer decision-making, has two parts: whether the farmer understands the biophysical processes (i.e., whether he or she, in fact, perceives a problem), and whether the normative economic modeling actually predicts farmer decision-making and response. Only recently have researchers begun to understand farmers attitudes to a variety of issues (e.g., soil erosion, pesticide pollution, rangeland degradation, and forest depletion). The former part involves a question of how indigenous knowledge research and participatory research methods may be better linked to cognitive and theoretical approaches to get at these issues. The latter part involves approaches that are needed to employ higher level mathematics, such as quadratic programming for agroforestry (Wojtkowski and Cubbage, 1989) and dynamic control theory to model decision-making to select IPM technology (Zacharias and Grube, 1986) or rangeland management (Karp and Pope, 1984). Such normative models may be used to evaluate alternative technologies (with researchers highlighting the substantial data requirements) and social policy questions; but it is unlikely whether they will capture the decision-making process underlying farmer adoption in tropical agriculture. To improve the evaluation and screening of technologies and management practices within NRM programs, social scientists will need to identify assessment criteria that more effectively bridge farmer decision-making and biophysical processes.

Developing sustainable agricultural systems that integrate the products of NRM and commodity research programs will increase the demands made on what are still relatively fledgling adaptive farming systems research (FSR) programs. This increasing demand comes at a time when donor support for FSR programs within NARS is declining, and the last CGIAR priorities analysis (TAC/CGIAR, 1991) recommended a significant decline in production systems research, much of which is on-farm research. Nevertheless, if benchmark research sites are to be successful, a network of adaptive FSR sites will be critical for testing the methodologies and technologies emanating from the sites across a wider set of conditions. Moreover, FSR will have to accommodate a more complex research task. To date, much on-farm adaptive research has had a close link to particular commodity programs, and the technology evaluation has tended to focus on cropping system components but has been evaluated within a farming systems framework. The Purdue group in Burkina Faso (Sanders, Nagy, and Ramaswamy, 1990) exemplifies a whole-farm approach that started with sorghum technology but then was extended to tied ridging, animal traction, and other cropping components, particularly cotton.

Integrating NRM and commodity research vastly expands the number of potential components that can be evaluated within FSR programs. On the one hand, crop management (fertilization, tillage, pesticide use, crop cover, crop choice, and intercropping) directly determines the quality and productivity of the underlying soil and water resources. On the other hand, technologies that further enhance resource quality and productivity (such as improved organic matter management, agroforestry, IPM, and contour planting) must contribute to increased yield and income for farmers to adopt them. Moreover, sustainable agricultural management of resources such as wetlands, vertisols, or grazing lands will depend on the management of the crop or livestock enterprises overlaying these resources. Crop and resource management components are, thus, "assembled" within the adaptive research phase, where implications for labor use, land allocation, niche exploitation, and externalities are also addressed. How these crop-resource management systems are assembled and evaluated for a particular time period, as well as the evaluation scale and the degree that farmer and researcher participation is split, are all issues that FSR researchers need to reassess in light of this expansion beyond crop management. Again, the crux of the problem is integrating biophysical and socioeconomic evaluation. The experience with FSR in agroforestry offers some insights into the expanded set of methodological issues that need to be addressed (see volume 15 of *Agroforestry Systems*).

If the approach to sustainable agriculture or its variants such as LEISA is to assemble sustainable systems at an adaptive research stage, then questions arise about how they are to be transmitted through the technology transfer and extension processes and what will be the nature of the adoption and diffusion process for these technologies? Walker (1981) summarizes the problem as thus, "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 de Polanco (1982) rigorously documented this sequential adoption process for barley producers in Mexico. Yet, the underlying tenets of sustainable systems are that they interact and integrate components that buffer the crop system, produce greater stability, and integrate crop and resource management considerations. In sum, the whole system is much more productive and sustainable than are the individual components. The focus of sustainability research is on integrated pest management systems rather than pesticides, on agroforestry systems rather than trees, on integrated soil management rather than fertilizers, and sustainable low-external-input farming systems rather a new variety. One of the priority challenges in sustainability research is making technology compatible with the sequential process of adoption. The most experience probably has been with agroforestry systems, and Kerkhof (1990) concludes in his review of 19 agroforestry projects in Africa that "on the key question of sustainability, few projects have yet reached the stage where they can confidently predict that the changes they have introduced will continue and spread after the project is finished."

The technology package issue puts even more demands on the adaptive research stage. The design or assembly process must put together the most appropriate, or prototype, system. It also must sort out a sequential order for that assembly, such that each component is adoptable but, in turn, leads to the complementarity between components embodied in a fully integrated system. Farming systems research has only partially taken up this challenge and, yet again, it reinforces the critical role that FSR will play in the sustainability agenda at a time when donors and academia are turning to other pursuits. The issue also raises the question of the type of linkages between research and extension necessary to deal with this new research emphasis. To date, it is probably fair to say that the extension systems have been largely bypassed when dealing with techniques in IPM, agroforestry, wetland management, or integrated soil management. Extension systems are not well structured to accommodate a range of alternative techniques that must be tailored to farmer and agroclimatic conditions.

Innovative options in the transfer of resource management technologies are difficult to find in the Third World. The principal approach has generally been a single-component approach. Thus, reduced pesticide spraying is the key to IPM strategies on rice in Indonesia and cotton in Latin America, and a biocontrol agent is the key to cassava mealybug control in Africa. Nowhere has a fully integrated concept deploying varietal resistance, cultural practices, biological control and, where absolutely necessary, pesticides been employed. On the soil side, the situation is similar. Extension of composting, bench terracing, strip cropping on the contour, litter banks, and improved tillage have occurred, although almost always as a single component. Yet, these options have been promoted as the solution to the problem of sustainable soil management. If sustainable agriculture is accepted as requiring more than this, then more innovative technology transfer approaches will have to be developed.

Agroforestry (especially as hedge-row intercropping) does not have the component option since it induces quite radical system changes. Extension of agroforestry innovations has been strictly linked to projects which usually involve research capacity, nursery development, significant on-farm research, a specialized extension component and, often, a subsidized input or credit scheme. This approach significantly raises the costs of technology transfer and is justifiable if it sets in motion a more autonomous process of technology diffusion. To date, there has been little expansion of the technology within the farm from the on-farm trial plots, much less technology diffusion, to other farmers. Most of the projects have focused too much on the number of plots that have been planted rather than on trying to understand and put in place a system that will lead to more cost-effective transfer or, even better, autonomous diffusion.

Sustainable agriculture will require more complex and sophisticated information flows from research, to extension, to the farmer, and these information flows will have to be more finely targeted. More innovative technology transfer will have to be based on a better understanding of the "natural" dynamics of agricultural systems. In Africa, technology introduction should enhance Boserupian processes of agricultural intensification driven by increasing population growth. Ruthenberg (1980) provides a very substantial base on which to understand agricultural intensification, and many of the techniques being promoted within the sustainable agriculture basket can be found within those intensification processes. An important point in this regard is that improved fallows, better crop rotations, and improved organic matter management require more labor (i.e., involves a movement along the production function) and, yet, are key to sustainable management of the soil resource. But if these practices are combined with some fertilizer and improved seed techniques, a quantum bump in productivity is possible (i.e., a shift out of the production function). Understanding where different regions are at in the intensification process will significantly aid in appropriate targeting of technology and in sequencing the techniques. If they are done well, autonomous diffusion should result. It should also be highlighted that the really difficult areas will be those with low-population density and poor market access. Because these areas drive much of the tropical deforestation, developing sustainable agricultural systems without major increments in labor will be difficult indeed.

Another, and probably more important, force in inducing agricultural system change is commercialization (Binswanger and von Braun, 1991). The crop and livestock components provide the income in the farming system that drives investment in the natural resource base. Investment in resource management will be more effective if it can be linked to income generation. For example, in the highland areas of Kenya, the relatively rapid adoption of improved dairy breeds in a stall-fed (zero-grazing) system has allowed linkage to such forage production alternatives as legumes, agroforestry, and strip cropping with grasses which, in turn, has led to sustainable land management. Agroforestry projects are more successful where there is a good market for poles. Agroforestry projects in Africa have not done well when the driving mechanism is fuel wood production, contribution to soil fertility, or increased crop yield (Kerkhof, 1990), although the problem here is probably an inappropriate matching of project design to the project site conditions. The African agroforestry experiences reinforce the need to match resource management technologies to the interplay of commodities and markets. Simple nationwide recommendations are no longer sufficient for extension. Extension will have to create a capacity for targeting recommendations and develop transfer and diffusion strategies which will depend on an in-house socioeconomic research capacity. The sustainability challenge will hopefully open up a badly needed debate over extension design and strategy in the Third World.

Challenge 4: Sustainability and Research Planning and Evaluation

CGIAR faces a plateau in funding availability at a time when it is attempting to incorporate sustainability research into its structure. Restrictions on research funds raise the issues of allocating budgetary resources between resource management and crop and livestock research and how the system might determine an optimal balance between the two. There have not been any good frameworks by which to address this question, and choices have been made on either an ad hoc basis or on the basis of partial approaches. Sustainability introduces a further level of complexity—how research priorities are set within the system as a whole and within individual IARCs—which significantly complicates the task of evaluating the performance of agricultural research and estimating the impact. Some of the issues surrounding this problem are briefly discussed in this section.

Sustainable agricultural development, in its broadest reading, refers to agricultural growth that does not diminish environmental quality or natural resource capital. A debate revolves around whether this is an absolute injunction or whether it is merely a subsidiary to a higher level societal objective of optimizing aggregate welfare in the society. A conservationist ethic, and the environmental impact assessments that flow from it, would maintain that the line should be held firm on any environmental deterioration or depreciation of natural resource capital. The economic policy framework embodied in the aggregate welfare concept would allow substitution (e.g., agricultural land for forest land) or trade-offs (e.g., improved agricultural productivity for some increase in pesticide levels in the water if aggregate welfare were increased). Sustainability in this framework is evaluated in income terms, which then allows decisionmakers to assess potential trade-offs between sustainability and growth or between sustainability and equity, as well as to evaluate net benefit streams arising from crop and natural resource management research (Graham-Tomasi, 1991).

Priority setting is basically ex-ante impact assessment and, thus, mirrors the ex-post impact assessment. Sustainability is introduced into the analysis in terms of a broader and more detailed valuation of cost and benefit streams arising from new technologies and the movement from a private cost-benefit accounting to a social accounting (Lynam and Herdt, 1989). The cost side expands to include externalities such as downstream siltation and changes in water quality and health effects, whereas the benefit side shifts to such issues as how to identify and value all the possible benefit streams of a tropical forest or how to evaluate enhanced productivity of the soil resource base. Sustainability introduces two complexities into the analysis. First, it vastly complicates the measurement problem and, second, it does not easily allow benefit and cost assessment through the impact of technology on market prices.

The increased complexity of the measurement problems are best discussed in terms of examples. IRRI and CIP are currently involved in an evaluation of the costs of pesticide use. These detailed micro studies are measuring costs in terms of the dispersal of pesticides through the ground water and surface water (although determining the resultant health and ecological costs are even more difficult), the direct health costs to farmers and sprayers from pesticide exposure (this involves epidemiological studies), the reduction in indigenous biological control agents and, of course, the direct cost of the pesticides (the only factor that enters into traditional cost-benefit analysis). The study is further complicated by the use of a very broad range of different agrochemicals on rice and potatoes, each having different potential health effects and different transport characteristics through soil and water media. Just to understand and estimate these costs in two or three field sites requires a major commitment of research resources (IRRI, 1992).

Most centers are currently increasing research devoted to improved soil management through such practices as alley cropping, organic matter management, improved tillage, green manuring and rotations, enhanced rhizobia and mycorrhiza associations, strip cropping, and bench terracing. Two measurement problems are to evaluate the improved productivity of the soil resource and the reduced social costs due to erosion. The basic conceptual problem is how to evaluate the initial stock of soil capital (as distinct from the seasonal flow of nutrients and water to the plant that actually determines crop yields) and the changes over time. Adoption of improved practices in a very deep, fertile soil may result in very little change in crop productivity for some time (and with such techniques as alley cropping could actually result in a decline) but could actually reduce deterioration in the stock of soil capital. The science to measure changes in the stock of soil capital is, in many respects, not yet in place. This productivity change in the resource base has been measured through output changes, but this method introduces issues of selecting an appropriate time period, of deciding how to incorporate price changes in aggregating a diversified farm output, and determining the opportunity costs of nonmarket-priced resources such as feeding maize stover versus soil incorporation. Finally, estimating the downstream costs of soil erosion and siltation is very dependent on what water control structures exist. Location specificity often becomes a major issue in these types of cost evaluations.

The impact of commodity-based technology evaluation (either ex-ante or expost) has generally utilized an economic-surplus framework. Changes in farm-level costs and benefits are evaluated in terms of a shift in the industry supply curve, and income streams that flow from price changes for both consumers and producers can be calculated. In essence, much of the economic impact is simulated; economists do not directly measure the changes in farmer income or the changes in consumption and nutrition of the poor before and after technological change. Incorporating sustainability issues into impact assessment will generally not be possible through this approach. Instead, it will require tracking effects through environmental systems as well as economic systems. This procedure will involve detailed microstudies and, then, aggregating up the cost and benefit streams to the market level (Graham-Tomasi, 1991). In many cases, indirect benefits due to price changes will be difficult to track through the market system. The benefits to improved soil management will be expressed through increased productivity in a range of commodities and will, thus, have the potential to generate consumer benefits. Such benefits will be extremely data intensive to measure.

Sustainability concerns and resource management research are going to increase exponentially the costs of impact assessment. Is it worth the price? Donors increasingly insist on such evaluations. Moreover, as resource management is established in CGIAR and as it consumes an increasing share of a static budget, questions will inevitably be raised about the returns to this type of research, and what is being sacrificed in other areas, especially given the promise of biotechnology and its dependence on well-developed breeding programs. The task, therefore, is to develop cost-effective approaches for impact assessment in resource management research. Such approaches have to be able to work with significant heterogeneity. Preconditions heavily determine the returns to resource management research. Thus, returns to soil erosion research will be heavily influenced by soil type, topography, and existing management practices. Moreover, the framework has to allow for aggregation of micro-level studies to a market basis. The two issues suggest procedures of selecting micro-scale study sites based on a macro-scale characterization of the target area and, then, aggregating the micro-level results back up through the macro framework, which will require integrating biophysical and economic data. The development of large relational databases and geographical information systems (GIS) is now being used in IARCs for characterization work and the development of these macro-scale frameworks. Soils, climate, and topographic databases are now readily available; work is only just starting on socioeconomic databases for GIS systems (Grandin, 1989). Selection of intensive field research sites should, from now on, be based on these macro-scale sampling frames. Since this approach is in its infancy, a whole range of methodological issues have yet to be worked out in interpolation techniques, aggregation, weighting procedures for statistical analysis, and error control. Nevertheless, social science is being left behind in this rapidly evolving area. As a result, social science could be left out of many debates in natural resource management. On the other hand, geographers are being better integrated into the social science fraternity working at the nexus of agricultural research and development.

Conclusion

Sustainability offers a wide range of challenges to the international community involved in international agricultural research, only some of which have been covered in this paper. The response to these challenges to date suggest that sustainability does not just imply adding on a few additional programs or overlaying a new perspective on existing programs but, in fact, requires some key organizational changes in institutions, from the IARCs all the way through to the extension system. These changes will be costly and the future outcomes are not even barely perceptible, all of which has introduced some uncertainty and hesitancy in decision-making, especially when what is at stake is the future growth in world food supplies. For many donors such as IDRC and ODA, agriculture has disappeared from program titles and has been replaced with natural resource management; but name changes do not reflect actual program changes. Most donors are pulling back support from traditional commodity research and, yet, are showing considerable hesitancy in committing large amounts of funds for sustainability research, basically because the way forward is far from clear. Certainly, the sustainability banner has not pulled a substantial amount of new funding into CGIAR—apart from the commitment to the new forestry center that is being established. An implicit theme underlying this paper is that such hesitancy is warranted and, if anything, CGIAR is probably moving faster than the donors in taking up the sustainability challenge.

Natural resource management research can absorb a significant amount of the funds devoted to international agricultural research without necessarily making a significant contribution to agricultural production. The locus of research can shift away from the high-potential agricultural areas to the forest margins, marginal lands, hillside agriculture, and unexploited resource niches. Research problems are more complex in the latter areas and will require a significant investment of resources to both stabilize the resource base as well as increase productivity. Moreover, sustainability lengthens the time frame and, therefore, increases the costs of research. Whereas biotechnology techniques such as anther culture or RFLP maps vastly improve the efficiency of the breeding process, natural resource management research is still in the stage of just developing systematic design and testing methodologies. Further, natural resource management has significant implications for institutional and operational costs. Field research increases significantly. The costs of technology transfer will also increase dramatically. Setting priorities in resource management research will be imperative; more difficult will be the search for mechanisms for improving the efficiency of research and technology transfer processes for natural resource management techniques.

Priority setting will be equally important for social science research undertaken within the sustainability rubric. In the author's opinion, social science's contribution to the questions of technology and institutional design, as well as to understanding technology testing and adoption of soil and water management techniques, will have a larger impact than will the work on policy and tenure in forest and arid areas, which seems to be dominating the academic literature if not capturing limited social science research funds. Social technology in the form of innovative tenurial arrangements and access regulations will certainly be the principal intervention in, for example, arid land pastoral systems or wildlife management programs in East and Southern Africa, as well as in many of the areas at the agricultural margin in the humid forest zone. However, the point made many times in this paper remains, which is that this is all work at the agricultural margin. Academic interest should not obscure where the real need lies for social science in its needed contribution to developing sustainable agriculture.

A strategy for sustainable agricultural development starts from the fact that the structure and dynamics of the agricultural sector will largely determine how land, water, forest, and savannah resources are managed. CGIAR was correct in bringing forestry research and other natural resource management research under the international agricultural research umbrella. Natural resource management, apart from minerals and oil which are in the industrial sphere, has to be integrated with agriculture, and probably subsidiary to it. Subsuming agriculture under natural resources will wrongly skew priorities, and donors, in particular, should be very cognizant of the pitfalls in this tendency. Decisions made over the past few years, along with those to be made in the next few years, will basically chart the course for agricultural research into the next millennium. In the rush to sustainability, we need to ask two basic questions: Have we even begun to ask the right questions? and, Are we cognizant of the costs to future world food production of overshooting the mark?

Notes

The author is a Senior Scientist in the Agricultural Sciences Division of the Rockefeller Foundation and based in Nairobi, Kenya. The views expressed in this paper are the author's own and do not reflect a position of the Rockefeller Foundation or its membership in the Consultative Group on International Agricultural Research. The author is grateful to Michael Collinson for constructive criticism of an earlier draft of this paper.

1. Structural adjustment programs have markedly emphasized the expansion of nontraditional export crops, and horticulture is being promoted from Central America to Eastern Africa to Southeast Asia. However, the susceptibility of vegetables to diseases and pests in the tropics, the high-production costs of these commodities and, therefore, the tendency to invest in risk-reducing inputs, and the relatively low-proportion that pesticides assume in overall production costs lead to the major use of pesticides on these crops in the tropics (Murray and Hoppin, 1992).

2. Setting research priorities first by ecozone and then by crops can result, as in this case, in different priorities than setting priorities first by crop and then addressing resource management issues in priority crop growing areas.

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Using Local-Level Knowledge to Improve Agriculture and Natural Resource Management

Billie R. DeWalt

Recent years have seen an increasingly polemical debate concerning the appropriate role of agricultural science and technology in developing solutions to problems of world hunger. On the one hand are individuals who argue that agricultural science has been extraordinarily effective in increasing food production, thus staving off Malthusian predictions of mass starvation. These individuals argue that further applications of science are needed because of continuing population growth.

Especially among humanists and social scientists, however, there is an increasing questioning of agricultural science and technology because their applications have not led to socially just or ecologically sustainable societies. Although the world is producing far more food per capita, much of this food has been used to provide an increasingly affluent diet for those with sufficient economic means, while there are still masses of starving people. Further, there is a growing recognition that the technologies used for this increased production are not sustainable and, in many cases, environmentally damaging (Brown, 1989; Commoner, 1971; Hightower, 1973).

Reconstruction of a more sustainable and socially just agriculture has led many individuals to argue that we need to give greater attention to local knowledge systems (Brokensha, Warren, and Werner, 1980; Richards, 1985; Thrupp, 1989; Warren, 1991). Their arguments are based on creating more appropriate and environmentally friendly technologies; empowering people, like farmers, to have greater control over their own destinies; and creating technologies that will have more just socioeconomic implications.

Agricultural scientists have often ignored this literature because of the sometimes missionary fervor with which proponents preach the virtues of local knowledge systems.[1] Scientists are often blamed for the ecological and inequality problems; the implication of such an idea is that all we need to do is learn the local knowledge systems of farmers and we will have many of the answers to development ills. Understandably, agricultural scientists are wary of such perspectives.

In this paper, I will try to establish a framework from which to view the potential of local knowledge and scientific knowledge systems. I will first discuss the strengths and weaknesses of scientific and local knowledge systems. Next, I will give three examples to illustrate the strengths and limitations of local knowledge systems. These examples will point to which situations we should look to for guidance and ideas from local knowledge systems. Finally, I will discuss how scientists, social scientists, and people with local knowledge can work together to improve agriculture and natural resource management systems.

The Advantages of Local Knowledge Systems Compared with Science

Kloppenburg (1991) has provided an interesting framework in which to view the strengths and weaknesses of science and local knowledge systems as approaches to understanding the world. Following many other critiques of science, Kloppenburg (1991:530) argues that the approach used to produce scientific facts is Cartesian reductionism, or the process of "breaking a problem down into discrete components, analyzing these separate parts in isolation from each other, and then reconstructing the system from the interpretations of the parts." Further, the goals of science are to produce what Latour (1986:7–14) has called "immutable mobiles," or information that can be transferred without transformation to any spatial or social location. The strengths of scientists are that they learn an extraordinary amount about very limited areas of knowledge; they become very savvy about the principles or mechanisms by which things work (through the construction of theoretical knowledge); they have a very effective means—the scientific method—by which to approach problems and to engage in explanation; and they transfer the knowledge that they acquire across time, space, and societal setting.[2]

As practiced, these strengths have also created problems for science. The reductionism of science often leads to a woeful ignorance of the wider context within which the particular phenomena under study occur. One problem is that the selection of phenomena to be studied is determined by the ability to break it down to "researchable pieces." Complex systems and those characterized by a myriad of interactions are likely to be ignored. A second problem is that scientists often advocate the change of one part of the system without paying attention to the results for the overall system.[3] A third problem is the tendency to focus only on the short term, not looking at what the potential long-term implications of a change in technology might be.

More problematic, perhaps, is that science has led to a certain hubris among those who practice it. Many scientists have lost touch with the ultimate goals of what they are trying to accomplish because of their isolation. As Kloppenburg (1991:530) puts it, "As Cartesian science is elaborated and institutionalized in laboratories, it loses touch with the local knowledge and everyday experiences...." At its worst, this attitude leads to an assertion that research is value free and that scientists need not be concerned about the ethical, social, or ecological consequences of their research. More benign, but potentially as dangerous, is that scientists denigrate the knowledge and experience of nonscientists.

As part of the general criticisms that have been made of science in recent years, some philosophers of science (e.g., Feyerabend, 1975) and social theorists (e.g., Kloppenburg, 1991) have asserted that science is just one among many ways of knowing about the world. It has also become fashionable to imbue indigenous or local knowledge systems with a sanctity or "truth" that can inform us about ways to solve the world's problems (Brokensha, Warren, and Werner, 1980; Richards, 1985). As with science, however, we need to recognize the potential strengths and weaknesses of local knowledge systems.

Perhaps the greatest strength, as well as the greatest weakness, of these knowledge systems is that they are local. As Kloppenburg (1991:531) has pointed out, local knowledge produces what he calls "mutable immobiles." The comparative advantage of local people is that (1) they are very savvy about their local environment and have accumulated a lot of experience concerning those things that affect their existence; (2) many of them have a keen awareness of the interconnectedness of plants, animals, and soils—their interrelationships and ecology; and (3) they have become very ingenious at making do with the natural and mechanical resources at their disposal (seemingly every plant has a use).[4] The problem with local knowledge is that it is very rich in contextual detail but it has little utility outside of particular places (Kloppenburg, 1991:531).

Using this perspective, we can now examine several cases that elucidate these strengths and weaknesses of science and local knowledge systems. These cases will demonstrate the complementary and productive relationship that should exist between scientific and local knowledge systems.

The Langosta in Honduras: The Limits of Local Knowledge Systems

An interesting example concerning the limits of local knowledge systems comes from southern Honduras, a region in which the International Sorghum/Millet (INTSORMIL) Project has been working since 1981. In 1981 and 1982, a team of researchers and I conducted a baseline study of farming systems in this region, especially focusing on farming systems used by small farmers. One of our objectives was to identify, from the farmer's perspective, the most important constraints to production, especially on sorghum, which was an essential component of their production and dietary systems (DeWalt and DeWalt, 1989).

Our research indicated that farmers had evolved a very sophisticated intercropping system of maize (a crop indigenous to the Americas) and sorghum (a crop indigenous to Africa and India), which fit well with the climatic and subsistence needs of the region and its people (DeWalt and DeWalt, 1982). This system, presumably developed by farmers through experimentation, produced a maize variety with a very short growing season and a sorghum with a very long growing season. In spite of these varietal refinements, the local farmers were unable to cope with some of the major insect pests in the region.

> The major insect pest mentioned by farmers in Pespire was the langosta (locusts). The langosta seems to come in waves and to leave most fields untouched while wreaking major destruction on other fields. Farmers report that they have no way of knowing when and where an outbreak of langosta will occur. Consequently, few farmers take any precautionary methods against the insects, which generally do most of their damage when the plants are quite small. (DeWalt and DeWalt, 1982:42)

From a personal perspective, the above description was unsatisfactory to me for a number of reasons. For one, descriptions of the damage and habits of the insects made me skeptical that the problem really was due to locusts (langosta in Spanish means either locust or lobster). Second, none of the agricultural scientists in the region could give me a scientific name for the insect involved. Third, the farmers were pretty vague about the insect, could not tell me anything about its life cycle, and had no local technologies for controlling it. So, local knowledge among both farmers and scientists in southern Honduras was quite inadequate.

Because farmers in the region considered it such a problem, INTSORMIL scientists in the region continued their interest in the langosta. Their subsequent research found that the langosta is, in fact, a complex of noctuids involving at least four distinct species: *Spodoptera frugiperda* (J. E. Smith; fall armyworm), *Metaponpneumata rogenhoferi* (Moschler), *Spodoptera latifascia* (Walker), and *Mocis latipes* (Guenee). During 1988 and 1989, on-farm research investigated the influence of inter-cropping practices on insect pest populations (Portillo et al., 1991). These pests were found to differentially affect important cultigens, like maize and sorghum, at different times in the cultivation cycle; *S. frugiperda*, *M. rogenhoferi*, and *S. latifascia* showed a distinct preference for maize and *M. latipes* infested both species equally. Depending on rainfall and other climatic conditions, the pests shifted their feeding habits between weeds and the cultivated crops. In addition, at least two of the species (*M. rogenhoferi* and *S. latifascia*) did not seem to complete their life cycle on maize or sorghum. Insecticide spraying by farmers seemed to have little effect on the pest complex. Portillo et al. (1991:295) concluded that

> The occurrence of the lepidopterous pest complex (langosta) on sorghum and maize creates the biological illusion that the component species coexist conjointly. Actually, the complex is the product of a fine-grained mosaic of different micro-habitats, each supporting a well-adapted successful species. Because of the geographical and biological diversity involved by the complex, controlling the langosta is a formidable challenge. Although many farmers spray their crops after the langosta has arrived, this has no effect on the core population of at least two of the species, nor does it reduce their subsequent generations since these species are unable to complete or appear to have difficulty in completing their life cycle on maize or sorghum.

The authors indicated that a much greater understanding of the ecology of each of the pests is needed before effective strategies to combat the complex can be developed. Their perspective is that an array of integrated pest management practices offers the greatest possibilities for controlling the complex.[5]

This case illustrates the limitations of local knowledge systems. Despite attempts to identify this problem as early as the beginning of the nineteenth century (del Valle, 1804), farmers have been unable to develop any significant understanding of it or ways to control it. Although there still have not been any demonstrated means to mitigate the damage of the langosta complex, research scientists have identified the different pests involved in the complex. Research has also suggested the future directions that must be taken for effective control. Because several of the insects breed primarily on weeds, rather than on the cultivated crops, chemical controls are likely to be too costly and ineffective. Integrated pest management techniques are thought to be a more promising solution, but farmers and scientists must continue working together to develop intervention strategies.

No-Tillage Farming in Kentucky: Local Knowledge Pushing Science

The second case illustrates a blending of local and scientific knowledge systems. In the early 1960s, farmers in western Kentucky had reached an enviable level of agricultural technology, compared to that of farmers in developing countries. Use of the tractor with weeder and harrow attachments, large combines, and intensive use of fertilizer had created a system of agriculture in which maize yielded over 100 bushels per acre and wheat and barley yielded about 50 bushels per acre. These farmers had extensive contact with a research and extension system that provided them with good technical assistance. Their farming systems largely conformed to the recommendations of the research and extension system.

Some farmers, however, regarded the plow-plant-tillage system as problematic for three reasons. First, intensive tillage was contributing to problems of soil erosion. Tillage made the soil vulnerable at the time of year that rainfall and wind velocity made erosion most likely. Second, wet weather during the planting season often delayed establishment of crops and reduced yields. Farmers were interested in techniques that would save time in establishing their crops. Third, the short growing season made multiple cropping impossible using the technology recommended by researchers and extension agents. The most common rotation was to grow maize for one or two years, followed by barley.

In 1962, a local farmer, who had earned a master's degree from the University of Kentucky decided to try no-tillage techniques. At the time, the herbicides 2,4-D and atrazine were available to control weeds. Using his knowledge of experiments in the southern and midwestern areas of the United States, Harry Young rigged an ordinary planter with extra weight to make it cut deeply into untilled soil. With this adapted machinery, he planted seven-tenths of an acre of maize. When a good harvest convinced him that the experiment had succeeded, he began promoting the benefits of no-tillage cultivation to other farmers, researchers, and extension workers. Several extension workers at the University of Kentucky, who had simultaneously been doing applied research and on-farm trials, worked with Young and other farmers to further develop the technology.

At the University of Kentucky, a team of agronomists, agricultural engineers, entomologists, and extension workers turned a part of their research effort toward investigating the feasibility of no-tillage systems. Their work was, in many ways, similar to the farming systems research and development approach—it involved multidisciplinary collaboration, farmers were active participants in developing and evaluating the system, and annual on-farm trials were conducted.

Most farm machinery companies were not interested in the no-till technology because it competed with their sales of larger tractors and tillage instruments (Phillips and Phillips, 1984). Allis-Chalmers, however, did not have a conventional-tillage planter and saw it as an opportunity to fill a new market niche. In 1965, Allis-Chalmers introduced a no-till planter. By 1967, paraquat, a superior knockdown herbicide, also became available and further stimulated the movement toward no-till.

On-farm research demonstrated that no-tillage farming resulted in greater production because it made double-cropping possible (Phillips and Young, 1973). Now it was possible to plant soybeans following wheat. In addition, there was "better soil moisture retention, savings in labor, less soil damage from machinery, better timing in planting and harvesting, and reduction of some weather risks" (Choi and Coughenour, 1979:2). Most farmers also reported that there was a substantial savings in energy costs.

These developments proved the feasibility of no-tillage technology, and farmers across the upper-midwest began adopting it. By 1971, an estimated 420,000 acres of land in Kentucky were being planted using no-tillage techniques. Over 600,000 additional acres in other states and Canada were being planted using the technique (Phillips and Young, 1973).

This case illustrates one in which local farmers in the early 1960s essentially adapted techniques that were still seen as only "promising" by agricultural scientists. Scientific research was underway in various southeastern states on no-tillage or minimum-tillage technology, but it was the farmers themselves who decided they needed the technology immediately. Farmers began using home-produced equipment and began experimenting with techniques they felt would improve their operations.[6] Once farmers began showing the utility of the no tillage method and promoting it, researchers and extension workers felt obliged to work more intensively on the technology. It is to their credit that they listened to and worked with farmers rather than following their own priorities for research.

This case is a good example of how local and scientific knowledge systems can interact to advance agricultural technology.[7] Farmers were aware of the scientific work on minimum-tillage systems. Frustrated by the lack of progress, some farmers began experiments of their own. These farmers' experiments were transferred to the extension workers, scientists, and corporations, which then modified and improved on the farmers' techniques. These improvements were then transferred back to farmers who quickly adopted no-tillage technology.

An interesting parallel to the no-tillage case has arisen in U.S. agriculture. Because of the increasing concerns about rising input costs, damage to the resource base, and the potential health hazards of what has now become "traditional" U.S. agriculture, there has been a search for alternative agriculture—or more correctly, alternative agricultures. Rather than ask agricultural researchers to provide guidelines for these alternative agricultures, the National Research Council (NRC, 1989) panel provided case studies of 14 farms that were being efficiently managed. In other words, in seeking alternatives to the status quo in U.S. agriculture, the NRC sought out local knowledge to provide guidelines concerning possible productive new directions.

Some have concluded that the NRC "had little choice but to seek out farmers who had themselves developed alternative practices since the agricultural science establishment had virtually nothing to offer" (Kloppenburg, 1991:523). Yet, as the NRC report itself makes clear, these farms were being operated using a mix of alternative and conventional practices. Farmers had incorporated many research findings into their operations, but they had combined them with their own experience and experiments. "Farmers and other innovators often develop, through their own creativity, new approaches to solving common farming problems" (NRC, 1989:247). It is important that we take advantage of this creativity and innovativeness. We should not rely solely on either the findings of agricultural scientists or on the local knowledge of farmers.

Tropical Forest Management: The Limits of Scientific Research

Perhaps the most critical agricultural research issue of the next century will be to determine effective, sustainable management systems for the humid tropics of the world. Science and technology have thus far had little success in providing viable solutions for these regions. Intensive resource extraction like tropical logging, mining, or petroleum extraction (NRDC, 1991) is clearly destructive for these important ecosystems. Livestock schemes, where the tropical forest is replaced by pasture, and large scale agroforestry schemes, such as the infamous Jari project in Brazil, have so far not proven to be sustainable alternatives. Unfortunately, very little agricultural research has been done in such regions of the world.

It may be argued that the humid tropics do not lend themselves to the kind of reductionistic agricultural research that breaks problems down into their constituent parts. The extreme biodiversity of the humid tropics, with little concentration of plant, insect, or animal life within any delimited area, argues for a greater need for research on ecological systems. In such situations, local knowledge systems may be maximally useful as a guide for scientific research.

There are several examples of extensive studies that demonstrate the sophisticated knowledge that native peoples have of their ecological circumstances (e.g., Posey, 1985; Conklin, 1957). The example I wish to discuss is based on research by Dominique Irvine (1987), who studied the Runa of the Ecuadorian Amazon.

The Runa of San José obtain food through gardening, hunting, and fishing. Maize, coffee, and cacao are grown as market crops, while manioc gardens provide a large part of their consumption needs. These gardens are cleared using slash and burn techniques. Much of the effectiveness of their subsistence, however, comes from the knowledge of managing the succession within this shifting cultivation system. Rather than simply abandoning a field during its fallow period, Irvine (1987) argues that the Runa engage in management for what she calls "resource enhancement." Management includes selectively "weeding" naturally occurring pioneer species; protecting (or occasionally transplanting) desirable fruit, palm, and other trees; and planting trees such as coffee and cacao. These fallows are also managed to serve as game attractors to enhance hunting success. The fruit trees that are protected in the fallows serve as food sources for such game as caviomorph rodents. The result, in comparison with unmanaged fallows, is greater diversity of species and greater economic and subsistence value in the new forest canopy (Irvine, 1987).

Irvine's research was not just intended to show the wisdom of indigenous techniques of managing the forest under conditions of low-population density. Instead, she wanted to show how their technology was changing in response to growing population density. These are not communities whose traditions limit them to survival only under invariant ecological and social conditions.

> My study of succession management suggests that the "seeds" of agricultural intensification are found in the agroforestry cycle. Rather

> than being bound by the problems of soil management inherent in continuous root crop cultivation, people can supplement these staples and extend the agricultural cycle by augmenting tree crop production. There is considerable variation within San José in the degree and manner of fallow management. I would argue that this variability indicates that intensification is an option for increasing land productivity. . . . Population pressure resulting from prolonged settlement has encouraged a degree of resource enhancement through succession management. (Irvine, 1987:188–89)

Unfortunately, the agricultural research that is now occurring in the Amazon of Ecuador is focused mainly on "traditional" western agriculture; that is, row crops in pure stands are produced, perhaps with the addition of alley-cropping. Little work is based on the resource-enhancement strategies of the local people. Instead, forest management practices are being threatened by public policies that promote the expansion of the agricultural frontier, especially the conversion of forest to pastures (Uquillas, n.d.).

Several years ago, the Bruntland Commission report, which provided a big impetus for the current focus on sustainability, commented on the importance of local knowledge systems.

> These communities are the repositories of vast accumulations of traditional knowledge and experience. . . Their disappearance is a loss for the larger society, which could learn a great deal from their traditional skills in sustainably managing very complex ecosystems. It is a terrible irony that as formal development reaches more deeply into rain forests, deserts, and other isolated environments, it tends to destroy the only cultures that have proved to thrive in these environments. (WCED, 1987:114)

The cultural diversity that has been produced by the human experience is being eroded faster than the biological diversity of the planet. In my estimation, this is cultural wasting—the systematic process by which the unique social, technological, moral, expressive, and other indigenous knowledge of groups is lost as people become absorbed and incorporated within the world system (DeWalt, 1984, 1988).

Conclusion

Local knowledge systems and scientific knowledge systems must be seen as complementary sources of wisdom. In some cases, such as the case of the Honduran langosta, a scientific knowledge system with a developed methodology for determining the ecological habits of insects was able to determine the complex of pests that has been causing damage to crops. Such an understanding is the first step in designing appropriate solutions. In the case of no-tillage systems in Kentucky, farmers took a leading role in adapting and applying some of the scientific research findings that had remained in the realm of journal articles and experiments. The subsequent pairing of scientific research with farmer experience was able to lead to a technology that became widely adopted. This system continues to undergo modification. In the case of management of agriculture in humid tropical regions, science has thus far made little progress. Ecologists and others have come to an understanding of the interactions in such ecosystems, but this knowledge has yet to be systematically applied to designing sustainable agricultural systems for human use. Local knowledge systems, such as those of the Runa, provide some useful guidelines concerning potential future directions of scientific research.

We must recognize that both those who use and develop local knowledge systems (mutable immobiles) and those who develop and apply scientific knowledge systems (immutable mobiles) are constrained by the way in which they have been trained to think and the contexts in which they live. The key is to provide both knowledge systems with an opportunity in which they can inform one another. Beginning with local knowledge of problems and solutions can be an important first step in agricultural research.[8] At the same time, we have to recognize that farmers know much less about some aspects of agriculture than others. Some of the life stages of insect pests or differences among plant diseases, for example, can only be perceived with microscopes or other scientific instruments (Bentley, 1989). Scientific knowledge systems have the advantage that they can broaden the base of understanding and provide a much greater array of options to farmers. Ultimately, in order to be effective, the results of scientific knowledge systems must be incorporated into local knowledge systems. At their roots, the iterative feedback between farmers and scientists is what the farming systems research and development, farmer first, and participatory development perspectives try to accomplish (Chambers, 1983; Rhoades and Booth, 1982; Richards, 1985; Cernea, 1991).

It is important, however, to recognize that establishing mutual respect among scientists and producers of local knowledge will not necessarily resolve the problems of creating more just and ecologically sustainable systems. Local farmers with intimate and intricate understandings have not been immune to the destruction of their own ecosystems. Humans have been undercutting their own welfare for thousands of years (Eckholm, 1976). In the same vein, farmers are not above exploiting their neighbors so technology they create or participate in developing will not necessarily create a more just socioeconomic system (Flora, 1992). Within the process of cultural evolution, technology and science are only parts of our society's adaptive strategies—whether they fit with our goals for society or whether they are ecologically sustainable is a different set of issues.

Means for accomplishing these ends should become part of the system of scientific investigation and technology development (DeWalt, 1991a, 1991b). Some characteristics of local knowledge systems that can assist in this realm are included in the literature.

> Some features of indigenous knowledge which give it salient relevance to sustainable development planning are its conformity to high labor and low capital demands; dynamics, having evolved over centuries; locally appropriate nature; cognizance of diversified production systems; emphasis on survival first and avoidance of risk; rational decision-making; various adaptive strategies for use at times of stress (e.g., drought and famine); ingenious system of inter-cropping; integration with social institutions; and flexibility, with considerable potential entrepreneurial abilities. (Vanek, 1989:167)

Social sciences can become a part of the process of both mediating between local and scientific knowledge systems and orienting research toward accomplishing more socially just and ecologically sustainable systems. The three examples discussed in this paper suggest some of the roles that social scientists have played in previous research. In the langosta case, the role was simply to identify the problem as significant to farmers. In the case of the no-tillage systems, social scientists were involved in documenting that the system was profitable and was being adopted widely by farmers. In the Runa case, Irvine's research identified the resource management strategies of local people. She and others are now working with federations of indigenous groups to try to improve these management practices (Uquillas, n.d.).

The role of social scientists can be even greater in promoting the complementary nature of local and scientific knowledge systems. In many ways, social scientists are what Turner (1969:95) has called a "liminal personae." That is, we are "betwixt and between"—coming from the society and culture of scientists but often identifying with or focusing on the needs and goals of those we study. There are a number of steps that can be take, however, to more effectively fill this liminal role and promote the complementarity of these knowledge systems.

First, we should look for solutions that will benefit small farmers or that will help to create more egalitarian societies. Because we depend on others to create the knowledge and technology base to make this possible, we have to work closely with biological agricultural scientists to identify the kinds of technologies and policies required. In order to accomplish this task, social scientists must better learn how to communicate with biological scientists. Some social scientists have learned to, at least haltingly, speak the language of the scientists as well as the language of the people on whom development efforts are focused. Further efforts, however, are needed. Finally, the knowledge that we create or report is often very particular and only tangentially transferable to understanding other systems. We should aim for knowledge that falls somewhere between immutable mobiles and mutable immobiles. Our task should be to try to identify "mutable mobiles," that is, contextualized, wholistic knowledge that can be adapted and applied to similar phenomena in other circumstances.[9]

Notes

I appreciate the useful comments made by C. Milton Coughenour and Jere Gilles on a previous draft of this paper.

1. In this paper, I use the term "local knowledge systems" rather than the more commonly used term "indigenous knowledge systems" because indigenous knowledge often connotes "native peoples' ideas and beliefs" and "traditional knowledge." All people, whether or not they are indigenous to a given area, have developed understandings of the world that are based on their observations of their immediate surroundings. We are trying to capture this understanding through the study of local knowledge systems. For our purposes, we can use McClure's (1989:1) definition with the provision that the term indigenous be replaced by local: "Indigenous [Local] knowledge systems are learned ways of knowing and looking at the world. They have evolved from years of experience and trial-and-error problem solving by groups of people working to meet the challenges they face in their local environments, drawing upon the resources they have at hand."

2. Latour attributes the great power of science to what he calls "inscriptions"—the ability to produce images, and to read and write about them. Because these images can be superimposed, reshuffled, recombined, and summarized, and because they are able to be communicated to others, they acquire substantial importance. "By working on papers alone, on fragile inscriptions which are immensely less than the things from which they are extracted, it is still possible to dominate all things, and all people. What is insignificant for all other cultures becomes the most significant, the only significant aspect of reality (Latour, 1986:32).

3. A prime example here might be the search for hybrid seed varieties that satisfy the goals of greatly increasing productivity, but whose organoleptic qualities are poor.

4. Many individuals talk about local knowledge as though it were a highly codified system. Local knowledge, however, is very unevenly distributed among the individuals who make up communities; there are exceptionally knowledgeable individuals and there are often "specialists" who have a great deal of knowledge of certain realms. Identifying these specialists or gifted informants is an important first step in learning about local knowledge.

5. Dan Meckenstock has recently discovered an interesting document that reflects the historical nature of the langosta as a problem throughout Central America. José del Valle, a famous writer of the early nineteenth century, published a pamphlet in 1804 entitled *Instrucción sobre la plaga de langosta: Medios de Exterminala, o de Disminuir sus Efectos, y de Precaber la Escasez de Comestibles* (Instruction about the Langosta Problem: Means to Exterminate It, or Diminish its Effects, and to Prevent the Scarcity of Foodstuffs). The pamphlet reports that the langosta causes substantial damage to crops, thus increasing the threat of hunger. It indicates some understanding of the ecology of the pest reporting that the female lays her eggs in untilled (*inculto*) areas. The integrated pest management techniques recommended by del Valle include trying to destroy the eggs by plowing, burning fields, or letting pigs loose to root them out.

6. I have written about a similar case in Mexico in which local farmers created a seed drill to fit their own circumstances. In this case, the "traditional" technology used by poorer farmers was to use the digging stick for planting. The "traditional" technology used by wealthy farmers was a seed drill pulled by a tractor. Local farmers, and ultimately local blacksmiths, developed a seed drill that could be pulled by horses, mules, or oxen. The implement was within the economic reach of most farmers and resulted in a substantial savings of labor compared with planting using the digging stick (DeWalt, 1978).

7. This case exemplifies the farmer-back-to-farmer model that Rhoades and Booth (1982) have advocated. They argue for the necessity for research to begin and end with the farmer. As scientists (or farmers) identify potential solutions to problems, these techniques need to be tested on farms. The results are then fed back to scientists and farmers who can work on fine-tuning the technology or creating better solutions. The essential idea is that there is constant communication and feedback among scientists and farmers.

8. The work of Thurston (1992), who has examined local systems of plant disease management, is an excellent example of beginning with local knowledge and

solutions, as is Mathias-Mundy and McCorkle (1989) on ethnoveterinary practices.

9. An illustration of this comes from the Amazon region of Ecuador. One of the indigenous federations has asked technical assistance from the Kuna people of Panama for designing a natural resource management plan for their territories. They have also sent a group of trainees to Peruvian Amazon to learn from the Yanesha about forest management (Uquillas, n.d.).

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Session 6

Issues of Property and Development

- Land Tenure and Agriculture Structure: Implications for Technology Adoption
- Risk and Public Goods: Implications for Technology Adoption

Session Chair: Larry Burmeister

Speakers: Michael Roth
Jean-Paul Chavas

Land Tenure and Agrarian Structure: Implications for Technology Adoption

Michael Roth, Keith Wiebe, and Steven Lawry

Land tenure and agrarian structure, defined broadly as the nature and distribution of rights and access to land and other resources, have an important influence on technology adoption. Economies of size in access to capital and output markets can bias technology adoption and wealth accumulation toward larger, wealthier farmers. Small farm sizes or excessive fragmentation of land holdings may constrain adoption of certain "lumpy" inputs (tractors). Subsidies on machinery, credit, and fuel introduce a scale bias toward capital intensive technology, and can lead to farm consolidation (Roth, Dolny, and Wiebe, 1992).

Considerable attention has been focused on the relative merits of individual versus common property systems, much of it inspired by Hardin's (1968) discussion of the "tragedy of the commons." Hardin's failure to distinguish between "open access" and true common property resources, in which use and management is shared by a group of users, supported the belief that private property is necessary for efficient resource use (Larson and Bromley, 1990). This debate over the merits of individual and common property systems highlights what is arguably the most important factor linking land tenure with technology adoption: security of property rights in land. Land tenure security is a complex notion based on the clarity and durability of land rights. There is widespread consensus among land tenure specialists that security of tenure is necessary for agricultural investment and resource conservation (Feder, 1985). Where tenure is insecure, economic theory suggests that improvements in tenure security should: (1) reduce the incidence of land disputes through clearer definition and enforcement of rights; (2) increase credit use through greater incentives for investment and improved credit worthiness; (3) increase land transactions, facilitating the flow of land from less efficient to more efficient uses and users by increasing the certainty of contracts and lowering enforcement costs; and (4) increase agricultural output by increasing incentives to invest in or protect the land resource through effects (1) to (3).

Opinions vary on the degree to which indigenous tenure systems in Africa provide secure tenure. African indigenous tenure systems are sometimes said to induce inefficient allocation of resources because property rights are not clearly defined, costs and rewards are not internalized, and contracts are not legal or enforceable (Johnson, 1972). There are examples in South Africa's homelands of land-surplus households leaving land idle instead of renting to land-poor households for fear of losing their land permanently, despite acute land shortage (Lenta, 1982; Lyne and Nieuwoudt, 1991). There is a long colonial history of land registration in Africa aimed at correcting perceived problems of inefficient resource allocation, soil erosion, declining productivity, and consequences of the "tragedy of the commons." Other researchers emphasize the dynamic nature of indigenous tenure systems (Boserup, 1981; Noronha, 1985), and Bruce (1992) cites a number of examples where indigenous tenure systems provide ample tenure security for innovation and efficient land use.

Even if indigenous systems are weakening and exhibiting characteristics of declining tenure security, this in itself is not sufficient justification for state intervention. Programs aimed at improving the capacity of the community to efficiently and equitably allocate and regulate land use, while effective in some cases, are ineffective in others. Attempts to individualize and strengthen land rights by land adjudication and registration have sometimes had marginal or negative effects on tenure security (Atwood, 1990; Shipton, 1989; Barrows and Roth, 1990). Costs of land registration are substantial and have important budgetary impacts if they are to be met by scarce public resources. Whether land registration has a positive payoff through linkages (1) to (4) above, and whether the discounted present value of that payoff is sufficient to offset the costs of tenure conversion, are the central issues in the economics of tenure and technical change.

Tenure Security

Land tenure security is the individual's perception of his or her rights to a piece of land on a continuous basis, free from imposition or interference from outside sources, as well as his or her ability to reap the benefits of labor and capital investment in land, either in its use or upon its alienation. This definition contains both legal and economic dimensions. The legal dimension implies absolute confidence that one holds undisturbed the rights embodied in his or her tenure, even if that tenure is by definition of short duration and confers meager rights.

The economic dimension emphasizes three further elements—robustness, duration, and assurance—that define the value and certainty of economic benefits derived from de facto tenure in the land resource (Place and Roth, Forthcoming). *Robustness* is defined as the quantity of rights held or the quality, if certain rights are more important than others. *Duration* implies that the time horizon be of sufficient length to enable the holder to recoup with confidence the future income stream flowing from an investment.[1] *Assurance* means that rights in practice are held with varying degrees of certainty. Assurance thus accommodates greater diversity of actions in the exercise of land rights than would be implied by strict legal terms. Tenure security from an economic perspective is a function of these three elements. Tenure insecurity can thus arise from three primary sources: inadequate quantity of rights; inadequate duration; and weak assurance in the individual's ability to exert rights due to high costs of enforcement.

Overlapping tenure systems pose an additional degree of complexity. Security of tenure in most of Africa derives fundamentally from the indigenous tenure system(s), but is shaped to varying degrees by state institutions (legal statutes and state land administration). If enforcement of the state tenure system were absolute, land rights under the indigenous system would disappear. The typical outcome is a mesh of overlapping rights with varying degrees of assurance.

Issues of tenure security must be framed in two dimensions: with respect to what piece of land, and for whom. One cannot automatically assume that an individual with multiple parcels of land will hold uniform land rights on each, nor does an individual necessarily have equal certainty in his or her ability to exercise an identical set of land rights should they exist on multiple parcels. It also cannot be assumed that land-use decisions can solely be traced to the tenure security of one individual. Multiple individuals may hold one or more rights to the same piece of land depending on the season (e.g., use rights by the family in the wet season, and access rights by the community for water and fodder in the dry season).

Tenure Conversion

Colonial governments across Africa recommended programs of land registration to promote individualized tenure. British colonial administrators, in particular, perceived that the prevailing tenure systems, being communal, restricted the ability of entrepreneurs to acquire or expand their land holdings, conferred inadequate incentives for either individuals or groups to conserve and invest in the land resource, and contributed to problems of severe land fragmentation, erosion, and land disputes. The colonial administrators believed that the western model of land registration would increase tenure security, reduce litigation costs, encourage agricultural investment, increase access to credit, encourage development of a land market, control land transfers to ensure an economic size of land holding, and arrest fragmentation (see, e.g., Swynnerton, 1954).

Individualized tenure, typically defined as demarcation and registration of freehold, is generally assumed to be highly correlated with all dimensions of tenure security. However, land registration systems are not homogenous.

First, two general systems of land registration are distinguishable: "compulsory or systematic" registration, where registration is exogenously imposed by the state; and "purposeful or sporadic" registration, where the choice to register land is left to the land holder.

Second, registration systems do not confer equivalent rules and land rights from country to country (i.e., systems are not equally robust). The land law in Uganda permits alienation of land through the land market. However, the 1975 land law of Somalia and Senegal's 1964 Law of National Domain grant land holders certain use rights, but prohibit land transfers except with the approval of the state (Somalia) or rural council (Senegal). The Somalia law further allows only one parcel per household and imposes variable limits on the size of holdings depending on soil quality and land use.

Third, land registration systems do not confer rights for periods of equal duration. "Freehold tenure" implies that rights are granted to the land holder in perpetuity. "Leasehold tenure" confers certain land rights for periods of finite duration, and are often subject to land-use conditions. Registration in Uganda prior to 1968 was based on freehold, but after 1975 freehold tenure was abolished in favor of 199 or 99 year leaseholds. Registrations in Somalia are renewable leaseholds that provide land holders with access rights for 50 years.

The way in which registration programs are implemented and legal statutes are written fundamentally affects tenure security. The allocation of land by chiefs or elders in much of Africa already provides individuals with secure access to land use or the right to bequeath land without legal title definition or registration. Careless imposition of state reforms can, thus, lessen tenure security. For example, land market restrictions in legal statutes increase the transaction costs associated with land transfers. Leasehold rights are generally less secure than freehold rights due to uncertainties over the outcome of lease renewal. Certain land holders may experience tenure insecurity in the presence of registration, particularly households who are unable to afford or acquire title, or family members within registered households who lose rights due to the conventional practice of vesting legal rights in a single individual, usually a male adult. Some level of insecurity will prevail as long as the land code confers an inadequate bundle of rights, the duration of one or more rights is insufficient, or rights are ambiguously defined and enforced.

Measurement of Tenure Security

Devising an objective scale or index of security of tenure is difficult because tenure security is unobservable.[2] A number of alternative proxies have been tried:

1. Strata distinguishing different land tenure systems (e.g., village or ethnic stratification). Tenure security is not measured directly; rather, attributes of tenure security are inferred from differences among performance indicators (e.g., land markets, income, investment, or productivity).

2. The number (bundle) of land rights held, as perceived by the household head or by individual plot holders. The greater the number of individual rights in the bundle of rights conferred by the tenure arrangement, the greater the real or potential value of the land resource to the holder. In recent studies in Ghana, Rwanda, and Kenya, the World Bank used perceptions of land rights as a proxy for tenure security. Binary responses (one if the respondent affirms that a particular right is held, zero if not) were obtained for each of a well-defined set of rights: (1) *use rights*—rights to grow perennial crops, grow annual crops, make permanent improvements, bury the dead, collect firewood, collect wild fruit, and cut trees; (2) *exclusion rights*—right to exclude others from growing crops, collecting wild fruits, gathering firewood, grazing animals, using footpaths, or cutting trees; and (3) *transfer rights*—right to sell, give, mortgage, lease, rent, bequeath, and register.

3. The mode of acquisition, which is correlated with the nature of land rights acquired in the land transaction. Land acquisitions through borrowing or renting typically imply the transfer of certain use rights but not transfer rights. Inheritance normally permits heirs rights of exclusion and temporary transfer (renting) in addition to use rights, while land purchase usually implies the ability to transfer all rights. Parcels acquired on nonlineage land are generally less secure because they face greater risk of being reclaimed by members of the lineage group.

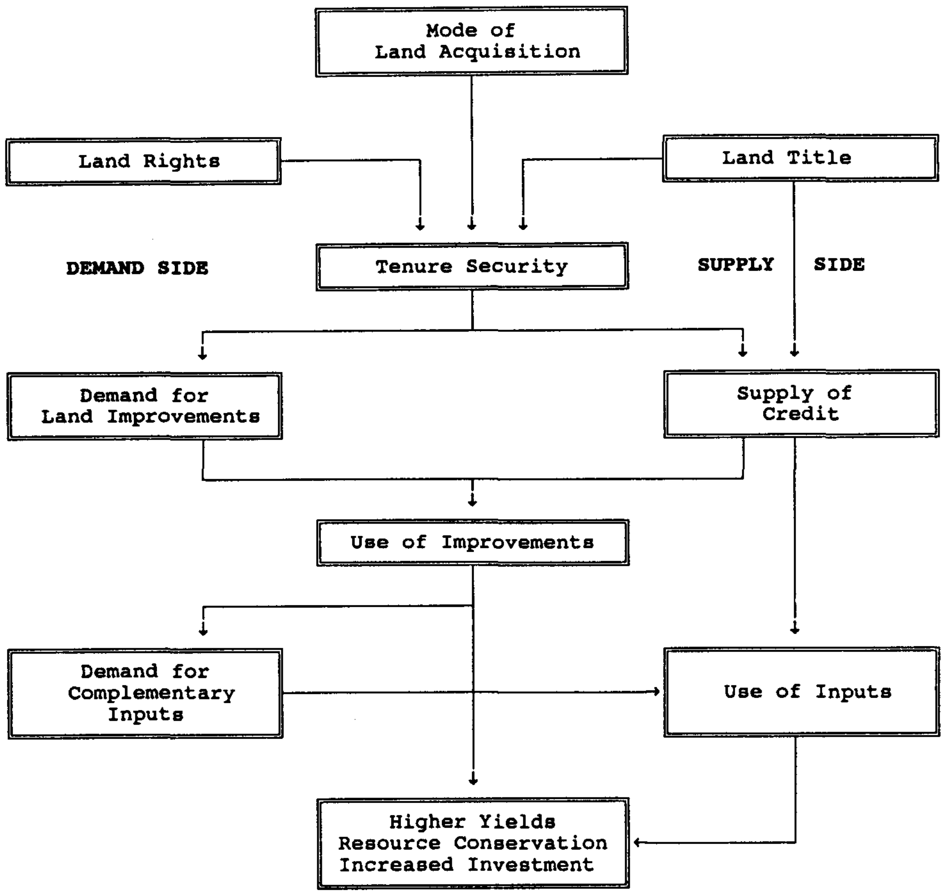
4. The presence or absence of land registration, distinguishing differences between state tenure and indigenous tenure systems.

5. The presence or absence of the land title or registration certificate. Lenders' requirement of the title certificate as proof of ownership in evaluating collateral confers to the certificate an economic rent not provided by registration alone.

General Theoretical Model

A conceptual model relating tenure security to agricultural investment is illustrated in Figure 1. As the figure indicates, tenure security is hypothesized to be in-

Figure 1. Conceptual model linking land tenure with agricultural performance.



fluenced separately and jointly by three types of tenure status—perception of land rights held, mode of land acquisition, and land registration/title. Tenure security, in theory, includes both demand-side (incentives to farmers) and supply-side (incentives to lenders) effects. On the demand side, an enhancement in tenure security would increase farmer demand for medium- to long-term land improvements and, to a lesser extent, for mobile farm equipment. This increase in demand would be derived from two sources. First, greater tenure security would increase the likelihood that the returns from investments will be captured by the operator. Second, increased tenure security would reduce the incidence of disputes, freeing up resources which would otherwise have been used for litigation. Demand for complementary short-term inputs or improvements (e.g., fertilizer and labor) would be expected to increase as well, from enhanced tenure security and/or from land improvements (e.g., higher water retention from construction of ridges increases fertilizer profitability). Given these hypotheses, additional investment would lead to higher yields as long as the farmer has adequate access to viable technologies, inputs, extension advice, household labor, and financial resources.

Because of potential supply-side effects, higher yields are possible even if households lack sufficient financial resources of their own. Individualized tenure accompanied by transferable title may improve the credit worthiness of the land holder, especially for long-term credit, and may enhance the land's collateral value, thereby raising lenders' expected returns. The path breaking work of Feder and Onchan (1987) in Thailand established the importance of transferable land title in increasing the collateral value of the land asset, in increasing title holders' access to formal credit, and in increasing the adoption of land improving investments.

Tenure and Alley Farming in Cameroon, Nigeria, and Togo

Alley farming is a technology in which rows of trees and shrubs are established between rows of annual crops. The trees control soil erosion and produce biomass that can be used as mulch and as livestock feed. Lawry and Stienbarger (1991) explore the relationship between land and tree tenure and the adoption of alley farming in three countries of West Africa's humid zone. Since alley farming involves the planting of trees that mature relatively slowly and remain productive over a long period, Lawry and Stienbarger hypothesize that the adoption of alley farming practices will be strongly influenced by tenure security. The adoption of alley farming is complicated by the fact that customary tenure systems in Africa often associate tree planting with the establishment or enhancement of permanent claims to land. The link between tenure security and alley farming thus rests on two factors: farmers have an incentive to invest in tree planting only on land they expect to control over the long term, and farmers may be permitted to plant trees only on land over which they have an established claim.

Field work was carried out in 1990 in Cameroon, Nigeria, and Togo. While alley farming has been practiced in Nigeria since 1984 (in the form of on-farm trials by ILCA and IITA), alley farming was not observed on sampled farms in Cameroon and Togo. In the latter two countries, tree planting and mulching were investigated as alternative long-term agroforestry and soil fertility-maintenance practices.

The authors distinguish between two types of rights to land. *Primary rights* consist of rights that have been purchased or inherited, where as *secondary rights* consist of rights held under various forms of tenancy, such as rental or sharecropping. While secondary rights are usually held only over the short term and generally involve restrictions on use rights or management practices, primary rights are long-term and permit greater autonomy with regard to land use and management.

In Cameroon, only two of 411 holdings in the sample were tenancies; the remainder were held under primary rights. Of these, 8 percent were purchased, 56 percent were inherited land that had already been divided among heirs, and 34 percent were inherited land that had not yet been divided. Since alley farming was not practiced by farmers in the sample, the planting of nonfruit trees was used as a measure of the potential for alley farming adoption. Nonfruit trees had been planted on 15 percent of purchased parcels, on 8 percent of divided inheritance holdings, and on 4 percent of undivided inheritance holdings (Table 1). Since undivided inheritance holdings remained subject to conflict over the future division of land

Table 1. Tenure and Tree Planting (Cameroon, Nigeria, and Togo).

	Trees Planted			Practicing Alley Farming (Nigeria)
	Cameroon	Togo	Nigeria	
		(Percent of holdings)		
Purchased	14.5	55.8	31.6	31.6
Divided inheritance	7.9	61.3	53.5	48.7
Undivided inheritance	4.4	53.2	38.0	17.6
Secondary rights	-	25.5	26.9	24.4
All	8.1	46.4	44.5	34.3
(n)	411	1196	650	654

Source: Lawry and Stienbarger (1991:26, 31, 37, 43).

rights and purchased land involved the lowest frequency of reported land conflicts, these findings suggest a direct relationship between tenure security and the potential for adoption of alley farming.

Farmers in Togo reported a similar relationship between land rights, land conflicts, and the planting of trees. Of 1,240 holdings sampled, 10 percent were purchased, 25 percent were divided inheritances, 33 percent were undivided inheritances, and 32 percent were held under secondary arrangements. Trees had been planted on 56 percent of purchased holdings, on 61 percent of divided inheritances, and on 53 percent of undivided inheritances. By contrast, trees had been planted on only 26 percent of holdings under secondary rights.

In Nigeria, 654 holdings were sampled, of which 3 percent were purchased, 49 percent were divided inheritances, 34 percent were undivided inheritances, and 12 percent were held under secondary arrangements. Trees had been planted on 32 percent of purchased holdings, on 54 percent of divided inheritances, on 38 percent of undivided inheritances, and on 27 percent of holdings under secondary rights. Furthermore, since alley farming had been introduced in Nigeria by ILCA, it was possible to evaluate patterns of adoption of that specific technology as well. Alley farming was practiced on 32 percent of purchased holdings, on 49 percent of divided inheritances, on just 18 percent of undivided inheritances, and on 24 percent of holdings under secondary rights.

The presence of trees on all tenure categories in Cameroon, Nigeria, and Togo suggest that the indigenous tenure system is not constraining innovation or investment for at least some farms. The data further suggest that tree planting in general, and alley farming in particular, is positively associated with tenure security in the form of strong, clear, and permanent rights to occupy and use land. Primary right holders were more likely to plant trees and adopt alley farming than were secondary right holders. Even among holders of primary rights, those with purchased land and inherited land that had already been divided among heirs enjoyed demonstrated a greater tendency to plant trees than did those with inherited land that had not yet been divided.

Nevertheless, research from Kenya, Uganda, and Somalia (see below) suggests that other factors must also be taken into account before firm conclusions are drawn about the relationship between tenure security and technology adoption. Lawry and Stienbarger note, for example, that the incidence of divided inheritances appears to be positively associated with soil fertility and proximity to residence. The apparent link between tree planting and tenure security may in fact be driven, or at least confounded, by other factors such as land quality and location.

Statistical Analysis of Tenure Impacts in Kenya, Uganda, and Somalia

A preliminary analysis of tenure's impact on technology choice is represented by the comparison of simple means in Table 2 based on survey data from Kenya, Uganda, and Somalia. Households in column A have parcels registered either purposefully or under systematic registration schemes. Column B represents households with unregistered parcels. Data are presented for three research sites: the former white highlands of Njoro, Kenya; the Shalambood irrigation scheme on the Lower Shabelli River in Somalia; and the Rujumbura pilot land registration scheme in Rukungiri district of Uganda.

In all three instances, investment and/or productivity are higher under the registered category. In the case of Kenya, farms with registered title had higher yields (2779 vs. 2254 kg/ha) and profits (3441 vs. 595 Ksh/ha) than did farms without registered land. In Somalia, farms with registered land holdings experienced a higher incidence of investment in equipment leveling (47% vs. 29%), bunding (82% vs. 64%) and fruit trees (13% vs. 3%). In Uganda, farms with all parcels registered showed higher rates of continuous manuring (44% vs. 27%), fencing (35% vs. 9%), grass stripping (38% vs. 27%), stump removal (35% vs. 17%), terracing (42% vs. 4%), and tree crops (mainly coffee) (52% vs. 28%).

Based solely on the analysis of means across strata, the data appear to indicate that enhanced tenure security, in the form of registration, is stimulating higher productivity and investment response through demand and/or supply-side effects. A more thorough conclusion, derived in the subsequent section, is that those who register land, and those parcels that are registered, are self-selected according to specific household (management, wealth, farm size, nonfarm employment) and parcel characteristics (land quality). Once attempts are made to control for these self-selection biases, the impact of the tenure variable weakens or disappears.

Technology Response Controlling for Tenure, Household, and Parcel Characteristics

A more in-depth analysis of the relationship between tenure and selected performance indicators is summarized below for the three case studies and data introduced in Table 2. The theoretical model underlying the following regressions and empirical analyses is described in Appendix A.

Kenya

Carter, Wiebe, and Blarel (1991) investigate the relationship between land registration and farm productivity in the Njoro area of Kenya's highlands. Much of Kenya's highlands were occupied by large white-owned farms during the colonial era. With independence, some of these farms were transferred intact to pri-

Table 2. Simple Means Analysis of Technology Use, Acceptance or Productivity.

	With Registration	Without Registration
	A	B
Kenya:[a]		
No. of farms in sample	64	36
Mean farm size (ha/farm)	5.4	1.6
Maize yield (kg/ha)	2,778.7	2,254.1
Output (maize, beans, wheat, livestock) (Ksh/ha)	6,596.4	7,264.2
Manure (sh/ha)	1.0	28.1
Fertilizer (Ksh/ha)	193.2	60.9
Chemicals (Ksh/ha)	29.5	12.9
Other nonlabor inputs (seeds, livestock) (Ksh/ha)	809.8	982.0
Family labor (Ksh/ha)	1,383.0	3,691.5
Hired labor (Ksh/ha)	408.1	1,720.1
Machine services (Ksh/ha)	330.6	173.7
Profit (Ksh/ha)	3,441.2	595.0
Somalia:[b]		
No. of parcels in sample	38	142
Mean farm size (ha/farm)	9.3	2.3
Parcel investments (% of parcels with)		
Levelling by hand	.0	18.3
Levelling with equipment	47.4	28.9
Bunding	81.6	64.1
Fruit trees	13.2	2.8
Fertilizer (kg/ha)	0.4	0.7
Uganda:[c]		
No. fields in the sample	193	650
No. parcels in the sample	48	213
Mean farm size (ha/farm)	3.7	2.0
Percent of fields w/ input applied:		
Fertilizer	0.0	0.0
Improved seed	2.6	0.8
Pesticide	0.5	0.5
Percent of parcels w/ investment (%):		
Continuous manuring	43.8	26.8
Fencing	35.4	8.9
Removing stumps	35.4	16.9
Terracing	41.7	4.2
Tree crops (mainly coffee)	52.1	28.2

[a] Carter, Wiebe, and Blarel (1991).
[b] Roth, Unruh, and Barrows (Forthcoming).
[c] Roth, Cochrane, and Kisamba-Mugerwa (Forthcoming).

vate individuals or to land-buying companies; many of the latter were eventually subdivided among companies' members. Government resettlement schemes also made smallholdings available to African farmers. Njoro Division, located about 200 kilometers northwest of Nairobi at an elevation of 7,000 feet, contains farms representing the entire spectrum of size and tenure variations, and was the site of field work by the authors in 1986.

The key question is whether differences in productivity among registered and nonregistered farms are driven by enhanced tenure security or whether they reflect underlying differences in access to markets for land, labor, and capital. Since title acquisition is costly, farms with favorable access to markets are more likely to acquire title. The nonrandom separation of the sample into titled and untitled farms means that the effects of these other factors must be considered explicitly.

Two regressions presented in Table 3 illustrate the relationship between productivity and registration while controlling for market access. The dependent variable in the first regression is the total value of all crops produced per cultivated acre (in log terms). The dependent variable in the second regression, family income per acre, is the per-acre value of all crops

Table 3. Yield Regression Results, Njoro, Kenya.

	Coefficient	Std Error	T-statistic	P-value
Regression A. Ln (Output/Acre)[a] on:				
Constant	8.014	0.234	34.217	0.000
Ln(Size)	-0.531	0.219	-2.424	0.017
$Ln(Size)^2$	0.171	0.078	2.194	0.030
Title[c]	-0.083	0.448	-0.185	0.854
Title*Ln(Size)	0.032	0.251	0.129	0.897
LBC[c]	0.961	0.259	3.708	0.000
LBC*Ln(Size)	-0.395	0.143	-2.761	0.007
n = 109				
$R^2 = 0.28$				
Regression B. Family Income/Acre[b] on:				
Constant	2290.911	584.638	3.919	0.000
Ln(Size)	-1239.767	546.686	-2.268	0.024
$Ln(Size)^2$	416.371	194.459	2.141	0.034
Title[c]	251.083	1117.337	0.225	0.823
Title*Ln(Size)	-3.921	626.918	-0.006	0.995
LBC[c]	1603.682	647.476	2.477	0.015
LBC*Ln(Size)	-844.670	357.090	-2.365	0.020
n = 109				
$R^2 = 0.14$				

a Value of all crops produced per cultivated acre (in log terms).
b Per-acre value of all crops less value of all inputs besides family labor.
c Title and LBC are dummy variable for title possession and land-buying company participation, respectively.

Source: Carter, Wiebe, and Blarel (1991:32).

produced less the value of all inputs other than family labor. Several indicators are employed as proxies for market access, including farm size and mode of land acquisition.[3] Of 109 farmers surveyed, 39 percent had acquired their land through land-buying companies, 52 percent through settlement schemes, and 8 percent rented or borrowed the land they farmed.

Once market access is incorporated in the regression analysis of agricultural productivity, title status loses its significance as an explanatory variable (Table 3). By contrast, both farm size and mode of land acquisition are highly significant in explaining the two indicators of productivity. Output value and family income per acre exhibit a "U-shaped" relationship with farm size, decreasing at first as the intensity of family labor application falls, and then increasing as the intensity of fertilizer, chemicals, and machine services rises with farm size. Farms of about 10 acres were the least productive, representing the bottom of the "U" shaped curve; these farms were too large to apply family labor intensively but too small to enjoy favorable access to working capital for purchased inputs.

While agricultural productivity does not appear to be affected by differences in title status *across* farms, the authors point out that title may still influence investment and productivity on individual fields *within* a given farm. Acquisition of title for a particular field would increase the farmer's incentives to invest in improvements on that specific field. However, by improving the collateral value of the farmer's holdings, the change in title status should increase the farmer's access to credit in general, permitting increased investment on all fields. Observations of higher productivity on titled fields within farms that hold land under multiple tenures would, thus, provide evidence of demand-side effects of tenure security. Nevertheless empirical analysis did not support this hypothesis. In fact, application of fertilizer was highest on rented fields, as was the output of the area's principal crop, maize, suggesting that rented land is operated by farmers who are relatively well-placed in terms of access to markets and resources.

These findings support the conclusion that it is favorable access to market opportunities, rather than title status per se, that drives observed differences in agricultural productivity in Kenya. The authors draw two broad conclusions. First, while there are compelling theoretical reasons to predict that enhanced tenure security will lead to increased innovation and productivity, higher yields are driven in practice by factors affecting market access (farm size, mode of acquisition) while title has no significant influence. Second, evidence that title acquisition does not increase productivity, even on registered parcels within farms holding both registered and unregistered land, suggests that title is not considered necessary for tenure security by farmers in Njoro Division.

Uganda

Kigezi District lies in the extreme southwest corner of Uganda. Three-quarters of the District is covered by rugged escarpments and steep-sided mountains that rise to over 8,000 ft. and deep, precipitous gorges and valleys that sometimes descend below 5,000 ft. This mountainous terrain changes to undulating landscape on the eastern boundary of the Ankole District. Moderately sloping hillsides and valley floors provide rich and cultivable soils, but the more rugged hillsides contain rocky soils that are easily eroded. Competition for land is keen. As early as 1970, population pressure had begun to push cultivation onto these marginal hillsides with a marked increase in soil erosion (Obol-Ochola, 1971).

Rujumbura was the first county in the Kigezi District to be targeted for registration under the 1955 Land Tenure Proposals. Nyakaina was the first parish selected for adjudication and registration in the county, later to become known as the Rujumbura Pilot Land Registration Scheme. In 1987, a study was conducted on tenure security and land registration in Nyakaina, and in a bordering parish, Kyamakanda (Roth, Cochrane, and Kisamba-Mugerwa, Forthcoming). The research design targeted data collection at three principle strata of households: Nyakaina registered land holders (n = 100 households), Kyamakanda registered land holders (n = 40), and Kyamakanda nonregistered land holders (n = 100).

Logit regression analysis was used (see Table 4) to examine the effect of registration on six intermediate-term and long-term, fixed-place investments. Intermediate-term investments with benefits occurring over a one to five year time horizon include continuous manuring, mulching, and fencing. Long-term investments with benefit streams occurring over a longer time horizon include tree crops (mainly coffee and bananas), terracing, and nonfarm buildings (dwelling, rental unit, restaurant, pub, or shop). The investment variable is binary (1 if the investment is present; 0 if not); attempts to gauge the value, cost, and scope (i.e., area covered within the parcel) of the investments, in practice, proved to be prohibitively difficult.

Investment demand may be influenced by a number of household-level attributes: experience, measured in this analysis by age of household head; managerial skills of the household head, measured by years of education; political status, measured by current or past involvement in one or more political offices; farm involvement, measured by whether the household head is a full-time farmer; wealth, measured by either household income, livestock (standardized units) owned, or land-per-resident ratio; and land dispersion or exposure to disputes, measured by number of parcels held.

A priori, it is expected that experience and managerial skills would increase the likelihood of an investment occurring through application of improved techniques and better farm management. The model results in Table 4 indicate that age of household head has a modest positive effect on manuring, fencing, tree crops and terracing, but results are significant only for fencing (.048). Age has a significant negative effect (-.035) on the probability of investment in nonfarm buildings, indicating that these investments are being undertaken by younger household heads. Results for the education variable are mixed, but the positive coefficient for nonfarm buildings (.464) is the only one that is significant. Education, thus, appears to open up small-scale business opportunities and to encourage diversification of economic activity.

Political status would have a negative effect on investment if time is diverted away from farm management, but would have a positive effect if it increases control over labor in the community, enhances access to inputs, improves financial management or strength, or increases acceptance of new technology. However, results are mixed, and only for mulching (.757) is the likelihood of investment significantly improved with political status.

Table 4. Logit Investment Models and Registration, Uganda Land Registration Study.

	Continuous Manuring	Mulching	Fencing	Tree Crops	Terracing	Nonfarm Bldgs
Constant	-1.175	-.488	-4.157*	-3.938	-2.821	-2.122*
	(.940)	(.782)	(1.025)	(1.192)	(1.681)	(1.036)
Parish (Kyamakanda=1)	0.53	-.796*	-.650*	-1.093*	-3.130*	.319
	(.305)	(.260)	(.322)	(.288)	(.690)	(.398)
Location (in parish=1)	.403	1.558*	.387	2.420*	.781	-.699
	(.579)	(.471)	(.563)	(.927)	(1.082)	(.551)
Size of parcel (acres)	.031	.033	.082*	.085*	.011	.007
	(.033)	(.030)	(.037)	(.031)	(.052)	(.034)
Flat land (y=1)	-1.266*	-.613*	-.456	-.722*	-3.500*	.300
	(.358)	(.259)	(.385)	(.329)	(1.098)	(.353)
Swamp/other land (y=1)	-.523	-.353	.935*	.411	-2.502*	-1.003*
	(.359)	(.287)	(.349)	(.327)	(1.107)	(.458)
Access road present	1.228*	.421**	.646*	.818*	2.109*	.391
(y=1)	(.260)	(.238)	(.293)	(.258)	(.468)	(.326)
Registration (y=1)	.682*	.521*	.869*	.329	.281	.521
	(.315)	(.263)	(.325)	(.289)	(.608)	(.389)
Investment made prior	.917	.118	-1.071	-.319	-1.918	
to acquisition (y=1)	(.615)	(.251)	(1.165)	(.445)	(39.520)	
Ownership time (years)	.006	.008	-.025*	.021*	-.031**	.001
	(.011)	(.009)	(.011)	(.010)	(.019)	(.014)
Age household head	.006	-.001	.048*	.009	.032	-.035*
(years)	(.011)	(.010)	(.013)	(.011)	(.021)	(.016)
Education household head	-.219	-.186	.063	.130	-.219	.464*
	(.210)	(.181)	(.229)	(.206)	(.393)	(.222)
Full-time farmer (y=1)	-.904*	.047	-.495	.020	-.063	-1.146*
	(.299)	(.272)	(.345)	(.319)	(.581)	(.363)
Political office (y=1)	.373	.757*	-.131	-.052	-.107	.494
	(.272)	(.235)	(.311)	(.267)	(.566)	(.333)
Total family income	-.060	.094	.055	-.030**	.010	.170*
('000)	(.100)	(.100)	(.200)	(.010)	(.030)	(.040)
No. livestock units	.081*	-.029	.044	.009	-.021	-.054
	(.029)	(.026)	(.029)	(.028)	(.040)	(.034)
No. parcels	-.319*	-.233*	-.118	-.101	-.342*	.531*
	(.095)	(.067)	(.077)	(.074)	(.153)	(.097)
Land/resident ratio	.078	.009	.070	-.043	.320**	.286*
	(.098)	(.087)	(.098)	(.089)	(.168)	(.099)
No. observations	480	480	480	480	480	480

Note, * = significant at the 5 % confidence level; ** = 10 % level. Figures in parentheses are standard errors of the coefficient. A squared term for income was also included to control for outlier points, but were found to be nearly zero and insignificant.

Source: Roth, Unruh, and Barrows (Forthcoming).

Degree of farm involvement can also produce different theoretical outcomes: full-time farming would have a positive effect on investment demand if greater effort and management are applied to the farm enterprise, or a negative effect if it results in entrenchment of old ideas and techniques, reduced exposure to government services, or to less involvement in markets. Model results show that being a full-time farmer significantly decreases the incidence of continuous manuring (-.904) and nonfarm buildings (-1.146). The likelihood of mulching, tree crops, fencing, and terracing are not significantly affected.

Wealth would have a positive effect if it helps relax financial constraints or if economies to scale are realized from larger farm size. It would have a negative effect if households are unable to attract sufficient labor to fully operate the farm enterprise, if it increases leisure time, or if it dampens economic initiative. Results show that family income has a positive effect on nonfarm buildings (.170), but a negative effect on tree crops (-.030). Livestock ownership has a significant positive effect on continuous manuring (.081). Those households with higher land per resident ratios are more likely to invest in terracing (.320) and nonfarm buildings (.286).

Greater dispersion of land holdings could have a negative impact on investment from two sources. A higher number of parcels would increase exposure to disputes, particularly if those parcels are widely dispersed and far removed from the household. Number of parcels is also a crude proxy for fragmentation, and for higher labor costs in farming activities. Model results indicate that increasing the number of parcels has a significant negative impact on manuring (-.319), mulching (-.233), and terracing (-.342), but is positively related to investment in nonfarm buildings (.531).

Land investment could also be influenced by parcel characteristics: locational factors, measured by location of parcel relative to place of residence, to access roads, and to parish location; land quality, measured by size and terrain of parcel; investment status, that is, whether the investment was already present at the time of acquisition; temporal attributes, measured by ownership time; and registration status, that is, whether the parcel is registered, regardless of whether title is held.

Three proxy variables are incorporated in the model to control for locational factors affecting investment decisions. Parcel location relative to the homestead is a crude proxy for enforcement costs associated with monitoring and enforcing investment claims. Parcels further away from the homestead (outside the parish) would be expected to experience more disputes and higher tenure insecurity than parcels nearer the homestead (within the parish). Results indicate that closer proximity increases the likelihood of all farm investments (except buildings), and significantly so for tree crops (2.420) and mulching (1.558). Presence of an access road prior to acquisition was included as a proxy for ease of access to markets and ease of monitoring and enforcement. Presence of an access road increases the likelihood of terracing (2.109), manuring (1.228), tree crops (.818), fencing (.646), and mulching (.421). Parish location is incorporated to capture the effects missed by other parcel and household characteristics. Location of a parcel in Kyamakanda tends to significantly decrease the odds of terracing (-3.130), tree crops (-1.093), mulching (-.796), and fencing (-.650), suggesting that latent structural differences between the two parishes are affecting investment demand.

Mixed results are obtained for land quality attributes. Larger parcel size increases the probability of all investments being undertaken, but the effect is not great, and is significant only for tree crops (.085) and fencing (.082). Continuous manuring, mulching, and terracing generally tend to be undertaken on hilly land, indicated by negative coefficients for flat land and swampy/other land. Fencing and tree crops are more likely to occur on hilly and marginal lands (swampy land and other).

Ownership time (years passed since acquisition) is included as a proxy for the time required to make, and to accumulate capital for, land improvements. In the first few years following parcel acquisition, increasing ownership time would be expected to have a positive impact on investment. However, once long-term improvements are made, further investments are unnecessary until their benefits are fully exhausted. Thus, ownership time is theorized to have a zero or positive effect on short-term investments, but a negative effect on long-term investments. Results for short-term investments (continuous manuring, mulching) are positive, as expected, but not significant. Results for longer term investments such as fencing (-.025) and terracing (-.031) are negative and statistically significant.

Investment status is incorporated in the model to control for investment already in place at the time of acquisition. The presence of long-term investments at acquisition would have a negative effect on post-acquisition investment as long as the investment at acquisition covered the entire parcel, and ownership time has not exceeded the investment's residual income stream. The effect for short-term investments (fertilizer) would tend to be zero or positive if habits have formed in management practices. Model results show that presence of the investment at time of acquisition has a positive (but insignificant) effect on continuous manuring and mulching, and a negative (also insignificant) effect on fencing, tree crops, and terracing.

As for tenure status, registration has a significant positive effect on fencing (.869), continuous manuring (.682), and mulching (.521), all yielding intermediate payoffs, and a positive but insignificant effect on investments in tree crops, terracing, and nonfarm buildings. Thus, the effect of registration is highly variable across investments and is confounded by locational factors (parish, roads), market access (size of parcel and farm), and parcel quality indicators.

Somalia

The Shalambood research site consists of an 8,500-hectare area on the Lower Shabelle River near Merca at the heart of Somalia's principal food and export crop-producing region. Boundaries of the site mark the area of the Shalambood irrigation scheme, which was developed by the Italians starting in 1926. The boundaries of the scheme enclose 63 former Italian Aziendas. The majority of the Italian owners departed before or shortly after Somalia's independence in 1960, leaving the land to the government, to the farm workers, or to private investors. Water for irrigation comes from the Genale reservoir and flows by gravity through the Dhamme Yassin primary canal and a web of secondary and tertiary canals to farmers' fields. The irrigation scheme has fallen into a state of disrepair and is badly in need of rehabilitation; poor water control causes water shortages over wide areas in the dry season and excessive flooding on parts of the scheme during the rainy season.

An in-depth survey of unregistered and registered farmers in the Shalambood irrigation scheme was undertaken from May 1987 to January 1989 (Roth, Unruh, and Barrows, Forthcoming). Stratified random sampling techniques were used to obtain information from two strata of land holders: 77 unregistered small holders and 36 registered small holders. Regression models were fitted to parcel-level data to explain the likelihood of adoption of four separate fixed-place investments on irrigable land: leveling by machine (a binary variable, 1 if the investment has been undertaken, 0 if not); leveling by hand and machine (pooled observations); bunding (again, a binary variable); and value of time and cash expenditures spent on canal maintenance. Logit regression analysis was used to estimate the models for leveling and bunding; OLS regression was used to estimate the equation for canal maintenance.

Each set of investments embodies different demands for labor and capital. Bunding is the most widespread investment (124 of 183 parcels had bunding present). Bunds are constructed by hand to control the direction and flow of irrigation water within the parcel or to control flood waters. Leveling is considered by farmers to be the most important and constraining technology affecting productivity on the scheme. The best leveling requires machines, although machine leveling is expensive. Other things being equal, enhanced tenure security would be expected to have the greatest influence on equipment leveling and the weakest influence on bunding.

Canal maintenance is essential to ensure water delivery. Canals become clogged with silt and weeds and require frequent cleaning. Excavators owned by the government periodically clean the primary and secondary canals, for which households contribute money. Households lacking sufficient labor also pay the local Water Users Association for canal maintenance. The investment variable for canal maintenance is the logarithmic transformation of total cash outlays spent on canal maintenance (i.e., actual cash payments plus the imputed value of days worked).

Model results in Table 5 show that parcel size has a positive effect on leveling (.543 and .719), indicating economies of scale in mechanized operations, or the greater ability of larger farms to hire workers. The significant positive effects observed for commercial wealth (value of buildings, shops, and equipment) (.001) and animal wealth (.149) indicate that households are meeting the cash requirements for mechanical leveling through nonfarm activities. Leveling also tends to increase with family size (.106 and .122), years of residency (.033 and .027), and with official government status (1.070). Improvements in water access tend to reduce leveling demand (-.502), as the greater water availability lessens the need to spread water evenly and prudently throughout the parcel. Leveling also tends to decline with deterioration in the quality of the canals (-.135 and -.095), affirming that canal leakage assists water spreading.[4]

While the positive relationship between parcel size and leveling indicates the presence of scale economies in mechanization, the negative relationship between leveling and farm size (-.476 and -.695) indicates either a resource constraint (resources are too limited to carry out level-

Table 5. Investment Demand Regressions, Somalia[a].

	Machine Leveling	Hand and Machine Leveling	Bunding	Canal Maintenance
Constant	1.463	1.242	1.613	1.341**
	(1.341)	(1.229)	(1.133)	(.345)
Distance (minutes)			-.016**	.002
			(.008)	(.002)
Color and texture index	.149	-.028		-.080
	(.200)	(.180)		(.061)
Slope index	.534**	.605**		-.184**
	(.230)	(.205)		(.061)
Ease of tillage/compaction	-.327*	-.207	.568**	
	(.198)	(.190)	(.214)	
Fertility and parcel quality	.348*	.226		
	(.212)	(.192)		
Irrigation water use	-.027	-.011	-.267	.172**
	(.251)	(.238)	(.282)	(.079)
Access to irrigation	-.502**	-.231	1.106**	.206**
	(.220)	(.191)	(.240)	(.062)
Size of parcel (ha)	.543**	.719**	.191	.125**
	(.209)	(.204)	(.232)	(.052)
Ownership term (years)	.017	-.011	.032	.017**
	(.023)	(.021)	(.023)	(.006)
Quality of canal index	-.135**	-.095**	-.096**	-.030**
	(.046)	(.040)	(.043)	(.013)
Age of household head	-.057**	-.038**		
	(.025)	(.019)		
Sex of hh head (1=male)	-2.246**	-2.049**	1.167	-.271
	(.729)	(.738)	(.735)	(.239)
Years hh resident in area	.033*	.027*	-.018	
	(.018)	(.014)	(.013)	
Government official (y=1)	1.070*	.858	-1.102*	
	(.573)	(.538)	(.581)	
Family size (persons)	.106*	.122**	-.012	.041
	(.062)	(.056)	(.097)	(.029)
Days nonfarm work (family)				.001**
				(.000)
Total number of parcels	.505	.995**	-.171	.163
	(.418)	(.409)	(.382)	(.117)
Total farm size (ha)	-.476**	-.695**	.152	-.055
	(.197)	(.194)	(.168)	(.049)
Wealth ('000 Sh, log)	.001*	.001		.000*
	(.001)	(.000)		(.000)
Standard stock units (SSU)	.149**	.077	-.101	.044**
	(.071)	(.064)	(.062)	(.019)
Title (parcel titled) (y=1)	.236	-.290	-.041	-.197
	(.607)	(.568)	(.638)	(.181)
Number of parcels	183	183	183	183

[a]Figures in parentheses are standard errors. *=coefficient significant at the 10% level, **=coefficient significant at 5% level.
[b]Family workers
Source: Roth, Unruh, and Barrows (Forthcoming).

ing on all parcels) or a lack of need (the largest framers are positioned adjacent to the primary canal). Leveling also tends to decline with the age of the household head (-.057 and -.038), or if the household head is male (-2.246 and -2.049).

The likelihood of bunding tends to increase with ease of tillage (.568) and with greater availability of irrigation water (1.106). Bunding also tends to increase with farm size, parcel size, and ownership term (years parcel held), although results are not significant. The significant negative coefficient for distance (-.016) indicates that bunding tends to be carried out on the periphery of the scheme, further from the primary canal. As the quality of canal improves, the incidence of bunding tends to decline (-.096). More bunding tends to be carried out by males, partly due to the superior location of mens' parcels relative to the primary and secondary canals. Bunding also tends to decline with years of residency, number of parcels, animal stock units, and official government status (-1.102).

The imputed cash value of costs for canal maintenance tends to increase with higher irrigation water use (.172), water availability (.206), size of parcel (.125), distance, ownership term (.017), number of parcels, and size of family work force; all are consistent with the expectations. The positive relationship between canal maintenance and days of nonfarm work (.001), wealth (.000), and standard stock units (.044), again reinforces the hypothesis that farmers are turning to nonfarm sources of employment or income to finance canal improvements. Canal maintenance tends to decline as topography becomes flatter (-.184), as canal quality deteriorates (-.030), with male-headed households, and with farm size.

The effect of registration is mixed and highly insignificant across models. The apparent inconsistency in results between Tables 2 and 5 (i.e., a higher incidence of investment for registered households in Table 2 but registration having no significant effect in Table 5) is due to the high correlation between registration and other household and parcel characteristics that influence investment. Possession of registration is positively correlated with size of parcel (ρ = .504), irrigation water use (ρ = .397), farm size (ρ = .357), years of education (ρ = .254), involvement in any past land disputes (ρ = .213), official status (ρ = .177) and wealth (ρ = .172), and is negatively correlated with years of residency (ρ = -.259) and total number of parcels (ρ = -.206); all are significant at the .01 level. Those who acquire registration, thus, tend to be younger, wealthier, and better educated, tend to have official status and larger farm sizes, and tend to have experienced land disputes. Parcels that get registered tend to have better access to irrigation water. The fact that any households sought to acquire registration implies a derived demand for enhanced tenure security. Nevertheless, other factors—managerial capacity, market access, and land quality—appear to be more important than registration in influencing investment response in the Somalia case.

Conclusion

This paper has provided theoretical and empirical evidence that tenure security is necessary, but not sufficient, for the adoption of productivity-enhancing technology in agriculture. Depending on the social and economic conditions prevailing in any given area, indigenous tenure systems are capable of providing adequate tenure security, as was found to be the case with respect to tree planting and alley farming in Cameroon, Nigeria, and Togo. The analysis of data from Kenya, Uganda, and Somalia indicate that simple correlations between tenure status and performance indicators can lead to spurious conclusions about tenure's effect, and that the effect of tenure security on technology adoption may be overwhelmed by other factors, including market access.

As long as constraints on access to input and output markets limit incentives to innovate and invest, tenure security itself does not represent a binding constraint on technology adoption in most of sub-Saharan Africa. Of the 228 households surveyed in Uganda, only 15 obtained loans during the previous five years, and few of these came from commercial sources. In the Somalia study, only four loans had been taken out by smallholders in the previous year, none of them from commercial sources. Formal borrowing in the Kenya sample was limited to large farms with titles. However, the rural-urban terms of trade that worked against agriculture in the 1970s and 1980s have now begun to shift in favor of agriculture, thereby increasing pricing incentives and the potential for increased demand for investment, credit, and complementary inputs. If, along with these enhanced incentives, there is an easing of constraints on the supply of inputs and credit, tenure security may eventually become a binding constraint on innovation and investment. Such a development would be expected to induce demand by farmers for enhanced tenure security. Evidence of this demand is already available in specialized settings such as irrigation schemes, peri-urban areas, and projects involving costly fixed-place investments (i.e., tree-planting). Uchendu (1970) and Shipton (1989) note the emergence of individualized forms of tenure in the context of population growth and agricultural commercialization in Africa; in such cases, tenure itself becomes the subject of institutional innovation.

However, tenure change leading to titling and registration is not likely to result from a general disaffection with indigenous tenures on the part of subsistence farmers. Rather, such reforms are likely to be initiated by entrepreneurial farmers who lack rights to land in the local tenure system, or who are prevented by customary prohibitions on land sales from accumulating holdings of desirable size and quality. Entrepreneurial behavior arises where some farmers, based on superior market access and on greater willingness to take risks, perceive gains from innovation and commercialization. Realization of such gains often requires changes in institutions, including tenure, supportive of new forms of economic activity. Title may facilitate the flow of credit, financing forms of investment generally not undertaken by subsistence farmers.

Thus, the rise of commercial agriculture will generate demands for land reform, at least among an entrepreneurial group. Implementation of reforms based on state registration may result in a scramble to register by noncommercial farmers as well, because of the insecurity generated by the displacement of indigenous tenure forms and institutions. Changes in agrarian structure, including tenure changes, can result in serious social problems in rural areas. Effective titling and registration systems are costly to establish and maintain, and tenure insecurity can result where they are not properly implemented or successfully institutionalized. Furthermore, productivity differences that arise from differential patterns of technology adoption may lead to long-term changes in agrarian structure as land markets become active. Entrepreneurial farmers with large holdings are often best positioned to capture the benefits of new technologies.

It is the expectation of significant returns to technology adoption and investment that may lead entrepreneurs to accumulate land, and where indigenous tenure rules constrain land access, to press for tenure changes based on titling and registration. If successful adoption of productivity-enhancing technologies is highest on large farms, Binswanger and Rosenzweig (1986) and Carter and Wiebe (1990) note the potential for increasing inequality in the distribution of land holdings over time. Market-based accumulation strategies, unchecked by local social controls, can lead to skewed patterns of land ownership on a scale unprecedented under indigenous tenures. This, in turn, can contribute to landlessness and premature migration to urban areas, where employment opportunities remain extremely limited.

This outcome can be mitigated to a certain extent through the development of technologies more accessible to smaller holders, through the development of scale-neutral and relatively low-cost technologies, through programs aimed at increasing smallholders' market access, and through the formulation of policies more supportive of smallholder participation in commercial agriculture. In the absence of such support, it is likely that the economic benefits of technical and institutional innovations will accrue to a very small proportion of the rural population. Furthermore, to the extent that increased productivity leads to lower producer prices through an output effect, the majority of rural producers, as nonadaptors, become worse off.

Implications for the CRSPs

Given these and other research findings, a number of specific implications are pertinent to CRSP research.

First, tenure security, in most instances, will not be a constraint to the adoption of improved technology for which the benefits are recovered over a short-time horizon (fertilizer, new seed varieties). However, for investments of intermediate or long-term horizon, as for complementary inputs dependent on such investment, tenure security is an important factor to take into consideration.

Second, tenure security is probably less important as a constraint on technology adoption than are other constraints, including access to credit, market access, farmer skills, and cash crop production opportunities. In these situations, the greatest returns to the CRSPs are likely to come from efforts to ease constraints on access to resources and market opportunities, rather than from improvements in tenure security. However, in a dynamic environment of technical change, where these constraints are alleviated and demand for innovation is robust, tenure security can pose an important constraint on technology adoption. Although very few studies of farm efficiency have been attempted in Africa, smallholders are generally more efficient in mobilizing labor and conserving capital. While smallholders may not currently have economies of size in marketing, their potential economies of size in production may well justify public investments in infrastructure that lower marketing costs.

Third, women provide the lion's share of agricultural labor in Africa. Despite a widespread literature indicating women's disadvantaged access to inputs, credit, and government services, very little attention has been given to gender issues in tenure security and investment decisions. Research focusing on small farmers' (particularly women's) access to extension services, credit, and input and output markets remains a priority.

Fourth, in certain situations, tenure security does become a binding constraint on technology adoption. Such situations include areas characterized by population pressure and commercialization. Adoption of technologies such as improved seed varieties or chemical fertilizers, which offer returns in the current production cycle, may not be constrained by farmers' (demand-side) concerns about losing their land, but may still be constrained by lenders' (supply-side) reluctance to extend credit for working capital to untitled farms. By contrast, innovations or technologies requiring longer term, fixed-place investments (such as irrigation or alley farming) will be constrained by both demand- and supply-side constraints. Adoption of CRSP-generated technologies may be increased by encouragement of tenure security-enhancing measures, whether these take the form of land titling and registration or reinforcement of evolving indigenous tenure systems. Alleviation of supply-side concerns will require additional attention to credit markets, perhaps including public guarantees of working capital loans to farmers lacking collateral.

Fifth, the pace and pattern of new technology adoption will generally be shaped by—and will tend to reinforce—existing patterns of unequal access to resources and markets. CRSP attention to patterns of technology adoption is, thus, essential not only to increase agricultural production, but also to encourage an equitable path of rural economic development over the long term.

Appendix A: The Model

The conceptual model in Figure 1 can be formalized into a five-equation structural model for a given household, under the assumption that the proxy measure of tenure status is exogenous:

A. Household level

(1) $C = f(HC, TS^*, r, P, T)$ *Demand for Credit*

B. Parcel level

(2) $L = f(HC, PC, P, CS, TS, C)$ *Demand for Land Improvements*

(3) $I = f(HC, PC, P, TS, C, L)$ *Demand for Complementary Inputs*

(4) $Y = f(HC, PC, L, I)$ *Yield*

(5) $TS = f(T)$ *Tenure Security*

where C is credit, L is land improvements, I is inputs, Y is yield, TS is parcel-level tenure security, HC is a vector of household characteristics (including managerial skills, labor access, income, wealth and market access), TS^* is a composite household measure derived from the tenure security of individual parcels, r is the cost of credit, P is a vector of input and output prices, T is tenure status, PC is a vector of parcel characteristics measuring land quality, and CS is the cost of land improvements. Credit access in equation (1) is influenced by household-level characteristics, tenure security, prices, the cost of borrowing, and tenure status in the event that possession of land title increases collateral value. Levels of investment in land improving technologies or input use in equations (2) and (3) are influenced by input and output prices, investment costs, levels of tenure security in the parcel, household credit availability, and household and parcel characteristics. Yields in equation (4) are influenced by household and parcel characteristics, land improvements, and input use. Equation (5) implies that tenure security (TS) is some function of tenure status (T).[5]

Because of the recursive nature of the model it is possible to eliminate the endogenous variables which appear on the right hand side of equations (1) to (4), creating the following set of reduced-form equations:

(1a) $C = g(HC, r, P, T)$ *Demand for Credit*

(2a) $L = g(HC, PC, P, CS, T)$ *Demand for Land Improvements*

(3a) $I = g(HC, PC, P, T)$ *Demand for Inputs*

(4a) $Y = g(HC, PC, P, T)$ *Yield*

The coefficient associated with tenure status measures the total direct and indirect impacts of tenure security on the performance indicators (C, L, I, Y) while holding other household and parcel characteristics constant. The estimate obtained in equation (4a), for example, measures the sum of the indirect effects of tenure security (through credit, land improvements, and inputs) on crop yields (Y).

A present value model such as that developed by Carter, Wiebe and Blarel (1991) represents an alternative approach for studying returns to enhanced tenure security:

(6) $E(PV_{ik}) = \Sigma_t \{[1-\o_{kt}(T_k)]\pi_{ikt}(M) / [1+r(T,M)]^t\}$

where the expected present value of returns to the i-th investment on the k-th parcel is the weighted, discounted sum of the yearly net income stream (π_{ikt}) generated by the i-th investment in each year "t" over the life of the investment. The term "$\o_{kt}$" is the probability that the farmer is evicted from the k-th parcel in the t-th year, and is a function of the tenure status of that parcel. Expected annual net returns from the investment on the k-th parcel is thus the value of the annual income stream ($\pi_{ikt}(M)$) weighted by the probability of actually realizing those returns ($1-\o_{kt}$). The term "r(T,M)" is the discount rate on the investment, and by convention is the shadow price of capital on the farm. Variables "T" and "M" measure tenure status and market access respectively, where market access, including household-specific input and output prices, is a function of household and parcel characteristics such as wealth, education and parcel size. The i-th investment is assumed to be undertaken if:

$$(7)\ E(PV_{ik}) > CS_t$$

where CS_t measures the direct costs of the investment in the current period. The i-th investment is worthwhile if the discounted present value of the investment exceeds the investment cost. Enhancements in tenure security have the effect of lowering rates of eviction. As the eviction probability declines, the present value of the net income stream increases, resulting in enhanced incentives for technology adoption. The greater investment effect would be reflected over time by higher productivity and net returns.

Notes

1. As land rights are often secure for the season, tenure security is generally less of a concern for short-term inputs (fertilizer) or innovations (new seed varieties) than for capital improvements with benefit streams occurring over a long time horizon (terracing, irrigation).

2. The presence of long-term capital investments is not a reliable proxy. Long-term investments may be undertaken, regardless of tenure status, to meet minimum food security needs. Conversely, investments may not be undertaken even in the presence of tenure security because of constraints on managerial skills, labor, capital, or access to complementary inputs.

3. Participation as buyers through a company implies greater capital access than obtaining land through resettlement schemes, as participants in the latter were selected precisely because of their inability to compete in the land market.

4. The quality of canal variable is a rank measure of canal quality, ranging from 1 (the canal leaks all the time and the leakage is very severe) to 8 (no leakage).

5. Farmer recall of input and output prices and investment costs are complicated in African economies by the widespread use of nonmonetary transfers and payments. Family labor is particularly difficult to value. Determining "real" prices and costs over time is further complicated by unreliable inflation figures. For these and other reasons, prices were omitted from the investment and productivity regressions presented in this paper.

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Risk and Public Goods: Implications for Technology Development

Jean-Paul Chavas

Technological progress has played a crucial role in improving agricultural productivity in the past decades. It has increased world food production significantly and allowed the feeding of a rapidly expanding human population (Mellor and Johnston, 1984). For example, the so-called Green Revolution has contributed to a large increase in farm production around the world. However, the benefits of these productivity gains have not been evenly distributed across individuals or nations. Over the last two decades, many African countries have exhibited relatively low farm productivity gains. Given a rapidly increasing population, agricultural output per capita, which was already low, actually declined in the 1980s in sub-Saharan Africa (Craig, Pardey, and Roseboom, 1991:175). Also, the use of new technologies has sometimes produced adverse effects on the environment. Given the current pressure on land and natural resources, the process of technological change in agriculture and its role in economic development are being reassessed.

The development and implementation of technology in agriculture is subject to much uncertainty. First, by definition, the creation of new technology and new knowledge is not known ahead of time and is, thus, uncertain. This uncertainty is fundamental and must be taken into consideration in the design and evaluation of agricultural research. Second, because agricultural sectors around the world face many sources of variability, such as unpredictable rainfall and market instability, they tend to be unstable (Blandford, 1983). This instability implies that farm decisions are always made in a risky environment.[1] This risk, in turn, has implications for the allocation of agricultural resources and for technological adoption by farmers. Moreover, because the adoption of new technologies typically involves learning-by-doing, there is some additional risk. Thus, risk or uncertainty can be expected to influence both the supply (i.e., creating a new technology) and the demand (adopting a decision) for technology. This suggests a need to understand better the role of risk in the process of technological change. This also raises the question of how to manage this risk in order to help stimulate productivity growth in agriculture. For research institutions, as well as for farmers, "risk management" consists of reducing uncertainty over time through efficient processing of information and learning. It can also involve risk reduction through private diversification or the development of insurance and risk-sharing schemes in society.

The objective of this paper is to evaluate the role and implications of risk for technology development. Special emphasis is given to the role of public goods and research institutions in the process of technological change. Information about new agricultural technology tends to have the characteristics of a "public good"[2] and, thus, motivates public institutions to become involved in technology development. Implicit throughout this paper are two basic assumptions. First, information is considered to be valuable because it improves the quality of any decision-making process (Chavas, 1991). As a result, any lack of information, or a slow and ineffective processing of information, is undesirable because it tends to have a negative effect on the efficiency of resource allocation. Second, most decision-makers are assumed to be risk averse and, thus, are made worse off by increased uncertainty (Lin, Dean, and Moore, 1974; Dillon and Scandizzo, 1978; Binswanger, 1981).

The paper focuses on two aspects of technology development. First, it investigates the issue of risk management in the creation of knowledge by agricultural research institutions. Second, it analyzes how public policy can influence the risk faced by farmers in order to facilitate technological adoption and productivity gains in agriculture. This analysis provides useful information on the role of the different parties involved in the process of technological change. In turn, this information should help policymakers develop policies that would stimulate agricultural productivity and improve natural resource management around the world.

Risk and Public Goods in the Supply of New Technology

The supply of new technology, a complex and incompletely understood concept, involves research and invention activities as well as luck. In general, everyone can contribute to the creation of new knowledge and new technology, including farmers, private firms, and public research institutions. Because new knowledge, by definition, is not known ahead of time, the output of research and inventive activities is necessarily somewhat unpredictable. Yet, the odds of a successful invention depend on many factors characterizing the search process. These factors, in turn, influence the comparative advantage and the relative contribution of the different parties involved in the development of agricultural technology.

The Role of Farmers

The role of modern farmers in developing new technology is often thought to be modest. Yet, the emergence of agriculture, about 10,000 years ago, took place without sophisticated agricultural research institutions (Heiser, 1990). This reminds us that some major technological innovations, such as the selection and cultivation of grains and the domestication of animals, took place without central planning or specialized researchers. Such revolutionary innovations likely involved some resourceful and innovative individuals trying to find new ways to feed themselves. While these individuals did not generate a rapid and sustained rate of technological progress (compared to current ones), their contribution to current agricultural knowledge should not be minimized. And such individuals probably still exist; they could be current farmers who, through luck or unusual creativity, develop new ways of managing natural resources in agriculture.

In general, any attempt to stimulate the innovative activities of farmers is clearly desirable, especially with respect to local knowledge and the adaptation of agricultural practices to local agroclimatic conditions. However, many aspects of agricultural technology are relevant in different agroclimatic conditions. In this case, a new technology developed and used by a single farmer would capture only a small share of its potential benefits. Also, given the uncertainty associated with the outcome of innovative activities, individual farmers generally cannot afford to spend much time or resources in search of new technologies. In such a situation, a consolidation of agricultural research activities across farms in a given agroclimatic region is clearly desirable. Over the last century, this consolidation has led to the creation of a complex agricultural research system composed of both private firms and public institutions.

The Role of Private Firms

Over the last decades, private firms have conducted an increasing amount of agricultural research around the world (Pray and Echeverria, 1991). However, with a few exceptions (Griliches, 1958; Chavas and Cox, 1992), most of the literature on the sources of agricultural productivity growth has focused on public research. As result, the role of the private sector is still poorly understood. The private sector's greatest impact has been on mechanical and chemical technology, and increasingly, it has involved biotechnology.

The role of the private sector has been heavily influenced by the nature of research output. New information or knowledge resulting from agricultural research is often characterized as nonrival and nonexcludable (Hayami and Ruttan, 1985). *Nonrival* implies that the good is equally available to all, that is, a "public good." *Nonexcludable* means it is difficult to exclude those who do not pay for it from using the good. This means that private producers cannot appropriate the full social benefits arising from the production of the good through market pricing, thus providing a disincentive for private investment. As a result, except in the areas where patent protection is established to allow excludability, private firms cannot be expected to achieve a socially optimal level of research. Protection by patent laws is often inadequate because the nature of agricultural production can make it difficult to restrict information about new technologies or practices. This is true in centralized economies as well as in market economies. In the cases where patent laws are effective (e.g., in the development of corn hybrid varieties), they tend to stimulate only private research projects generating benefits within the 17-year life of a patent; in contrast, basic research generates benefits in the long run (Chavas and Cox, 1992). As a result, private research tends to concentrate on patentable projects with short-term benefits.

An important attribute of the research process is the uncertainty of its outcome. Success in any research project cannot be guaranteed ahead of time. The stochastic nature of research outcomes is especially strong for basic research, which contributes to the market's failure to attain an optimal allocation of resources over time. A large variance of future benefits from a research project tends to cause a risk averse firm to discount future expected benefits by some positive risk premium (measuring the implicit cost of private risk bearing). Without the economic resources to spread the risk, the benefits of a research project often generate significantly less profit than expected. This induces an additional disincentive to private investment in research, especially in risky long-term research.

The Role of Public Institutions

Much information resulting from research is nonexcludable, making it necessary to establish public institutions to advance basic and applied scientific knowledge in agriculture. Public research has some comparative advantage, compared to private research, when the research output is nonexcludable and relatively risky. Chavas and Cox (1992) have found that, while private research tends to be biased toward research with short-term results (i.e., within the life of patents), public research tends to focus on research with long-term payoff. They also present evidence that both private and public research are very effective in increasing agricultural productivity, each generating a high-internal rate of returns (about 30 percent). This suggests that private and public research may have complementary roles: private research focuses on patentable research with short-term, less risky payoffs, while public research centers more on long-term research with nonexcludable or more risky outputs.

The nature of the agricultural research process influences its organization. Agricultural research is often characterized by the existence of economies of scale. A number of technological improvements have been found to be applicable across different agroclimatic conditions. In this case, duplication of research efforts in each agroclimatic zone would be wasteful. The attempt to avoid duplication has been a strong motivation behind the creation of public international agricultural research centers around the world. Compared with national and regional centers, international centers have several advantages. First, they can benefit from economies of scale in research by centralizing the research process. Second, by being large, they can better manage the uncertainty of the research output by spreading the risk among the parties involved. On the down side, the centralization of research tends to decrease its effectiveness in developing site-specific technologies, especially in regions where agroclimatic conditions are not uniform. In other words, national and regional agricultural research centers are also needed because they can help improve the adaptation of new technologies to local agroclimatic conditions.

The public good attributes of agricultural research together with its stochastic outcome make public support of agricultural research socially desirable. However, this implies that the funding of public research is subject to the complexities of the political process. Public research can be strongly influenced by the distribution of potential benefits among various interest groups. A socially desirable technological innovation is most likely to be implemented when the economic returns are positive and large. But a socially undesirable innovation (i.e., an innovation generating negative aggregate gains for society) may also occur if it gives positive returns to a well-organized interest group. However, a socially desirable innovation may fail to occur if it does not sufficiently reward the dominant political block. The failure in a number of developing countries to institutionalize the agricultural research capacity may be caused, in part, by the divergence between social returns and private returns to the groups with strong political power (De Janvry, 1973).

Risk and Public Goods in the Demand for New Technology

The innovation decision, that is, the decision to adopt a new agricultural technology, is ultimately made by the farmers. Many factors influence farmers' decisions. First, the adoption decision presumes that the technology has first been invented. This prior step is often the outcome of earlier research efforts. Second, the farmers must be aware of the existence of a new technology. When the associated information has the characteristic of a public good, it has motivated the involvement of public institutions in the diffusion of technology (e.g., extension services). Third, the farmer must be convinced that the new technology is adapted to local agroclimatic conditions and that it generates higher benefits than the current technology. When these conditions are satisfied, the farmer will exhibit an effective demand for the new technology. The role of farmers' education in the adoption decision has been fairly well documented. Education tends to improve the farmers' ability to process new information and, thus, reduce the subjective uncertainty associated with a new technology. Investment in human capital such as education can speed up adoption and contribute significantly to implementing the technological progress.

Risk plays a role in technological adoption for two reasons. First, because of learning-by-doing, the amount of uncertainty associated with any particular technology tends to decrease over time. Second, because most farmers are risk averse (Lin, Dean, and Moore, 1974; Dillon and Scandizzo, 1978), the additional risk generated by a new technology can be an impediment to its adoption. More specifically, most farmers are averse to "downside risk" (Binswanger, 1981; Antle, 1987; Chavas and Holt, 1992), making it imperative that the new technology does not increase "downside risk" (e.g., the probability of crop failure under unfavorable climatic conditions). If it did, even with higher expected returns, farmers may prefer the current technology over the new innovation.[3] In other words, even if the new technology does very well, on the average, farmers who are sufficiently downside risk averse would choose not to adopt the new technology because of its poor performance under unfavorable conditions. This could be especially true for subsistence farmers, who are trying to stay above some minimum survival level.

Thus, risk-management strategies play an important role in technology adoption. These strategies can be privately implemented within the confines of each farm household, or they can be publicly implemented by spreading the risks across households. Private risk-management strategies include crop diversification, inter-cropping, plot scattering, and financial diversification (e.g., the reliance on remittances). They also include developing flexible plans with options to respond to new information as it becomes available (Anderson, Dillon, and Hardaker, 1976; Chavas, Kristjanson, and Malton, 1991).

Public risk-management strategies include safety nets, such as price support programs, crop insurance, and various forms of income insurance, and are often implemented through public mechanisms. These public mechanisms are characterized by *conditional contracts*, that is, contracts stipulating transfers that take place only under particular conditions not observed ahead of time. Insurance contracts, which stipulate transfer payments to the insured individual only in the event of a prespecified unfavorable event, and price-support programs, which become effective only in the event the market price falls below a prespecified floor, are two such examples. Because they protect against downside risk, these public mechanisms are particularly valuable for individuals who are strongly averse to downside risk.

Conditional contracts can range from explicit, those associated with government policy, to implicit, those between individuals or households. In situations where government safety nets are well established, public policy can contribute significantly to the efficient redistribution of risk in society. Where government policy is weak, risk-averse individuals or households rely more on informal conditional contracts to manage risk (Bromley and Chavas, 1989). One example of this situation can be found in the complex reciprocity relationships in African villages (Watts, 1983). In general, any social structure or economic policy that can respond to new information as it becomes available is desirable. This may be the case of the land tenure system commonly found in Africa, which emphasizes flexible usufruct rights (as compared to the exclusive ownership rights typically found in the western world).

The conditional contracts underlying public risk management vary greatly across countries depending on the nature of the sociopolitical infrastructure. The quality of the information available for public decision-making can have a considerable impact on the effectiveness of any risk-management strategy. In general, imperfect information across individuals tends to reduce the potential benefits of contracts (Chavas, 1991). In countries where the sociopolitical infrastructure is weak, conditional contracts and public risk management are mostly limited to the local level (e.g., the village) where information is good. Thus, the possibilities of risk sharing are limited, especially if everyone faces similar risks. Alternatively, in countries where the sociopolitical infrastructure is well developed, the risk-sharing possibilities among many households can be substantial, which has implications for farmers' decision-making, technology development, and agricultural productivity.

Policy Implications

Implications for General Development Policy

To illustrate the above arguments, consider a development policy that neither attempts to improve risk allocation nor stimulates the development of conditional contracts within the economy in any way. In the semiarid tropics, then, risk could be managed quite successfully either privately or through implicit contracts within the family or village. Because yield risks are often similar among farmers in a given location, these contracts probably would not perform well as insurance schemes unless they covered extensive geographic areas. And without subsidies that would reduce transaction costs and uncertainty, the geographic coverage of such schemes would be limited. As a result, a significant part of the yield risk would have to be borne privately, which implies a strong incentive for private diversification strategies. If the benefits of reduced-risk exposures from such strategies are large, then farmers might willingly forgo some of the possible gains from trade. That is, they could diversify enterprise selection rather than specialize in activities in which they have a comparative advantage. Although such a risk-management strategy may be optimal from the farmers' viewpoint, it has serious implications for national economic development.

First, because researchers would be concerned with many more production activities than they were in the past, agricultural research efforts would be hampered. Agricultural research, in general, has been most effective when focusing on single cultures grown over extended geographical areas (e.g., corn or rice), suggesting that there are benefits in research specialization that would not be obtained in the context of a diversified agriculture.

Second, farm-diversification strategies would likely increase the transaction costs of trade. By spatially spreading various farm outputs, transportation costs are increased. Spatial diversification also increases information costs concerning spatial supply-demand conditions and, thus, makes market transactions more difficult. In this context, it would become more difficult for farmers to benefit from trade.

Third, by definition, farm diversification would not allow much specialization in production activities. This would not facilitate the division of labor and, therefore, could make productivity gains more difficult to attain. Also, it would slow down the spread of communication and education related to the production activities (e.g., extension services) because of economies of scale in providing the corresponding infrastructure.

These arguments suggest that, in the absence of insurance schemes over extensive geographical areas, the incentive for private diversification can have some adverse effects on economic development. In particular, the absence of insurance schemes may slow down productivity growth and technological progress and may reduce the possible gains from trade. This indicates that the investment in collective goods supporting the development of risk-sharing schemes can play an important role in technological progress. Such schemes should be considered and evaluated more seriously in the design of development policies.

For example, consider a policy that would lower transaction costs and improve information concerning a particular risk-sharing scheme involving a group of individuals. Shifting some of the risk from the individual to the group would decrease the incentive for private diversification. As a result, farmers would tend to specialize in activities where they had a comparative advantage. Also, productivity of labor would likely increase. Agricultural research could also focus on fewer products, thereby increasing its effectiveness in developing new technologies. Moreover, transportation costs and other market transaction costs would be lowered, thus stimulating trade and increasing the gains from trade. Finally, in the case of regional or national specialization, this would facilitate the development of infrastructure related to production and marketing activities.

Implications for CRSP Research

The effectiveness of agricultural research depends on many factors. Although collaborative research support programs (CRSP) cannot be expected to develop solutions to all technological problems, they can contribute significantly to agriculture productivity growth around the world. This can be achieved by stressing some comparative advantages of CRSPs, compared with other agricultural research programs, and building on them. Next we will discuss some key issues that relate to the effectiveness of agricultural research, in general, and CRSP research, in particular.

The Role of Human Capital. The quality of human capital is crucial in the research process, which implies that any research institution should recruit experienced research staff, with an excellent knowledge of current technologies and with good creativity. On the one hand, there is no guarantee that a scientist will always be able to find technological solutions to a particular problem; that is, there is no proven method to ensure research creativity. On the other hand, the quality of the research scientists and their working environment can have a tremendous influence on their success in developing new technologies. In particular, the essence of a good scientist is his or her ability to process information about current agricultural problems and their possible technological solutions. This information typically comes from farmers and from other individuals directly involved in the agricultural sector. Farmers' participation, thus, is a very important step in the research process. Another way of making research effective is to improve the training of research scientists and to increase their ability to identify new promising technologies. Finally, feedback from peers as well as from farmers can help research scientists create new knowledge and use it to find solutions to current problems. The CRSPs can contribute to improving the quality of human capital in selectively targeted research institutions where research needs have been identified.

The Benefits and Limits of Specialization in Research. The complexity of agricultural technology means it is unlikely that any particular individual would be able to grasp all aspects of its effectiveness and potential, making the research process particularly difficult. As a result, there is a strong incentive to specialize in the search for new knowledge. This specialization has taken place mostly along disciplinary lines in the academic community and has been very successful in the past. This success can be measured in two ways over the past few decades: (1) by the high growth rates in world agricultural productivity, and (2) by the high rates of return generated by agricultural research expenditures (Griliches, 1958; Chavas and Cox, 1992). Although research along specialized disciplines tends to be biased, it can be very effective at solving narrowly defined problems that are easily handled within a particular discipline. But, at the same time, disciplinary research is biased against broadly defined problems that do not fit well within any discipline. This bias should not be interpreted as an argument for dropping disciplinary research. It simply indicates the limitations of disciplinary research and its relative inability to address a broad class of real-world problems.

The Need for an Interdisciplinary Approach. More interdisciplinary research is needed to focus on those problems that do not fit the narrow focus of disciplinary research. Because of the complexity of current knowledge, no single scientist can grasp all the aspects of a truly interdisciplinary problem. Also, the difficulties of communication across disciplines should not be underestimated. In general, the focus of interdisciplinary research should be on creating teams of experienced and creative scientists with the ability to communicate effectively. These teams would typically include social scientists as well as physical and biological scientists. The contribution of social scientists can take place throughout the process: in identifying current problems, in designing research plans, in evaluating research results, as well as in diffusing new technologies among farmers. By their very nature, the CRSPs can contribute to team-building and can help improve the effectiveness of interdisciplinary research.

Assessing the Role of Risk in Research Design and Evaluation. The role of risk has received little attention in the literature (Anderson, 1991). As a result, the effects of this inherent uncertainty on private and public funding of agricultural research are not well known. It can be hypothesized that, because of the high risks of research output, risk-averse investors would be very cautious in their decisions to fund agricultural research, whether it be private or public. Anderson suggests this might help explain why higher funding levels for agricultural research have not been achieved given the very high rates of return to research that have been estimated in the literature (Griliches, 1958; Chavas and Cox, 1992). If, indeed, this is true, two immediate implications could be drawn: (1) by improving the management of research, the riskiness of its output would be reduced; and (2) by sharing or spreading the risk among individuals or institutions, the riskiness of output would be reduced. Both of these would be desirable effects. These implications suggest a need to take a more serious look at risk and its role in the funding, planning, and evaluation processes of agricultural research.

The Need to Address Sustainability Issues. Problems dealing with the long-term sustainability of agricultural practices and natural resource management, and their implications for future agricultural productivity, are becoming increasingly urgent. Particular concerns have focused on soil erosion, deforestation, desertification, and a loss of biodiversity. These problems go beyond disciplinary research and, thus, require an interdisciplinary approach. The issues of agricultural sustainability are complex; they involve evaluating the long-term effects of current practices. While short-term effects are usually easier to estimate, long-run effects are more difficult to evaluate. As a result, the assessment of current practices can involve a lot of uncertainty, with potential disagreement about their long-term impact on the environment and future agricultural productivity. For example, the use of a new technology may contribute to short-term productivity gains, but at the possible expense of future generations who could inherit a depleted natural resource base. This raises questions about the implications of technological development for intergenerational equity. Also, if current practices have adverse effects on the environment, it is important to know whether these effects are reversible or not. In general, we should be cautious not to develop technologies that have irreversible and detrimental long-term effects on the biosphere (Chavas, 1993). Alternatively, developing new technologies that would reduce or eliminate the irreversible negative effects of current management practices on future agricultural productivity would be desirable. This indicates how sustainability issues could help guide the development of new agricultural technologies.

Conclusion

The allocation of risk is an integral part of the research and innovation processes and should be an explicit part of technology development policies. Together with proper incentives and improved institutional support, the design and implementation of effective risk-management schemes are crucial to effective agricultural research. Processing information effectively and educating researchers and farmers (e.g., on sharing risk) can reduce the uncertainty associated with risk-management strategies. By looking at technological progress in a broad context, various scientific disciplines may integrate their views on the agricultural research process. This perspective should also help improve technology development by increasing farm productivity and stimulating economic development.

Notes

1. We define risk, in its broadest sense, as any event that is not known ahead of time. Also, the terms "risk" and "uncertainty" are interchangeable throughout this paper.

2. A good is said to be "public" if its use by one individual does not prevent others from using it.

3. This evaluation can be done using stochastic dominance analysis (Whitmore and Findlay, 1978).

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Session 7

Issues of Technology Development and Diffusion

- Farmer/Consumer Participation in Research Development
- Developing Effective Researcher-Extension-Farmer Linkages for Technology Transfer

Session Chair: Anne E. Ferguson

Speakers: Timothy R. Frankenberger
David G. Acker

Farmer/Consumer Participation in Research and Development

Timothy R. Frankenberger

The notion of farmer/consumer participation in agricultural research and development has recently received a great deal of attention (Ashby, 1991; Biggs, 1989; Baker, 1991; Chambers, Pacey, and Thrupp, 1989; Farrington and Martin, 1987). Conventional transfer-of-technology approaches assume that farmers passively receive technologies and recommendations from researchers and extension agents. Farmer-first models are challenging this conventional approach and are stressing the need to integrate farmers' ideas, opinions, experiments, and adaptations into the research process. Such approaches emphasize the need to expand the participation of farmers from passive roles (contractual, consultative) to active roles (collaborative and collegial) (Biggs, 1989; Chambers, Pacey, and Thrupp, 1989). This paper addresses a number of issues related to farmer/consumer participation in research and development that have direct bearing on the work conducted by the collaborative research support programs (CRSPs) sponsored by the U.S. Agency for International Development.

Who Are the Participants?

Farmer/consumer participation in research and development has neither been uniform nor equitable. Development efforts to improve farmer participation should primarily be aimed at those who have not benefited much from past research efforts. To determine who these clientele are, we must distinguish between three different types of agriculture. The World Commission on Environment and Development (WCED; 1987) has identified these as industrial agriculture, Green Revolution agriculture, and low-resource agriculture (see Table 1).

"Industrial agriculture" is characterized primarily by large farming units which are highly capitalized and rely on high inputs and often subsidies (Chambers, Pacey, and Thrupp, 1989). "Green Revolution agriculture" is found in well-endowed areas of the Third World that rely on irrigation or reliable rainfall (Ibid.). It is found in the larger irrigated plains and deltas of South, Southeast, and East Asia; parts of Latin America; and North Africa. High-yielding varieties with associated inputs are grown on both large and small farms.

Farmers involved in either industrial or Green Revolution agriculture have benefited greatly from agricultural research because their farming systems tend to be simple, monocropped systems in uniform, low-risk environments (Chambers, Pacey, and Thrupp, 1989). Farmers in these systems are also well organized to express their needs and demand products, services, and information (Merrill-Sands et al., 1991).

"Low-resource agriculture" is characterized as a type of agriculture that relies on uncertain rainfall rather than on irrigation and is found in more marginal areas with fragile soils (e.g., drylands, highlands, and tropical forests) (Merrill-Sands et al., 1991). These areas are vulnerable to degradation and, typically, have limited

Table 1. Three Types of Agriculture Summarized.

	Industrial	Green Revolution	Third/'CDR'
Main Locations	Industrialized countries and specialized enclaves in the Third World	Irrigated and stable rainfall, high potential areas in the Third World	Rainfed areas hinterlands, most of sub-Saharan Africa, etc.
Main climatic zone	Temperate	Tropical	Tropical
Major type of farmer	Highly capitalized family farms and plantations	Large and small farmers	Small and poor farm households
Use of purchased inputs	Very high	High	Low
Farming system, relatively	Simple	Simple	Complex
Environmental diversity, relatively	Uniform	Uniform	Diverse
Production stability	Moderate risk	Moderate risk	High risk
Current production as percentage of sustainable production	Far too high	Near the limit	Low
Priority for production	Reduce production	Maintain production	Raise production

CDR: complex, diverse and risk-prone.

Source: Chambers, Pacey, and Thrupp (1989).

infrastructure to support agricultural development. Agriculture of this type can be found in much of sub-Saharan Africa and remote areas of Asia and Latin America (Ibid.).

Over 1.4 billion people in the world are estimated to be dependent on low-resource agriculture for their livelihood (Chambers, Pacey, and Thrupp, 1989). However, generating and disseminating technologies to these people has proven difficult due to the physical, social, and economic conditions of the agricultural systems in these areas (Biggs and Farrington, 1991; Chambers, Pacey, and Thrupp, 1989). Simple, high-input packages have not meshed well with the complex and diverse farming systems found in these areas. In addition, low-resource agriculturalists have neither had adequate access to information generated by research, nor the organizational support to bring pressure to bear on research systems (Merrill-Sands et al., 1991).

Despite these difficulties, low-resource agricultural areas have great potential for production increases (Biggs and Farrington, 1991). In fact, a growing share of increased production needed to meet rising food demands will have to come from these areas (Merrill-Sands et al., 1991). New technology, much of which is being developed through the work of the CRSPs, will have to be tailored to the diverse and complex agroecological and socioeconomic conditions of these regions (Biggs and Farrington, 1991).

The key question is, why should the CRSPs be concerned about improving the participation of low-resource farmers in the research process? The answer lies in the common focus which most of the CRSPs share—the increased production and utilization of specific basic food crops and animals in developing countries (Knipscheer, 1989). Given that most low-resource farmers live in developing countries and produce or raise many of the crops and animals that the CRSPs are concerned with, they represent a key target group for CRSP activities. However, improving participation of these farmers in the research process is no easy task given logistical and institutional constraints. Before identifying these constraints and approaches that have been developed to overcome them, further discussion of the client group is warranted.

Low-Resource Farmers

Small-scale, rainfed farming systems in Asia, Africa, and Latin America are often much more internally complex in comparison to industrial or Green Revolution systems and more dynamic in exploiting unpredictable conditions (Chambers, 1991). As Chambers points out, poor people in these areas seek to multiply their enterprises, raise their incomes, and reduce their risks. Diversity is the key component in the sustainability of their livelihoods. Thus, many low-resource farming systems are moving in the opposite direction to that of industrial or Green Revolution agriculture. Instead of becoming more simple and uniform, they are becoming more complex and diverse (Chambers, 1991). Rather than intensifying external inputs, intensification is more internal.

Because of this complexity and diversity, many on-station researchers do not understand these systems well. Approaches for developing widely applicable technologies for relatively simple systems in uniform environments no longer are appropriate (Merrill-Sands et al., 1991). New approaches are needed for identifying multiple products that can be tailored to the identified needs of diverse clientele and production systems. In addition, the dynamic nature of these systems requires that diagnostic updates are regularly carried out to ensure that farmer problems and needs are taken into account.

The production systems of low-resource farmers are also driven by multiple objectives that encompass both consumption and production. For example, household food security is one important objective that must be taken into account. *Food security* is defined by the World Bank (1986:1) as "access by all people at all times to enough food for an active and healthy life." Food availability at the national and regional levels and stable access are both keys to household food security (Frankenberger, 1992). "Access to food" is determined by food entitlements which may include viable means for procuring food, either produced or purchased; human and physical capital; assets and stores; access to common property resources; and a variety of social contracts at the household, community, and state levels (Maxwell et al., 1992). The risk of entitlement failure determines the level of vulnerability of a household to food insecurity (Ibid.). The greater the share of resources devoted to food acquisition, the higher the vulnerability of the household to food insecurity.

However, household food security is but one dimension of livelihood security. *Livelihood* is defined by Chambers (1989) as adequate stocks and flows of food and cash to meet basic needs. Poor people balance competing needs for asset preservation, income generation, and present and future food supplies in complex ways (Maxwell et al., 1992). People may go hungry up to a point to meet another objective. For example, de Waal (1989) found during the 1984–85 famine in Dafur, Sudan, that people chose to go hungry to preserve their assets and future livelihoods. People will put up with a considerable degree of hunger to preserve seed for planting, cultivate their own fields, or avoid selling animals (Maxwell et al., 1991). Similarly, Corbett (1988) found that when coping strategies employed during stressful periods were sequentially ordered in a number of African and Asian countries, preservation of assets took priority over meeting immediate food needs until the point of destitution (Corbett, 1988 cited in Maxwell et al., 1992) (see Figure 1). Given the importance of livelihood security and coping strategies to low-resource farmers in risk-prone areas, risk avoidance and entitlement protection must be built into selection criteria for screening technology.

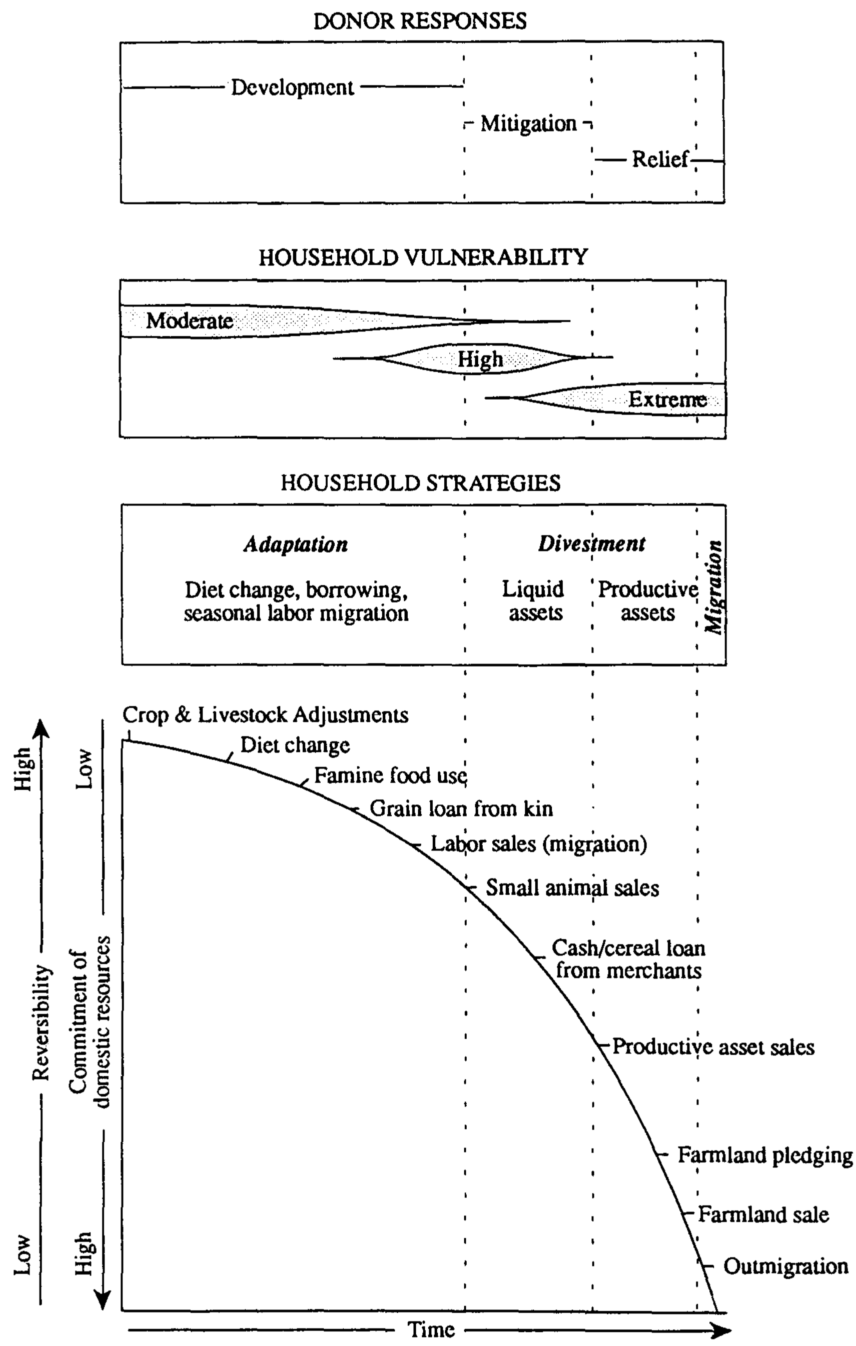
Food entitlements and their consequent failures are not shared equally by all members of the household (Maxwell et al., 1992). Intrahousehold differences exist in the allocation of resources for income generation and food acquisition and distribution. Researchers must understand these gender-based differences in order to determine the differential benefits derived from alternative technologies (Zandstra, 1991).

To deal effectively with the complex and diverse nature of low-resource farming, national and international agricultural research centers developed system approaches that involved multidisciplinary teams that diagnosed farmer problems and tested technologies at the farm level. Over the past 15 years, two-thirds of the research systems in Asia and sub-Saharan Africa and at least one-half of the research systems in Latin America have made substantial investments in on-farm research (Merrill-Sands et al., 1991).

Approaches for Improving Low-Resource Farmer Participation

Given the complexity of low-resource farming, some researchers began to realize during the late 1970s that many of the industrial and Green Revolution technologies were inappropriate to small farmers (Zandstra et al., 1981; Norman, 1980; Hildebrand, 1981; Collinson, 1981; and Harwood, 1979). Multiple varieties of on-farm, client-oriented research (OFCOR) were simultaneously developed in Asia, Latin America, and Africa to link research more closely with resource-poor households (Merrill-Sands et al., 1991). This type of research has come under a variety of labels including cropping systems research, farming systems research-extension (FSRE), farmer-back-to-farmer (Rhoades and Booth, 1982), and farmer-first-and-last (Chambers and Ghildyal, 1985). All of these approaches generally share a number of characteristics, including (1) an emphasis on holism—setting research priorities within the context of the whole-farm system, (2) attention to the needs of resource-poor households, (3) an emphasis on experimentation in farmers' fields, (4) an emphasis on multidisciplinary collaboration, (5) the recognition of the locational specificity of technical and human factors, and (6) an orientation that this type of research complements commodity and disciplinary research con-

Figure 1. Responses to household food shortages (after Watts, 1983) Office of Arid Lands Studies, the University of Arizona, 1991.



ducted on-station (Tripp, 1991; Merrill-Sands et al., 1991). Most of this farming systems research was carried out in four stages: diagnostic, design, technology-testing, and diffusion.

These OFCOR or FSRE approaches were very effective in bringing together researchers from multiple disciplines to work on farmer-specific problems. Many of the CRSPs used such approaches effectively throughout the 1980s to integrate multidisciplinary research (McCorkle, 1989). To determine how effective these approaches were in promoting farmer participation, we must first understand the different types of participation that are possible.

Biggs (1989) distinguishes four basic types of farmer participation: (1) Contractual—researchers establish contracts with farmers to obtain access to land and services, but the farmers' involvement is minimal. (2) Consultative—scientists interview and consult farmers about their problems and needs. This information is important for orienting the objectives and priorities of on-farm research. However, researchers decide on the priorities and design the trials and surveys. Farmers may also be interviewed at the end to evaluate the technology generated by the researchers. (3) Collaborative—researchers and farmers collaborate as partners in the research process and interaction is continuous. (4) Collegial participation—researchers work to strengthen the informal research efforts carried out by farmers. An attempt is made to enhance farmer capacity to make demands on the formal research system.

In the 25-OFCOR case studies reviewed in the study sponsored by the International Service for National Agricultural Research (Merrill-Sands et al., 1991; and Biggs, 1989), only one-third of the cases involved collaborative or collegial participation. However, more than half of these cases did involve consultative participation, with farmers playing a passive role.

The lack of active farmer participation beyond the diagnostic phase has much to do with the fact that conventional transfer of technology approaches are still the dominant paradigm in most agricultural research systems (Chambers, Pacey, and Thrupp, 1989). Many have argued the farming system research or OFCOR activities have enabled formal research and development systems to extend to the farm. That is, on-station researcher-managed experiments are now conducted on farmers' fields. Participatory approaches in technology generation are limited because technology generation is still considered the domain of the biological scientists (Knipscheer, 1989).

Although farming systems research (OFCOR) has made a huge contribution in understanding farmer circumstances, most of the on-farm research has been directed to increasing the adoption of already developed technologies. This research has predominantly been researcher initiated and researcher managed. Rarely have farmers actually participated in deciding the content of the research program or the desired features of technology design.

To enhance the active involvement of farmers in the technology development process, participatory methodological innovations were derived under a number of labels such as "farmer participatory research" (Farmington and Martin, 1987) and "farmer-first" (Chambers, Pacey, and Thrupp, 1989). Farmer-first models call for methodological reversals in agricultural research (Baker, 1991; Rhoades, 1989). This approach involves a shift away from a technology supply orientation and a hypothesis deduction model to an emphasis on indigenous farmer knowledge, innovative behavior, and farmer experimentation. Many advocates of this approach feel that farmer knowledge, inventiveness, and experimentation have long been undervalued and that farmers and scientists should be partners in the research and extension process (Rhoades, 1989). Research, thus, should be based on the problem analysis and priorities of farmers, with farmers being the central experimenters (Chambers, Pacey, and Thrupp, 1989).

According to the farmer-first approach, farmers participate in the technology development process in three ways. First, farmers are involved with identifying problems and setting priorities for research through their active involvement in the diagnostic phase. The role of the researcher is to elicit, encourage, facilitate, and promote the analysis by farmers (Chambers, Pacey, and Thrupp, 1989). Second, farmers are provided a range of possible solutions to identified problems from which they can pick and chose to suit their conditions and enhance their adaptability (Ibid.). This aspect allows farmers to become involved early in the technology design process, especially in screening alternative solutions. Third, farmers must be encouraged to actively participate in experiments for site-specific testing of technologies and adaptation. This process may entail improving the farmers' own capacity to carry out on-farm trials and experimentation (Ibid.).

Although farmer-first approaches have provided excellent suggestions for ways to improve farmer participation in the research process, caution must be exercised in adopting all of the recommendations in a wholesale manner (Baker, 1991). First, farmer-articulated demands nearly always relate to short-term priorities. An exclusive focus on these priorities can lead to an underinvestment in sustainable system options (Baker, 1991; Norman, 1980). Second, there are inter- and intradifferences in household priorities corresponding to gender roles, wealth, and village location that should be taken into account (Baker, 1991). Third, quantitative measures are often needed to convince policymakers and extension services of the value of technology options. Thus, some experimental rigor may be necessary (Ibid.). Fourth, farmer-first reversals in the technology design process will be met with much resistance in national agricultural research systems that primarily use a transfer-of-technology model. Such differences in objectives and methods could reduce institutional acceptance and researcher collaboration with on-farm research teams (Ibid.). Compromises may have to be sought to gain acceptance of such new participatory approaches.

Promoting Farmer Participation

Diagnosis

Building on the experiences of farming systems research-extension and other on-farm, client-oriented research approaches, a number of tools have been developed to understand farmers' conditions, constraints, needs, and opportunities in order to set research priorities. Two diagnostic tools that have been used extensively because of their timeliness and cost effectiveness are rapid rural appraisals and participatory rural appraisals. Although these techniques are related, they are not the same and should not be considered to be interchangeable.

Rapid rural appraisals (RRAs), a set of data collection techniques adapted from social science interview and survey methods, provide comprehensive sociocultural, economic, and ecological assessments of a target area for research planning and implementation (Molnar, 1991). The major distinguishing features of such approaches are that (1) interviews are conducted by researchers themselves, not by enumerators as in formal surveys; (2) interviews are essentially unstructured and semidirected (i.e., topical outlines) with an emphasis on dialogue and probing for information; (3) informal random and purposive sampling procedures are used instead of a formal random sampling from a sample frame; (4) the data collection process is dynamic and iterative; that is, researchers evaluate the data collected and reformulate data needs on a daily basis; (5) data are collected over a period of one week to two months; (6) triangulation is used to improve the accuracy; and (7) multidisciplinary teams implement the surveys (Franzel, 1984; Frankenberger, 1991). RRAs are especially effective in obtaining access to local sociocultural idiom, perceived problems, and general patterns of variation (van Willigen and Finan, 1990).

Despite the multiple advantages derived from using RRAs, it is important to recognize the limitations of such approaches. Researchers cannot be certain that households interviewed in the survey are representative of most households in the region. Time constraints usually do not allow for systematic sampling procedures to be followed. Thus, RRA techniques should be viewed as complimentary to other research methodologies such as formal surveys and in-depth anthropological studies. RRAs can be combined with the formal interview process to correct biases. For example, random-sampling procedures could be introduced halfway through field visits once hypotheses have been identified that need to be tested (Molnar, 1991).

Given time constraints, RRAs may also have trouble targeting the least visible target groups such as the landless, rural poor, women, and isolated ethnic groups. To compensate for this, RRA teams can focus on degraded resource areas and smaller marginal farms while interviewing households (Molnar, 1991). In addition, researchers may see a wider range of the communities by spending a night in the villages.

The participation of farmers in RRAs is primarily in a passive, consultative mode. Active participation of farmers occurs later in the diagnostic process. The major intention of RRAs, from my perspective, is to allow researchers to understand the diversity of farming systems and, corresponding, the constraints that are distributed within a given target area. Once the diversity and complexity is understood, specific villages can be selected that are representative of a wider array of villages so that further diagnosis can be carried out. It is at this point that participatory rural appraisals should be conducted.

Participatory rural appraisals (PRAs) also involve multidisciplinary teams that gather information in a systematic, semistructured way; however, they tend to focus on one village, and community participation is considerably more active (WRI, 1989). PRAs are intended to help communities mobilize their human and natural resources to define problems, consider successes, evaluate local capacities, and prioritize opportunities, as well as to prepare a systematic, site-specific plan of action and a means for facilitating community self-help initiatives (Ibid.). PPAs bring together the development needs as defined by the community with the resources and technical skills offered by the government, donor agencies, and NGOs.

PPAs use a number of techniques to elicit farmer involvement in identifying problems and deriving possible solutions. One method uses open-ended group discussions to enable farmers to analyze problems, identify research opportunities, and prioritize interventions. Such discussions are different from many of the group discussions carried out in RRAs because they not only generate information, but they also allow farmers to synthesize information and draw conclusions (Ashby, 1991). Thus, the group's own understanding of problems is advanced as well as the researchers'.

Diagrams have also been used effectively to stimulate questions and responses, allowing the farmers' knowledge to be made more explicit (Conway, 1989). Diagrams can simplify complex information, making it easier to communicate and analyze. Five different diagrams derived from agroecosystem analysis are often used. "Maps" are used to identify different parts of a farm and its relation to basic resources and land forms (Ibid.). Maps can be drawn by the participants themselves or in collaboration with researchers. "Transects" tend to be drawn by researchers who walk, accompanied by the local people, from the highest point to the lowest point in the immediate environment. Because people in each zone are consulted, transects help identify major problems and opportunities in the agroecosystem and where they are located (Ibid.). "Calendars" are used to indicate seasonal features and changes and allow farmers to identify critical times in their crop production cycles with regard to changes in climate, cropping patterns, labor access, diet, and prices (Ibid.). "Flow diagrams" are used to present a sequence of events in a cycle of production or marketing. "Venn diagrams" can also be used to help understand the institutional relationships within a village (Ibid.). As Conway (1989:86) points out, "the potential for eliciting the knowledge of rural people and for analysis by and with them is only just now being realized."

Meaningful participation of farmers in the diagnosis has been greatly facilitated by improvements in RRAs, PRAs, and other techniques. Diagnosis of low-resource communities has led researchers to appreciate the complexity of the livelihood systems which farmers pursue, expanding the enterprise coverage from a predominant crop focus to a broader crop-livestock and off-farm mix. Linkages between systems at the field, farm, village, region, and wider political economy have been identified (Zandstra, 1991). Diagnostic techniques have also improved our understanding of the local classification systems for plants, soils, types of land, crops, and wild plants, thereby facilitating researcher-farmer communication. Anthropologists and sociologists have played a vital role in fostering this improved interaction with farmers.

However, social scientists' excessive concern with diagnosis has contributed to the limited participation of farmers in other phases of the research process. As Ashby, Quiros, and Rivers (1989) rightly point out, diagnostic research has become a hothouse of methodology development spawning sondeo teams, informal surveys, rapid appraisals, key informant surveys, and so on. The farmer has become an object of investigation just as plants, soils, insects, and viruses are objects of study to be measured. Asking farmers questions has become an industry (Ashby in Chambers, Pacey, and Thrupp, 1989). Thus, to involve farmers in other phases of the research process, we must first involve the social scientists.

Design

Many researchers make the assumption that farmers will adopt the technologies that are generated by the research system once they have been tested and meet certain production criteria. However, farmers often take these recommendations and adapt them to suit their own resources and purposes (Ashby, 1991). This is why it makes sense to involve farmers early on in the testing phase so that the technology can be adapted to their circumstances. This early involvement of farmers could speed up the technology development process and reduce unnecessary costs for technologies that are inappropriate. At present, actual cost savings resulting from farmer involvement are only now being assessed.

Collaborative farmer participation in technology design and testing is more likely to occur when researchers are willing to allow farmers to contribute to the conceptualization of an experimental program. For example, farmers can be brought in at early stages to help researchers select varieties for on-farm testing (Ashby, 1991). Such an approach was used in Uttar Pradesh, India, for screening improved rainfed rice varieties (Maurya, Bottrall, and Farrington, 1988). Such a menu approach was also used in Rwanda, where farmers were invited into the experiment station to participate in the seasonal selection of potato clones (Haugerud and Collinson, 1990). During this selection process, researchers found that they had ignored many important features of interest to farmers.

When choosing participants for early screening of technologies, care must be taken to include those members of the household with the most expertise for the given crop or livestock species. For example, since women are primarily involved with bean production in Rwanda, they were asked to take part in evaluating hundreds of advanced breeding lines in the national bean research program (Ashby, 1991).

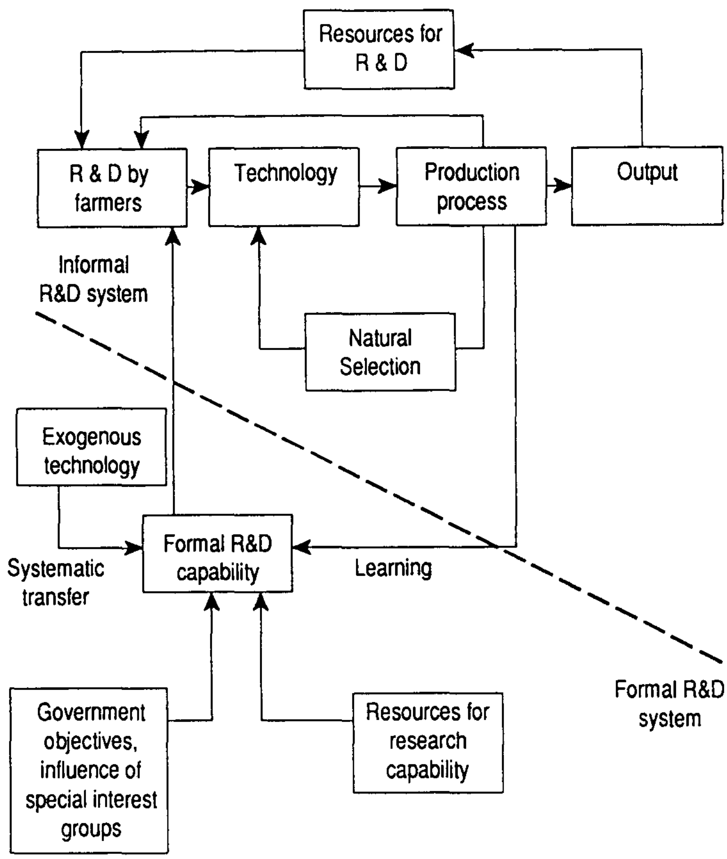
One of the major obstacles to involving farmers more effectively in the design and early testing phases is that researchers are afraid that farmers will lose confidence in the research system if appropriate recommendations cannot be given. Ashby (1991) points out that farmers need to be given more responsibility for technology design, testing, and adaptation, especially if research budgets are severely limited. This transfer of responsibility will likely bring higher returns through more rapid development of relevant technology.

On-Farm Experimentation

The extent of farmer experimentation has often been underperceived by most researchers. Much more could be done to strengthen informal research and development by building stronger linkages with formal research and development systems (see Figure 2). This could be achieved in a number of ways. First, social scientists could be more actively involved in identifying the various topics on which farmers are presently conducting their own experiments. Revelation of these experiments will help researchers understand which topics or problems farmers are most interested in as well as provide avenues for potential alternatives to solve these problems.

Second, researchers and extension personnel can help improve farmers' own capacities for carrying out experiments. Nonformal education and training could be provided to farmers to enable them to

Figure 2. A combined formal and informal agricultural R&D system. Source: Biggs and Clay, 1983 (cited in Chambers et al., 1989).



understand and implement controlled comparisons, replications, and random assignments (Ashby, 1991; Bunch, 1989). Such approaches have been successfully adopted by the Participatory Research in Agriculture project (CIAT) in Columbia, the PROGETTAPS project (IADB/IFAD) in Guatemala, and the Integrated Pest Control Program for Tropical Asian Rice (Ashby, 1991). In Gambia, the Farmer Innovation and Technology Testing Program has given farmers control of on-farm testing, where farmers take the initiative in requesting trials from research programs (Ashby, 1991; Mills and Gilbert, 1990). All these studies have shown that farmers with primary schooling can master the major principles of experimentation.

The goal of such participatory approaches is to encourage a process whereby people develop their own agriculture in a self-sustaining way (Bunch, 1989). We must get away from the idea of providing packages to farmers and, instead, allow them to choose from a menu of options that fit more appropriately with their conditions and needs. Highly structured on-farm trials limit farmers' ability to experiment with and manipulate the new genetic material (Sumberg and Okale in Chambers, Pacey, and Thrupp, 1989). It also precludes adjustments in other production practices or exploitation of production niches which could make the new variety more interesting (Ibid.).

Constraints to Farmer Participation in CRSP Programs

The previous section has outlined a number of ways to improve farmer/consumer participation in research and development. Unfortunately, there are several constraints that could inhibit CRSP programs from pursuing a number of these participatory activities.

Conflicting Objectives Imbedded in the CRSP Mandate. Although the CRSP mandate calls for special attention to small, low-resource farm families and the food production problems they face, it also requires that the CRSPs must contribute to the U.S. economy through their agricultural advances (Sibernagel, 1989). Given that low-resource agriculture is fundamentally different from the industrial agriculture which predominates in the United States, these goals may not be consistent. This may inhibit the CRSPs from working on farmer-preferred options that are viewed unfavorably by commodity group lobbies in the United States.

Host-Country Research Focus. In many of the countries where CRSP projects are located, host-country priorities may not coincide with the needs of low-resource farmers. This makes it difficult to work on research agendas that are derived from these farmers' needs.

Commodity-Focused Research Biases. Most of the CRSPs have a commodity-focused bias. This does not pose a problem when the farmers' needs coincide with topical areas that are addressed by the particular CRSP program working in the area. However, in many cases, the problem areas considered most important by farmers may not be part of the research agenda of a particular CRSP. For this reason, consideration should be given to having multiple CRSPs working in the same sites so that research options are more directly in tune with farmer priorities. For example, in areas where diagnostic research carried out by INTSORML social scientists reveals that the major problem faced by farmers is one related to cowpeas, the Bean and Cowpea CRSP could be called to address the problem.

The Dominance of Transfer of Technology Models. The CRSPs were established primarily on the basis of a transfer-of-technology model. That is, priorities are determined by scientists who generate technology on research stations and in laboratories to be transferred through extension services to farmers (Chambers, Pacey, and Thrupp, 1989). The incorporation of FSRE approaches into many of the CRSPs allowed for farmers' needs to be more explicitly addressed, but their participation was primarily in a passive, consultative role. Actively involving farmers in the design and testing of technologies will be facilitated when host-country CRSP research scientists recognize the importance of farmer participation throughout the research process.

Recommendations for Improving Social Science Input for Promoting Farmer/Consumer Participation

As stated earlier, improving farmer participation in CRSP research activities will be closely tied to strengthening social science involvement throughout the research process. Social scientists will continue to play an important role in diagnosing farmer problems and articulating farmers' needs to biological scientists. Several areas are particularly important that deserve more attention.

First, more emphasis should be given to household food security in diagnostic studies. In recognizing that household food security is one dimension of livelihood security, we need to understand that people will make tradeoffs between competing interests, such as asset preservation and immediate food consumption. These tradeoffs have particular relevance to which technologies would be considered the most viable options. Entitlement protection and risk avoidance need to be considered as criteria for screening technologies.

Second, social scientists could help the CRSP projects develop a systematic procedure for identifying vulnerable populations that are food insecure in the countries in which they are working. By mapping vulnerability in a given region or district, researchers could determine the likely areas where promising technologies could have an impact, which would help the spread effect of CRSP research.

Third, social scientists could help match up the various technologies developed by the CRSPs with the expressed needs of a farmer population within a given area. Interventions should not be restricted to the commodity focus of the particular CRSP working in that area.

Fourth, more work could be done on documenting the informal research and development of low-resource farmers. Such information could help identify the key concerns of farmers and the resources that are needed to strengthen farmers' capacities for experimentation.

Fifth, social scientists could help the CRSPs better understand the cultural context and social protocols that must be taken into account if farmer participation is to be successfully promoted. Hierarchical relationships may call for different approaches to involve poor farmers in the research process.

Finally, social scientists could help conduct studies to see if different participatory approaches are better suited in different contexts. Such studies could also help determine if farmer participation in design and early testing of technologies is more cost-effective than more conventional transfer-of-technology approaches.

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Developing Effective Researcher-Extension-Farmer Linkages for Technology Transfer

David G. Acker

Including a session on technology development and diffusion in a conference on social sciences and agricultural research signifies that collaborative research support program (CRSP) scientists are interested in seeing that the results of their scientific efforts positively affect the well-being of farmers and fishers.

This paper broadly examines the process of technology development and the roles of farmers, extensionists, and researchers in this process. Underlying the discussion are several fundamental questions. What is the relationship between improved research, extension, and farmer linkages and enhanced technology transfer? What approaches to technology development and diffusion are best suited to serve the needs of farmers and fishers? Who establishes the criteria by which technology is evaluated? Who is allowed to influence the technology development process?

The purpose of this paper is not to promote a favorite panacea. Given the complexity and variability of agricultural systems and institutional contexts, no single model of research-extension-farmer linkages can work in all situations. Rather, the purpose is to conduct a holistic examination of the technology improvement and diffusion process including a conceptual examination of the two traditions represented by the research-transfer (Bennett, 1992) or positivist (Woog, Kelleher, and Turner, 1992) model and the adult education (Bennett, 1992) or humanistic (Woog, Kelleher, and Turner, 1992) model. The fundamental question becomes, "Are we organizing this process to improve the farm or to improve the farm family?"

A great deal has been written about technology transfer, farmer participation, and related topics. Although the literature is voluminous, it has not benefited from sufficient synthesis and critical treatment. Much of this literature suffers from the panacea approach to problem solving. This paper attempts to synthesize some of the most critically important work in the field, to examine some approaches followed outside of the agriculture field, and to make this information available in a relatively predigested form to those involved in technology development.[1]

Just Do It . . . to or for Farmers

The approaches to technology development described in this section follow the technology transfer/production paradigm under which farmers are treated as recipients of technology, end-users, clients, or customers. The approaches range from those which embrace research conducted in near isolation of the world of farmers to those in which farmers are extensively consulted, such as farming systems research-extension. In short, approaches in this section operate under the assumption that scientists know or can learn what farmers need and can prepare solutions to these problems using science.

Underlying any approach to problem solving, technology development, or agricultural development is a set of assumptions. The assumptions may be explicit or implicit, depending on the circumstances or the number of years an organization has operated under them. Taken collectively, these assumptions form a model or paradigm which guides our thinking in subtle but powerful ways. A brief review of the historical record may help clarify the development of traditional technology transfer/production approaches.

At considerable financial and human resources costs, we have moved away from the traditional means of technology development and dissemination practiced for several thousand years. Under traditional or indigenous knowledge systems, agriculturalists modified, tested, and utilized technologies which were sometimes borrowed and sometimes ignored by their neighbors. Over time, with advances in the application of science to agriculture and the concomitant process of specialization, the traditional technology-sharing process was transformed from one involving a single individual to one involving a wide range of specialists scattered along the technology transfer continuum (Acker, Marcey, and Bunderson, 1992). Specialization of function of actors in technology transfer may well have its origin in the macroeconomic precept of specialization which has inspired the development of an assembly-line mentality in many operations (Price, 1991).

The prevailing technology transfer/production paradigm or pattern is organized as a sequence of steps which begins with research and produces a predominantly one-way flow of information through extension to farmers. Under this paradigm, if technology is developed by researchers, but not adopted by farmers, two assumptions are common: (1) extension is not doing its job, and (2) farmers are slow to catch on to new technologies.

Development of, and specialization within, the one-way, reductionist research, technology transfer paradigm has led to debate on a number of fundamental problems. Among these are the lack of effective linkages among specialized functions in the technology transfer process and the lack of relevance of the technologies developed under systems based on a predominantly one-way flow of information from scientist to farmer.

The latter problem may be related to the absence of farmers and farm families from the technology development process. The unilinear nature embraced by the dominant paradigm was neatly summarized by York (1985), when he endorsed a process in which the farmer is viewed as an end user rather than a participant in the process. The process of generating new technology and getting it used should be a continuum, reaching uninterrupted, from the scientist or researcher who generates the technology to the farmer who uses it.

The following typology displays common elements of the traditional technology transfer approach (Table 1). Traditionally, this is how the various major functions have been assigned in a technology transfer system. This typology serves as a useful foundation for detailed discussions about who is responsible for what functions. Problems frequently arise when an implicit or explicit typology such as this is operationalized as a "functionogram." Commonly, a box has been drawn around each function and a separate and dedicated organization is built to deal with the functions contained in each box. Then, to complicate matters, we have become habituated to the process, starting on the left and ending on the right

Table 1. Traditional Technology Transfer Typology.

Principal Phases	Technology generation	Technology transfer	Technology utilization
Principal Actors	Researchers	Extension	Farmers Fishers
Component Parts	Basic research	Education	Production
	Applied research	Supplies	Consumption
	Adaptive research	Services	Marketing
		Enforcement	Regulations

Figure 1. Sequence of steps in the dominant model of technology transfer. (Source: Adapted from McDermott, 1987.)

World Stock of Knowledge	Basic Research	Applied/Adaptive Research	Dissemination	Diffusion and Farmer Adoption

as if we were reading a line in a text book. Such a linear approach to problem solving often leaves little room for the incorporation of disparate forms of input and rules out the possibility of easy iteration. Figure 1 displays a common means of displaying this approach.

Horton (1991) reminds us of the language of the dominant technology transfer paradigm and its roots in the original notion that technologies could, and should, be developed by scientists at international agricultural research centers (IARCs) and national agricultural research systems (NARS) and, then, passed to extension agents. In turn, these agents were responsible for convincing farmers to adopt the technology which dribbled out of the end of this one-way pipeline.

Technology developers from Hawkesbury College in Australia talk about the production model of extension, which fits neatly alongside the technology transfer approach.

The advisor identifies problems (predominantly technological ones) within the farmer's enterprise. He then proceeds to put forward solutions to these problems, attempting to technologically fix the enterprise. The assumption is that the farmer will adopt the improvements and learn through his own interaction with his enterprise. The farmer himself is very much a secondary consideration beyond his role as a "grateful adopter." The root paradigm behind this theory is one of production. (Kelleher et al., 1990)

Collinson (n.d.) acknowledges the gap between research and extension but concludes that more damage is done because both operate under the technical paradigm or perspective while farmers operate under a systems or managerial perspective. He argues that if this perspective were adopted by researchers and extensionists, the technology transfer problems would be diminished.

Research-Extension-Farmer Linkages and Technology Relevance

This section attempts to synthesize key literature on research-extension-farmer linkages, but it is by no means an exhaustive review. For readers eager to pursue this topic in greater depth excellent sources are available such as the proceedings of the Association for International Agricultural and Extension Education, proceedings (and Journal) of the Association of Farming Systems Research and Extension, and the work of David Kaimowitz (1989) and Nicholas Minot (1984).

Problems. Well over half of farm families living in developing countries seldom see extension or research personnel. Extension personnel are frequently out of touch with research progress. Research stations have generally not had an open-door policy which would welcome participation by farmers and extension staff. In short, we can deduce that farmers have been and are now able to survive without research and extension. Starting from this humbling perspective helps us to see that we represent a service industry that provides assistance which is viewed as non-essential by many of our clients.

Many scientists with experience in developing countries know that research-extension linkages and communication can be constrained by a number of factors. These constraints can be debilitating to the process of agricultural development. There are cases where both research and extension organizations are each disseminating their own, and often conflicting, information (World Bank, 1985). There are cases where only a tiny thread exists between research and extension. If the researcher does not attend the one key meeting of the year, his or her research information won't be included in the annual summary of recommendations produced by extension. It is not uncommon to find research organizations which have multiyear gaps in the publication of annual reports of research activities.

The literature is quite rich on the subject of why research-extension linkages are so frequently weak. McDermott (1987:90) describes the problem in simple terms: "In the current LDC situation, almost always research stops too soon, extension starts too late, and a fatal gap is created in the technology innovation process."

According to the World Bank (1985), the principal causes of poor research extension-linkages are (1) organizational separation of research and extension, (2) educational differences between research and extension officers, (3) lack of clarification of roles and responsibilities in the technology development and transfer processes, (4) cases where unidirectional knowledge flow prohibits true professional interactions between research and extension, and (5) lack of appreciation for the validity of the tasks performed.

Woods (1985) cites a number of factors which affect research-extension linkages including "incentives, bureaucratic rules, organizational channels of communication, status among groups, motivation, physical constraints such as transport and facilities, rewards, job descriptions and performance reviews, and availability of qualified human resources." He organizes linkage constraints into five categories: (1) organization and management, (2) education and training, (3) discipline and background, (4) human factors and attitudes, and (5) resources.

In a survey of agricultural researchers and extension workers from 18 countries, Seegers and Kaimowitz (1989) identified institutional cultural conflicts which impede the improvement of research-extension linkages. They found that research workers doubt extension workers' capability in technical agriculture, and extension staff doubt the relevance of the research being conducted.

Robert Chambers (1979:1), in his classic work, *Understanding Professionals: Small Farmers and Scientists*, makes a convincing point that education of scientists may be viewed as a "lengthy process of conditioning in selective perception." Roling (1982) refers to the "splendid isolation" of technology innovation. Couple these with the long list of common biases (such as paved road bias, dry season travel bias, elite farmer bias, and frequent flier bias) and one can begin to see the enormous barriers all technology developers must hurdle in order to orient their programs toward the needs of farm families.

A classic example of the top-down approach is seen in the way in which research and extension were organized under colonial cash-crop extractive schemes. Emphasis was on the development or importation of intact systems. Research results were handed down to extension which, in turn, served as a messenger and enforcer of the technology. A major, one-way barrier existed between research and extension, which permitted information to flow from research to extension but not the reverse. In this approach, farmers were viewed and treated as passive recipients. Extension was viewed, more or less, as a delivery service.

Farming systems research (FSR), and later farming systems research-extension (FSR/E), developed largely as an antidote to the top-down approach of technology development. Its origins can be traced to a number of precursors, including a systematic approach to farm management developed in Missouri in 1945. This approach, called "balanced farming," looked at the farm and the farm family as integral parts of the management unit (Hagan, 1984). FSR/E has had a profound impact on the thinking of technology developers throughout the world.

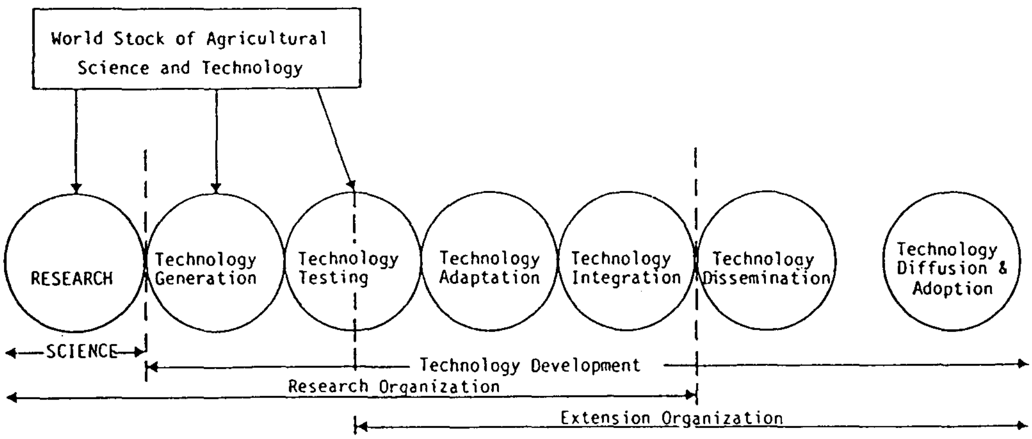
However, FSR/E has had an Achilles' heel in its heavy reliance on the team members' perceptions and framing of the problem, rather than having the problem framed by the farmers themselves. Team members may do their best to try to understand the complex situations of farm families but are limited by their experience and their conceptual blocks. In short, FSR/E is still something done to or for farm families.

Solutions. Field observation of the failure of a top-down model of technology development led Rhoades, Booth, and others to develop the "farmer-back-to-farmer" model. "This model of applied agricultural research and development focuses on the identification and solution of farmers' problems and requires interdisciplinary teamwork and consultations with farmers in all phases of a continuous research diffusion process" (Horton, 1991:226).

McDermott (1987:98) suggests a technology innovation model which "presents no clear line by which research and extension can be separated . . . thus, the research process shades into the extension process" (see Figure 2). McDermott (1987:90), a strong proponent of adaptive research, had this caution:

> We must see technology innovation as a publicly supported effort to improve agricultural production in the public interest. That means that the only way success of either research

Figure 2. Technology innovation process. (Source: McDermott, 1987:95.)



or extension can be measured in the typical LDC is by the innovations in agricultural production adopted by the farmer client. The development of an innovation by research that is not put to use simply does not count.

Kaimowitz (1989) reviewed the performance of research-extension linkages in two organizations with both research and technology transfer functions and identified five factors that attributed to their success: (1) a single-crop and single-client-group focus, (2) a uniform institutional culture rather than separate research and extension cultures, (3) sufficient resources for all to help avoid conflicts over which group has greater access to resources, (4) a relatively small-size organization, and (5) a private status to help avoid politicization.

Seegers and Kaimowitz (1989) describe several means by which extension and research engage in useful interaction. These include having greater input in research decisions, frequent informal personal contact between researchers and extension workers, greater use of joint field trials, simplified formats for technical information sources, and joint training events and meetings. The more channels of communication that are used, the healthier is the extension system.

Several models are worthy of examination in our quest to identify improvements in the organization of research-extension-farmer linkages. For example, an interesting model is found in the organization of "in-house" private research and extension services within commercial, single-commodity corporations or parastatals. In this model, highly integrated, single-focus research, extension, and marketing operations are organized to ensure that farmer behavior is tightly controlled according to research results, company regulations, and consumer preferences. Examples of this integration are found in commercial cotton production in Francophone, West Africa, and in coffee production in Columbia (Figure 3). This model has worked effectively for production increases of cash crops. No pretense is made of understanding or serving the general needs of farmers and farm families.

Another model is found in the more familiar U.S. land-grant college structure.

Figure 3. Corporate commodity approach.

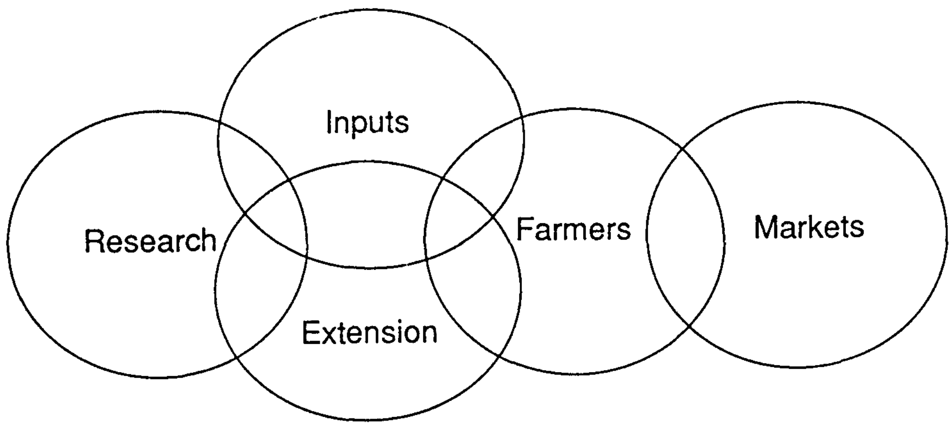
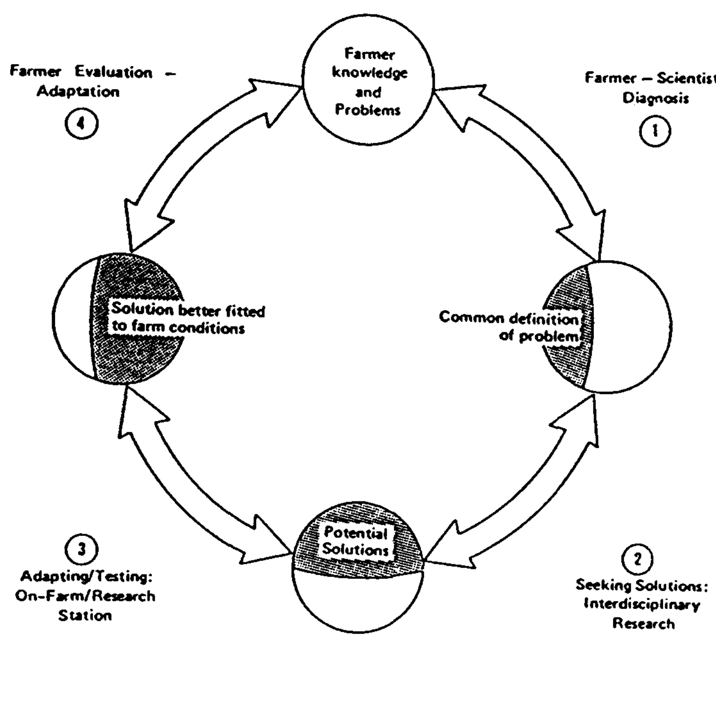


Figure 4. Farmer-back-to-farmer approach. (Source: Rhoades, 1984:34.)



Both research and extension functions often reside in the same person and almost always in the same department, thereby reducing the social distance between researcher and extensionist. It is worth keeping in mind that considerable variation exists in implementation under this model, ranging from a technology transfer approach to approaches involving considerable participation by farmers in research agenda setting.

A third model, the farmer-back-to-farmer approach (Rhoades, 1984), greatly increases the contact between researcher and farmer (Figure 4). Researchers and sometimes extensionists do their best to interpret farmers' circumstances and perform treatments on those circumstances and return the modified system to farmers for review and adoption.

There are even those who talk of streamlining the process by removing the "middle person" and allowing research to communicate directly with farmers. Colle (1989) makes the point that researchers could be communicators. Although they are only infrequently rewarded for communicating science directly to farmers, researchers could have a significant impact. Consider the possibility of scientists using mass media to go directly from the lab to the land with messages.

At ARAMCO Oil Company, large construction projects are managed by a temporary goal-directed organization and jointly staffed by ARAMCO and construction contractor employees. This integration of staff helps to ensure that team work and accountability are built into the process (Juraifani, personal communication, 1992). In agricultural technology development, research and extension could form task, commodity, or technology-driven temporary organizations or teams to tackle a significant farm problem. Rather than relying on one individual to provide a thread of liaison between research and extension, all team members could share this responsibility. These temporary organizations would be headed by one person who would serve as the technology improvement "czar" or coordinator, ensuring that research and extension both focus energies on client-oriented, technology development work and that collaboration among technology developers is enhanced.

A wide variety of suggestions on research-extension linkages can be gleaned from the literature. Kellogg (1985) speaks of the need for a shared mission between research and extension organizations. Suggestions of others include incentives for client-centered research, scientists sharing adaptive and some extension responsibilities, and cross training of research and extension personnel.

Summary. This section dealt with approaches to technology development which are controlled and conducted by the scientific community. Under the technology transfer/production paradigm, the research agenda is usually set by scientists after studying the farmer's circumstances. In short, these are approaches in which we "do it to or for" farmers. Those of us who practice our craft in this manner have been referred to as members of the debilitating professions; professionals who ensure that their services will always be in demand by never teaching their clients to perform the services themselves.

Just Do It . . . with Farmers

The approaches to technology development described in this section treat farmers as co-learners and co-participants in a participatory action research process. Such approaches assume that farmers, scientists, and extensionists are co-equals, all contributing critical knowledge to the process of technology development. Technology transfer, in the traditional sense of delivering something to farmers, is not part of these approaches because technologies are jointly developed with farmer and researcher involvement; thus, technology is not required to be transferred.

The literature in this area is mostly, but not entirely, quite recent. Client-centered research is a not a new concept. Lewin (1946) was responsible for leading some of the early thinking on action research methodology. According to Lewin, action research is special in two ways. First, the client is involved as an active collaborator in the generation of knowledge. Second, action research takes place in the real world and derives lessons from that world. Whyte (1991), who subscribes to a similar action research methodology, shares Lewin's view. He observed that "science is not achieved by distancing oneself from the world; as generations of scientists know, the greatest conceptual and methodological challenges come from engagement with the world" (Whyte, 1991:21).

The approaches covered in this section avoid what Roling (1982) called the "splendid isolation" of technology innovation. They clearly attempt to break with traditional, top-down, scientist-driven technology transfer. One of the conceptual foundations for this thinking is found in the writings of Freire. Freire (1970), argued for the abolition of the sender-receiver relationship and for the notion of learners engaged in a process where both could contribute and both would benefit.

Whyte (1991) describes participatory action research as involving "practitioners in the research process from the initial design of the project through data gathering and analysis to final conclusions and actions arising out of the research." MaClure and Bassey (1991:190) state that three particular attributes distinguish this participatory action research from traditional research strategies. Participatory action research (1) postulates shared ownership of the research enterprise, (2) is a method of community-based learning, and (3) aims to stimulate community-initiated action. The process instills in participants a sense of personal identification and ownership with the learning or discovery effort; thus, it is much more likely the participants will apply what they have learned.

Some have argued that participatory action research as Whyte describes it is no different from the approach taken in FSR/E. Lev (Forthcoming) disagrees, "Most of the FSR literature focuses on developing procedures to enable social and technical scientists to work together to learn from but not with farmers." This differentiates FSR/E from participatory action research in which farmers "are viewed as participants in a three-way co-learning process among social scientists, technical scientists and farmers."

Lev and McGrath (1989) are experimenting with whole farm case studies and farmer-scientist focus groups as a way of drawing out the knowledge of farmers in an organized manner and inserting it into the technology improvement process. As Lev and McGrath (1989) state, "Everybody contributes their unique perspectives. Everybody learns." They argue that researchers and farmers both have a great deal to contribute to the technology improvement process. However, their knowledge is distributed differently. Farm-

Figure 5. Depth versus breadth of knowledge. (Source: Lev and McGrath, 1989:5.)

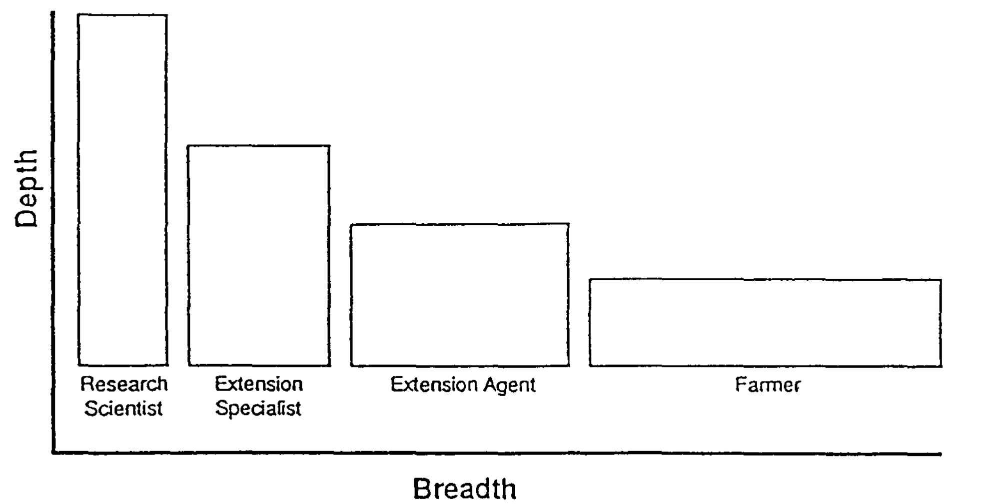
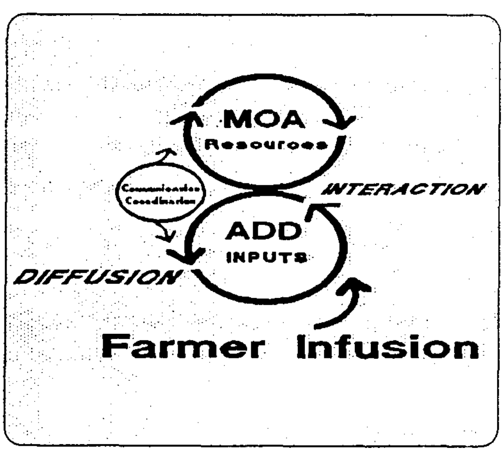


Figure 6. The Infusion model. (Source: Hilleman, 1990.)

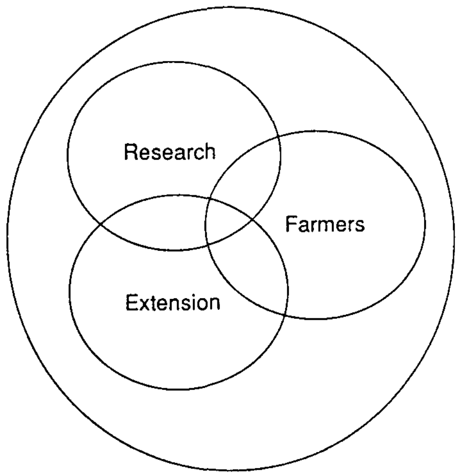


ers knowledge tends to be distributed broadly across a number of interrelated areas. Lev and McGrath represent this graphically by a wide, relatively short rectangle. Researchers, on the other hand, tend to have highly specialized knowledge in a narrowly defined area. This could be displayed symbolically as a narrow, rather tall rectangle (see Figure 5).

Hilleman (1990) introduced the infusion concept in Malawi as a complement to the diffusion concept of technology transfer. He describes infusion as information-seeking behavior whereas diffusion has to do with information-distribution behavior (see Figure 6).

Bawden et al. (1984) advanced rational arguments for co-learning and action research. At Hawkesbury College in Australia, faculty such as Woog, Kelleher and Bawden promote the development of a co-learning relationship among farmers, extension, and researchers. This arrangement elevates the relationships in the process to a new level: "Thus the farmer as a learner interacting with his environment and extension as the development of a learning system is becoming the new focus. There is a shift from a reductionist, positivist behavioral theoretical base to a systemic, interpretive, humanist one" (Kelleher et al., 1990).

Figure 7. Co-learning participatory action research.

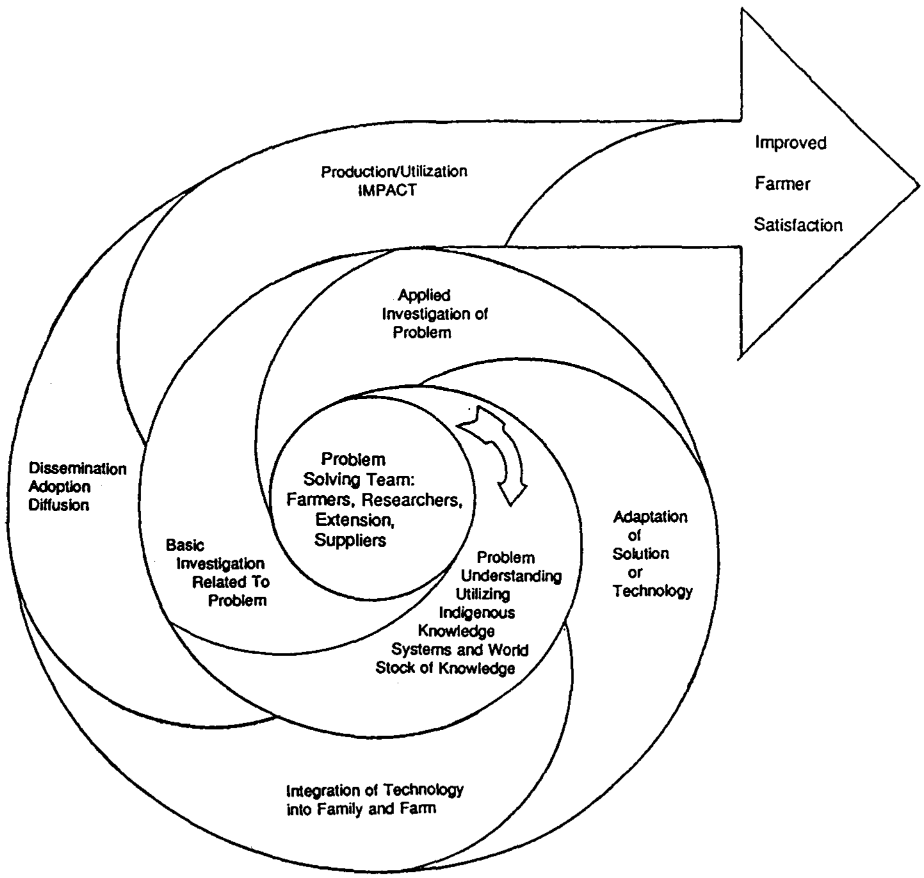


Osborne (1990) provides a useful modification to these approaches. He describes the integration of indigenous technical knowledge of farmers and the multisource model of technology innovation as the basis for what he terms "farmer participatory research. "This approach uses much higher levels of farmer involvement, farmer initiative, and utilization of indigenous technical knowledge than FSR/E. It also recognizes that many parties are involved in technology development including farmers, researchers, seed companies, and nongovernmental organizations (NGOs). Osborne stresses development of personal relationships with farmers and listening to farmers on their terms, in their villages, fields, and homes as a foundation for any intervention activity.

The approaches described above could be graphically conceptualized as seen in Figure 7. A process management concept with possible application to agricultural technology development is the concept of quality circles. Quality circles could help us learn about team work in the technology development process. Thompson (1982) describes *quality circles* as a structure within an organization composed of employees who share similar job functions and meet to improve productivity, encourage innovation, and solve work-related problems as a team. They are fully engaged through the stages of problem identification, development of solutions, implementation, and evaluation. An advantage of quality circles is that they are flexible with membership modifications occurring in response to changing circumstances. In agricultural technology development, quality circles could bring together teams composed of farm families, researchers, extensionists, input suppliers, and policymakers to solve problems. To some extent, the team of researchers, extensionists, and farmers could engage in a basic level of cross training to enhance mutual understanding.

In agriculture, organizational development and staffing patterns have followed too closely the compartmentalized, sequential schematic often drawn to display the conceptual elements of the traditional technology transfer process. Improvements on this approach might assume that both the players and the stages could be fluid. Figure 8 shows one way of looking at the interactivity among stages or phases of technology development as well as a team with great mobility and flexibility. The team, composed of farmers, researchers, and extension staff (and others as needed) moves through the process, sometimes looping back to an earlier stage or sometimes hovering over one stage to gather a more in-depth understanding, sometimes working on several stages simultaneously. The team of co-learners moves through the process much as a bouncing ball moves along a musical score, sometimes repeating a familiar refrain. The team engages in multilearning of several technology develop-

Figure 8. Nonlinear technology development model. (Source: Acker, Marcey, and Bunderson, 1992.)



ment roles, and exchanges roles, viewpoints, and ideas constantly (Takeuchi and Nonaka, 1986). In an agricultural application, this model would have a core of co-learners who are permanent throughout one entire technology development process with others who move in and out of the team structure as needed.

Summary. This section reviewed approaches that are collectively informed by theories under the co-learning or participatory action research paradigm. In these approaches, action is taken "with" farmers rather than done to them or on their behalf. Rather than being viewed as customers or clients, farmers are viewed as coparticipants or technology development collaborators.

Just Do It . . . As Instructed by Farmers

The approaches to technology development described in this section recognize farmers as educable leaders of technology development. They assume that technology development is more efficient and more relevant when farmers lead the process, and that farmers are indeed capable of leading the process and of acquiring the necessary technical assistance.

Lightfoot (1985) points out that farmers have long been active experimenters and cites Conklin's work in the 1950s on Hanuoo agriculturalists in the Philippines as an example. Lightfoot concludes that research should proceed as a hybrid of indigenous and formal techniques and that indigenous techniques could help us improve our formal techniques.

As an established NGO, World Neighbors began using an "experimenting farmers" approach more than two decades ago (Bunch, Ewert, and Gobbels, 1992). The approach grew out of a recognition of the natural abilities of farmers to conduct independent inquiry for problem solving.

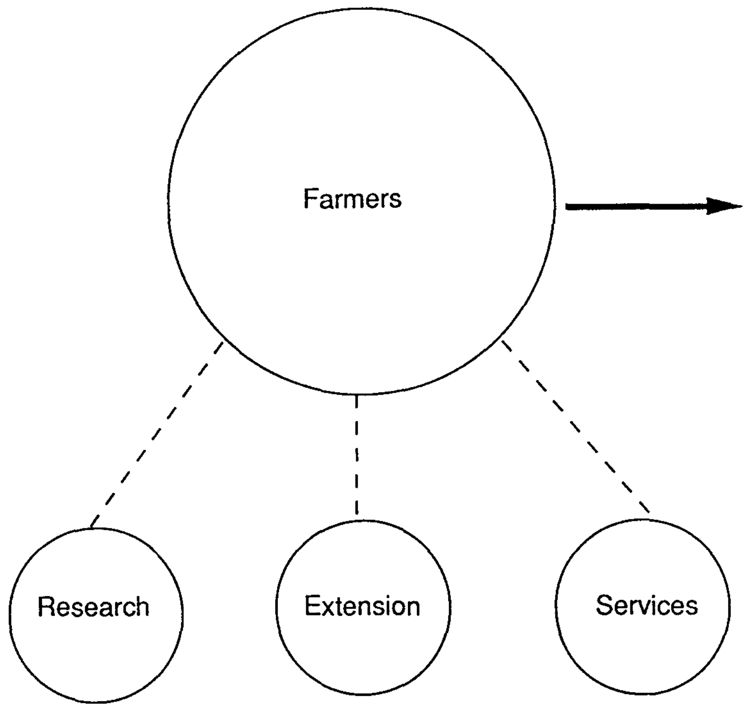
Progress is being made in valuing and utilizing indigenous knowledge in the agricultural research and development process (Warren, 1989). Prior to the 1950s, the value of indigenous knowledge was not recognized due to Western disdain for and ignorance of non-Western cultures. As understanding of these cultures grew, more opportunities arose for farmers to demonstrate their skills as rational decision-makers to the scientific community. Later, FSR, farmer-back-to-farmer, and other farmer-centered approaches became quite popular. Yet, within these approaches, researchers still fill in gaps in their understanding of indigenous knowledge with their own conjecture.

Roling (1982) displays thinking along similar lines. He describes an alternative to production-oriented extension approaches and calls his approach "human resource development": "Key words are community development, institution building, leadership development, mobilization, organization, and so on." This approach focuses on the development of rural people themselves and not on the development of natural resources through people.

Axinn (1978) talks about the technology acquisition system used by rural dwellers. The technology acquisition system is the informal system by which farmers and farm families gain access to and acquire technical information and other inputs required to support their various enterprises. Could this be used as a model for farmer/scientist involvement in problem solving and learning? Farmers could be trained to conduct research efficiently while researchers could learn to play a facilitative role. Naturally, in working with limited-resource farmers, supplemental resources would be required in order to free farmers to spend time and energy on such tasks. An approach such as this, in which farmers control the process, has certain parallels to the commodity commission approach to influencing the research agenda that is popular in the United States. Commodity commissions operate as organized groups of farmers who, among other things, pool resources and commission research as needed.

At the root of these processes is the empowerment of farmers, which is based on the idea that those closest to the problems have the best ideas about solving them. The term transformative research was coined by adult educators in 1988 and can be used to describe the approaches in this section. Deshler and Selener (1991) defined *transformative research* as research that is ethical, emancipatory, empowering, and holistic and that leads to social transformation. Through complete participation in the de-

Figure 9. Farmer-led learning systems.



sign and conduct of research, farmers and their circumstances are improved or transformed. The farmer-led learning systems might be characterized graphically as in Figure 9.

Summary. These approaches teach farmers to be technology developers in a manner that uses the full potential of their indigenous knowledge systems. Farmers learn to manage their own technology acquisition system to access resources of technical assistance, inputs, and other needs. Farmers create new knowledge rather than serve as recipients of new knowledge. These approaches aim to instill capacity in farmers to shape their own destiny. They encourage research which helps to transform the individual through empowerment and the agricultural system through technology improvement. The approaches in this section could also be viewed as belonging to the extreme edge of the co-learning paradigm described in the next section. Table 2 may help to summarize the characteristics of the paradigms presented earlier in this paper.

Current Donor Policy on Extension

The topic of researcher-extension-farmer linkages would not be adequately addressed without a few comments on the current state of extension. It is appropriate to begin the discussion with a look at the variety of roles extension may play. Depending on the setting it may be involved in education, enforcement, input supply,

Table 2. Comparison of Characteristics of Three Paradigms.

	Paradigm		
	Technology Transfer/Production	Participatory Action Research	Transformative Research
Role of Scientist	Science/ Experimentation Management of research process	Science/facilitation Co-learning	Education Science
Role of Extensionist	Messenger Convincer	Co-learning Facilitation Cultural bridge	Coordination Education
Role of Farmer	"Grateful adopter" Production Utilization	Co-learning Experimentation Adoption Production Utilization	Management of TD process Resource Acquisition Experimentation Adoption Production Utilization
Potential strengths	Science-based	Systems orientation Builds capacity of farmers	Relevance assured Builds leadership capacity of farmers
Potential weaknesses	Reductionist Relevance	Requires high levels of coordination	Reduced scientist leadership/impact
Primary focus	On-station On-research	On-station On-farm and farmers	Community and Household

political organizing, marketing, credit management, on-farm trials, farm services (such as artificial insemination and soil testing), community development, information collection, research, or other functions.

The current state of extension cannot be covered in a few paragraphs. However, there are a few important identifiable trends among donors which may be useful to consider in examining the relationship between the CRSPs and extension.

Leadership in the development of extension is no longer coming from donors. For example, during the last 15 years, the World Bank has supported little else besides the training-and-visit system, an approach which has yet to demonstrate its effectiveness in extensively cultivated systems in countries with limited resources. Moreover, it has seldom been implemented in such a manner that it has truly taken advantage of the power of participatory methods which have been successful elsewhere.

U.S. Agency for International Development (USAID) virtually abandoned support for public agricultural extension several years ago, dropping funding from a level of $113 million in 1979 to $18 million in 1989 (OTA, 1991). In a worldwide State Department cable sent to AID Missions on June 10, 1985, the Administrator stated, "Evidence suggests that the payoff to support for traditional public sector extension programs in LDC's including those based on the U.S. model, has been disappointing."

Although no references were made to specific evidence, this notice served as the beginning of the end of major support to public extension projects by USAID. For CRSPs operating from the headquarters of "the U.S. model," this was a signal that extension engagement by U.S. universities would no longer be viewed positively. Ironically, in Ralph Cummings' (1989:151) paper entitled "External Assistance in Agricultural Extension: The USAID Experience," he concludes with this statement, "AID intends to assist development of institutions that integrate education, research and extension and which relate to farmers and farm families." To the uninitiated, this sounds surprisingly like the "U.S. model," which functions through the land-grant universities. In short, little intellectual leadership in extension is apparent in USAID today.

Unfortunately, the decision by USAID to focus greater resources on research and fewer resources on extension fostered some misconceptions. First, it encourages people to conclude that research and extension were largely mutually exclusive alternatives rather than complementary to each other. Second, it reinforced the idea that inappropriate research or lack of technology was the villain rather than focusing attention on the interrelated nature of these functions in technology improvement.

At the same time USAID withdrew support to public extension systems, both the World Bank and FAO (1990) were increasing resources focused on public extension development. Whether the decision by USAID was based on sound judgement or just another manifestation of the mercurial swings inherent in bilateral assistance programs is a question worthy of investigation. In fairness to USAID, it has not abandoned entirely the support for extension. Privatized extension is still in favor with this administration. Yet, legitimate concerns have been expressed by critics of this policy that society as a whole does not benefit from offering extension services only to those who can pay for them.

Summary. Extension is alive and fairly well throughout the world with the exception of USAID. Extension thinking is evolving away from the concept of extension as a one-way messenger service and toward a facilitative, information-seeking colearner in a participatory action research process. Extension workers are eager to participate in technology development and can contribute critical skills to the process.

Some Questions for CRSP Consideration

How Should CRSPs Link With Extension?

CRSPs were not designed to be both research and extension projects. While a number of CRSPs have made admirable efforts at extending the results of their research through training and technical assistance, extension and technology transfer are mentioned infrequently in literature by and about the CRSPs (McCorkle, 1989; OTA, 1991). Perhaps this absence of attention clarifies how we have framed the problem as a technology deficit problem, not a technology dissemination problem. The separation of research and extension reinforces the notion that they are unrelated functions rather than complementary aspects of a larger process of technology development.

One could say that the CRSP program has been successful but that the companion project (related to extension) never got funded. CRSP staff, committed to seeing the products of CRSPs put to good use, are making efforts in extension. But these efforts tend to be outside the primary mandate of the CRSPs. This may result in a fragmented extension approach when a more comprehensive effort is needed.

What may be missing is a clearly articulated, carefully conceived extension program that spells out institutional relationships, organizational structures, personnel, objectives, activities, timelines, and responsibilities to promote engagement with and participation of farmers. The occasional workshop, survey, booklet, short-course or report represents a start but not a program. A concentrated, organized set of mutually reinforcing activities conducted in conjunction with an existing extension program will yield far more significant utilization of CRSP products for the benefit of farm families.

Should CRSPs focus on linking with host country (governmental and nongovernmental) extension services, or should they attempt to run their own extension activities through people on their payrolls? Have CRSPs learned from the problems encountered by IARCs in integrating their programs with host country institutions?

If one accepts the notion that research relevance and utilization can be enhanced through the involvement of extension and farmers more directly in the process of technology development, then what modifications in CRSP organization, mandate, and funding would characterize an appropriate response? What would be the impact on agricultural development if CRSPs expanded their role beyond research to play the role of technology development czar or coordinator to ensure that linkages are functioning among research, extension, and farmers.

How Should CRSPs Link With Farmers?

Two of the paradigms presented in this paper are quite different. One, the technology transfer/production paradigm, deals with the development and delivery of technology to farmers. The other paradigm deals with the development of farmers' capacity to learn how to develop their own technologies. It appears that some gravitation is occurring toward greater participation of farmers in technology development. Which approach is best suited to the needs of researchers, extensionists, and farmers? In the technology transfer/production paradigm, can farmers influence the technology development process? If CRSPs choose to follow the dominant technology transfer model, can a stricter customer orientation provide an improved model for relevant technology development? In the same manner that CRSPs are involved with developing cooperating country research capability, should CRSPs be involved in developing and encouraging capacity building in farmer-led learning systems? What would be the impact of shifting our focus away from technology transfer and toward teaching farmers to learn to develop their own technologies? Are farmers contributing to the establishment of evaluation criteria for successful technology? If one is skeptical of extension and farmer involvement as members of teams which have traditionally been staffed with researchers alone, why not experiment with a new model and compare the results with those of more traditional approaches?

How Should CRSPs Communicate About Technology?

"Total quality management" assumes that, in any organization, over 80 percent of the problems are in the processes, not the people. One of the first steps in the total-quality-management problem identification process is to develop a flow chart of one's operation in order to reveal bottlenecks in the flow of information, materials, and other resources. Have CRSPs developed such charts to explicitly display how the products of their research will reach farmers and where potential bottlenecks may occur? Have the CRSPs followed the information they create to see where it goes? How is it transmitted to extension? In what form is it transmitted to extension? Who handles the information along the way? How do farmers get the information? Regarding two-way flow of information, how do farmers' technology needs get communicated to CRSPs?

How Should CRSPs Organize?

Perhaps the way in which we have framed the question of improving research, extension, and farmer linkages has limited our view of the problem and encouraged paradigm paralysis. We have tended to examine modifications of the relationships among researchers, extensionists, and farmers and have accepted that their roles and functions are fixed. In one sense, we have restricted our analysis to those things that can be modified within the popular graphic representation of the research-extension-farmer triangle. If we expand the borders of the problem and look outside the triangle we may be able to frame the question as, what new coordination functions must be added in order to maximize the efficiency with which the three primary partners operate in the process of technology improvement and utilization?

Would relevance and utilization of CRSP research findings be enhanced if an agricultural knowledge system coordinator or a technology transfer coordinator were responsible for overseeing the technology development process from problem identification to adoption, including the functions normally carried out by both research and extension? What would be the impact of joint research/extension appointments of CRSP personnel on the functioning of the CRSPs?

How Should CRSPs Incorporate a Gender Perspective?

Frequently, women farmers and fishers are at the end of the long technology development pipeline. Imagine that in the pipe are men doing things with technology that women cannot see, cannot participate in, and cannot influence. One day, out pops a recommendation. What are the chances that women will adopt something about which they have little or no knowledge, for which they feel no special ownership, and which may not be especially well-suited to their needs? Have CRSP plans for incorporating women farmers, women extensionists, and women researchers been successful? Are CRSP scientists, both here and abroad, trained in or experienced with the incorporation of a gender perspective in both natural and social science research? Has the essential role of women as communication agents in a technology-sharing network been tapped by CRSPs?

How Should CRSPs Innovate?

CRSPs are in a unique position to experiment with technology development approaches. Could the CRSPs engage in experimentation with nontraditional approaches? For a radical example, what would be the effect of introducing a voucher system in which farmers all receive one voucher per year which they bestow on the individual or unit which has made the most significant contribution to improving their well-being. Each of these vouchers would be cashed by the institution or individual and would be their only source of salary. Those not receiving adequate salary support would migrate out of the field while those who are most effective would stay. Thus, the system would undergo constant improvement. Another innovation might be to provide "money back" guarantees to farmers on the technologies we release.

Are CRSPs involved with both technology innovation and innovations in the technology development process? Are CRSPs encouraged to exchange lessons learned on innovative approaches to technology development?

How Should CRSPs Use Technology?

Can emerging technologies help to bridge the gap between research, extension, and farmers? Enormous opportunities for information exchange are now possible due to a growing family of communication technologies. For example, hand-held video camcorders can be used to move information about crop, animal, and household conditions among researchers, extensionists, and farmers. The use of satellite-supported portable telephones, now being marketed in developing countries, may facilitate real-time information exchange. Remote sensing may have an expanded role to play as well. These and other technologies allow us to communicate among technology stakeholders as a supplement to, or partial replacement of, costly travel to remote areas for data collection and face-to-face meetings.

How Should CRSPs Educate and Train?

How should we train our replacements in the United States and our replacements in cooperating countries? Should our graduate programs focus on the preparation of single discipline reductive researchers in the biological and physical sciences? Or is it possible to create a scientist who is comfortable operating in the milieu of complex social and natural science problems? Is it possible to train technology developers who view research as one important part of the process which includes extension? Should existing scientific human resources be retooled or re-educated?

Conclusion

The CRSP model has created impressive linkages among scientists in developing and developed countries. By all accounts, it has exceeded many of the expectations of those who were engaged in the conceptualization of the program. Yet, while research collaboration has been strong, the collaboration has been largely, but not entirely, among researchers rather than between researchers and others in the technology development process. This is in line with the CRSP mandate as set forth by BIFAD and USAID. However, along the edges of this focus on researcher collaboration lies enormous potential for improving links among researchers, extensionists, and farmers, with the end result an increase in relevance of technology, increased utilization, and greater overall efficiency of the technology development process.

A new vision is required. We need to mindfully and explicitly address the means by which our research efforts meet the needs of farmers. As Baxter (1987:265) stated, "farmers, extension staff and agricultural researchers operate within one system." Improved research-extension-farmer linkages can enhance technology development within this single system. Specifically, CRSPs can contribute to the development of a new vision through the incorporation of extension and farmers on problem-solving teams and through the investigation of alternative approaches to technology development.

Woog, Kelleher, and Turner (1992) argue that technology development be conducted using multimethodological approaches informed by a breadth of theory. The basket of approaches presented in this paper may suggest alternatives for CRSP consideration.

We must keep in mind that *people* are the main target of development. Technology is a means, rather than an end. We need to carefully balance our investments in human capital and agricultural technology.

Notes

1. It may be helpful to clarify a few terms that will be used frequently throughout this paper. The term *research* refers to the various forms of research (including basic, applied, and adaptive) as well as the various settings in which research is conducted (international agricultural research centers [IARCs], national agricultural research services [NARS], and private commodity research). *Extension* refers to public extension, private/commercial extension, and extension activities conducted by nongovernmental organizations. Farmer refers primarily to developing-country, limited-resource female and male producers of food, feed, and fiber, who exist largely within their own indigenous knowledge systems. For purposes of this paper, the term farmer also includes fishers. *Technology development* is used to describe an overall process, which involves development of a vision of an improved system, constraint/opportunity analysis, technology generation, testing/modification, utilization, and impact. The title provided by conference organizers includes the phrase "technology transfer" in a way that may suggest a general definition and application. However, the phrase *technology transfer* will be used throughout this paper to denote a specific paradigm, which embodies a scientist-driven, production-oriented approach to technology improvement.

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Session 8

Estimating Impacts of New Technology

- Impact Measurement and Policy Distortions: Results from American and African Fieldwork
- Impacts of New Technology in Burkina Faso and the Sudan: Implications for Future Technology and Design

Session Chair: C. Milton Coughenour

Speakers: James F. Oehmke
John H. Sanders

Impact Measurement and Policy Distortions: Results from American and African Fieldwork

James F. Oehmke

Nonresearch government policies can have an influence on agricultural research (Alston, Edwards, and Freebairn, 1988; Oehmke, 1988). However, acceptance of these influences has been slow, with some arguing that the magnitude of any such influence is minor (Voon and Edwards, 1991; de Gorter and Norton, 1988). The purpose of this paper is to provide quantification of the influence nonresearch policies have on research benefits and costs.

Measurement of these influences is important for the evaluation of research programs. Distortionary policies can obscure or even diminish the positive effects of successful research.[1] That is, a research program that implements an appropriate methodology to study a problem, obtains useful results, disseminates these results to an extension service or to producers or processors, and whose results are adopted and utilized, may nonetheless have only limited impact on yields, output, or income due to prejudicial government policies. If this prejudicial influence does indeed occur, then two issues are important: (1) the research may have been successful when measured by reasonable criteria (such as the ability to generate results), and (2) some type of policy reform is in order. Consequently, it is important to measure the influence of nonresearch government policies in the impacts of research.

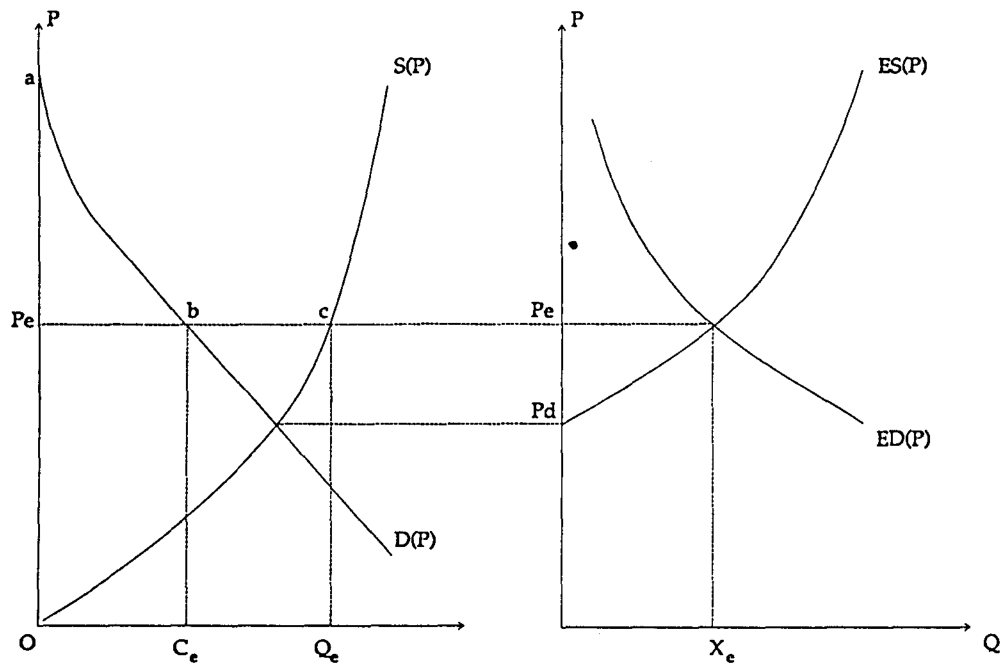
The next section models the effects of U.S. research and commodity policies on corn and wheat sectors. Since commodity programs are similar for these two crops, a single model suffices. The model used closely follows that of Oehmke (1991a). The third section uses the model to quantify the impacts of research on consumers, producers, and taxpayers. It also quantifies the influence of the commodity programs on these impacts. In the fourth section, two African examples of nonresearched research policy interactions are presented. The final section presents conclusions.

A Model of Research and Commodity Programs

Attention is focused on a single commodity that is traded in the world market. For clarity, the basic model in the absence of research and commodity programs is presented in Figure 1.[2] The graph on the left represents the domestic (U.S.) market. Domestic production and consumption are characterized by the supply and demand curves $S(P)$ and $D(P)$, respectively. Price P_d is defined by the condition $S(P_d) = D(P_d)$. Since $S^1 > 0$ and $D^1 < 0$, prices greater than P_d result in $S(P) > D(P)$. Thus, domestic production exceeds consumption, and there is output to be sold on the world market.

The world market is depicted in the right-side graph of Figure 1. The curve $ES(P)$ is defined by $ES(P) = S(P) - D(P)$, and represents the excess of domestic

Figure 1. A model of an internationally traded commodity.

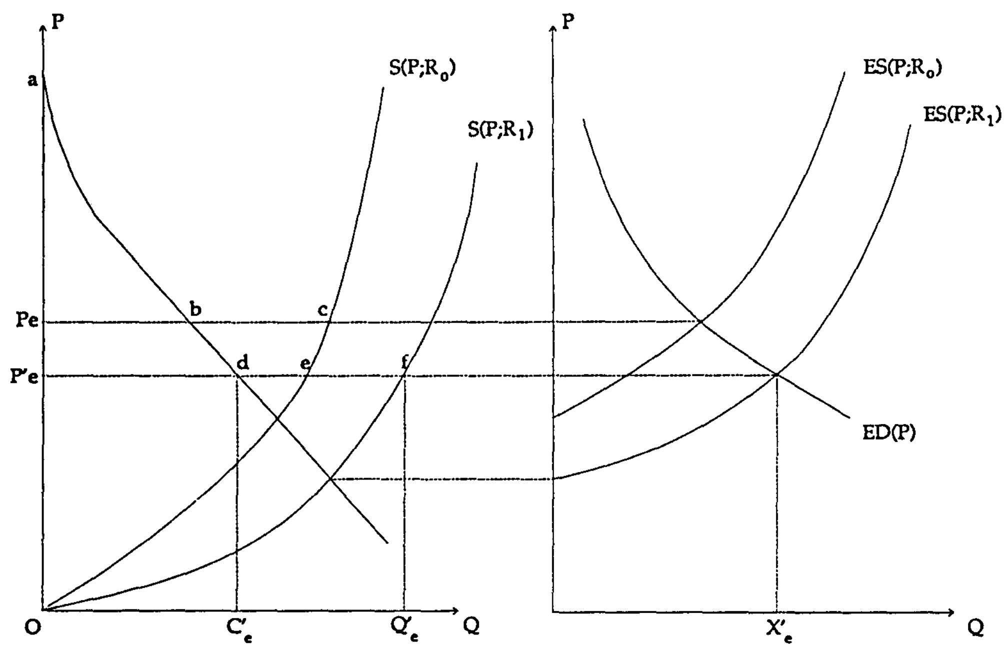


supply over domestic consumption. Thus, it represents the U.S. supply of exports. The curve ED(P) represents the rest-of-the-world's demand that is in excess of their supply. In other words, it represents the world's demand for imports from the United States. The world equilibrium price P_e is defined by the condition $ES(P_e) = ED(P_e)$. This condition states the supply of exports from the United States equals the demand for imports by the rest of the world. At the world equilibrium prices, domestic consumption is C_e, production is Q_e, and U.S. exports are $X_e = Q_e - C_e$. Figure 1 is drawn so that the United States is a net exporter ($X_e > 0$); this is appropriate for wheat and corn.

Standard measures of welfare include consumer's and producer's surplus (Oehmke et al., 1992; Mishan, 1981). U.S. consumer's surplus is depicted graphically by the area below the domestic demand curve and above a horizontal line through the price which consumers pay. In Figure 1 this is area abP_e. Producer's surplus is depicted graphically by the area above the domestic supply curve and below the horizontal line through the price that producers receive. In Figure 1, producer's surplus is represented by area OP_eC.[3] Tax costs are not relevant since Figure 1 represents a situation in which there are no government interactions.

Research is introduced as a parameter which shifts the supply curve down and to the right, as depicted in Figure 2. The original supply curve is now represented by $S(P; R_0)$, with R_0 corresponding to the initial amount of research (possibly $R_0 = 0$). The activation of a research program with expenditures $R_1 > R_0$ shifts the supply curve to $S(P; R_1)$, with a commensu-

Figure 2. The impacts of research in an undistorted market.



rate shift of the excess supply curve to ES(P;R_1). The world equilibrium price falls to P'_e domestic consumption increases to C'_e domestic production increases to Q'_e and exports increase to X_1.

The domestic welfare effects are shown in the left-hand side of the diagram. Consumer's surplus increases to adP'_e. Producer's surplus increases by $0ef$ due to the supply shift, but decreases by $P_eceP'_e$ due to the lower equilibrium price. The net effect can be either positive or negative, depending on the magnitude of the price change. As the excess demand curve becomes flatter, the price drop assisted with any specified supply shift becomes smaller, and so producer's surplus is more likely to be positively influenced by research. The sum of consumer's and producer's surplus is unambiguously increased by the shift. The increase in government expenditures equals the increased costs of research, $R_1 - R_0$.[4]

Commodity programs are easily introduced into the model as presented in Figure 1. The major aspects of commodity programs as specified in the 1985 farm bill include target prices and deficiency payments, loan rates, and acreage reductions. The main effect of the research program is to improve yields, or otherwise decrease production costs. In the year studied, 1990, loan rates did not influence the impacts of research, and consequently are omitted from the model.

The most notable feature of the commodity programs is the use of a "target price" to guarantee that farmers receive payments per unit of commodity that exceed the equilibrium price. This guarantee is usually carried out through use of a deficiency payment. The deficiency payment per unit is equal to the difference between the target price and a measure of the prices received by farmers (the higher of an average market price and the "loan rate" at which the government is willing to "buy" the commodity from the farmer). An interesting characteristic of the commodity programs is that land, not farmers, are enrolled in the program. That is, in order for a particular unit of a commodity to be eligible for the target price, that unit must have been produced on land officially enrolled in the program, known as program acreage or *base acreage*. Moreover, the amount of the commodity that can be grown on the base acreage and put into the program is limited by a cap on yields, which approximates the average yields from 1980-85 for each farm. If actual yields exceed the yield cap, then the extra production can be sold in the market but is not eligible for target prices, deficiency payments, or other program benefits.

A second notable feature of the commodity program is the possibility of an acreage reduction requirement. The requirement is that the farmer must not grow the program commodity (or other specified crops) on a certain percent of the base acreage in order to be eligible for program benefits. This requirement affects not only the quantity of output grown under the program, but also affects the total quantity produced by removing some amount of land from production of the program commodity.

While several other important features of the commodity program influence farm income, the target prices and acreage reduction have the most important influence in research benefits and costs. Hence, attention is restricted to these two provisions.

The commodity programs are depicted in Figure 3. For simplicity, the research-induced shift in the supply curve is momentarily omitted. A target price of P_t is paid on each unit of the commodity grown under the program. Since the program essentially fixes area and yields, the aggregate quantity eligible for target prices/deficiency payments is represented by the vertical line through the Y intercepts $\overline{Q}(\alpha)$. The parameters α represents the average reduction. It is assumed that an acreage reduction of a percent results in a decrease of α percent in the quantity eligible for program benefits.[5] Note also that the curve $S(P; \alpha)$ will lie up and to the left of the $S(P)$ curve of Figure 1. Since attention is focussed in the influence of research on commodity programs, the direct effects of commodity programs on welfare are neglected.

It is now possible to describe the influence of commodity programs on research impacts, by superimposing Figure 3 on Figure 2, as shown in Figure 4. The relevant supply curves are now $S(P; R_0, \alpha)$ and $S(P; R_1, \alpha)$; the curves of Figure 2, with $\alpha = 0$ implicitly, are omitted. With $R = R_0$ the equilibrium price is P_w, as before. As research shifts the supply and excess supply curves out and to the right, the world price falls to $P'_w < P_w$. Consumer's surplus increases from ahP_w to ajP'_w. It is unclear, a priori, whether this shift is larger or smaller than the increase of $P_e bdP'_e$ shown in Figure 2. Producer's surplus increases by Oik due to the larger quantity produced, but decreases by ilmn due to the lower world price. The costs of deficiency payments to support the target price increases from $(P_t - P_w)\overline{Q}(\alpha)$ to $(P_t - P'_w)\overline{Q}(\alpha)$, represented by area $P_w mnP'_w$. Graphically, it is difficult to think of general scenarios in which research impacts are positively influenced by the commodity program.

Figure 3. The impacts of commodity programs.

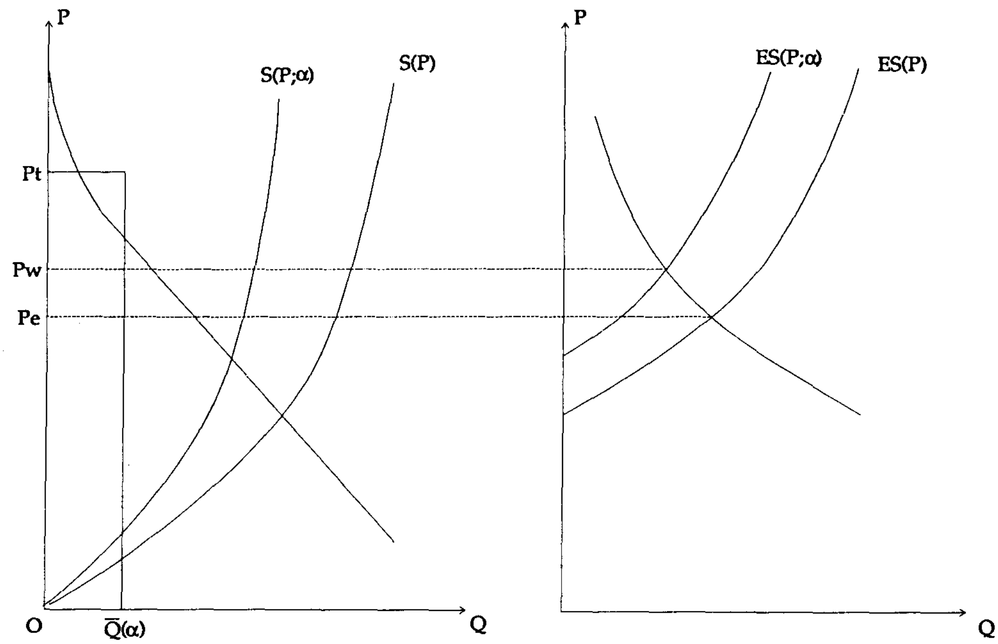
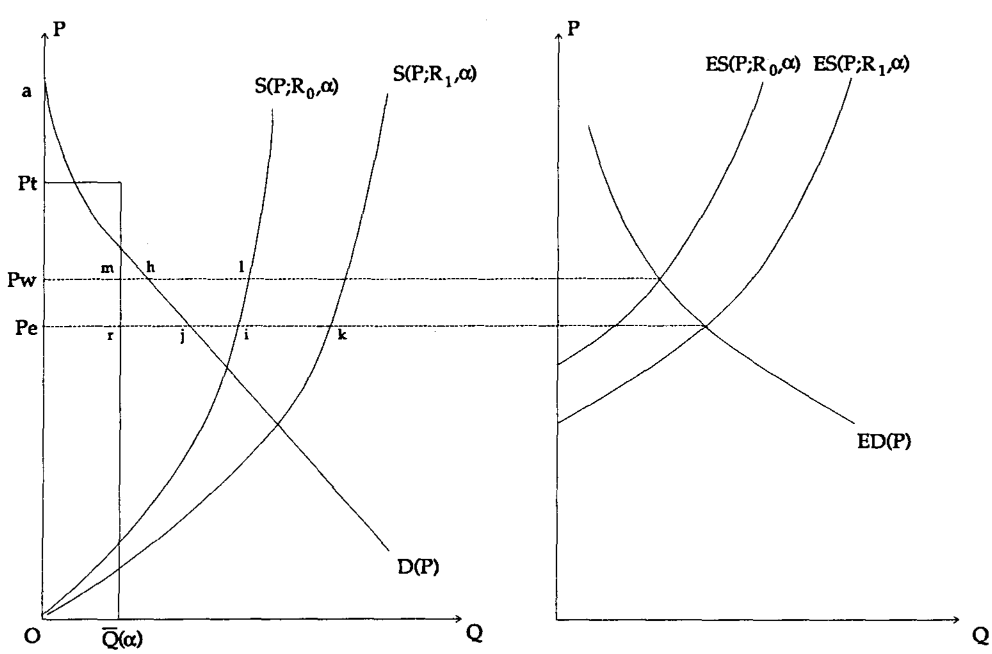


Figure 4. The influence of commodity programs on research impacts.



Empirical Analysis

Measurement of the relevant areas of Figure 4 requires specification of the supply, demand, and excess demand curves and of the way in which research shifts the supply curve. All curves are assumed to be constant elasticity curves:

Domestic supply: $S(P; \alpha,R) = a(\alpha, R)P^{\sigma}$
Domestic demand: $D(P) = bP^{-\varepsilon}$
Excess demand: $ED(P) = kP^{-\iota}$

The effect of an acreage reduction of α percent on supply is assumed to be a supply shift of $\alpha\beta$ percent, where $\beta \leq 1$ allows for imperfect transmission of area reduction into quantity reductions. This happens when farmers take poor quality land out of production to meet the acreage reduction, increase the use of nonland inputs, change rotations, or otherwise adjust to the acreage reduction program. The impact of research on the supply shifter, α, is also assumed to be constant elasticity, following Norton (1981) and Zentner and Peterson (1984). Consequently,

$$a(\alpha,R) = (1-\alpha\beta)R^{\rho}.$$

The implicit assumption that α and R affect supply only through the parameter a means that the consequent supply shifts are proportional shifts. The specification of the research effect is peculiar when research expenditures are low: $S(P; \alpha, 0) \equiv 0$. However, this formulation is consistent with the empirical work cited above, and seems to perform well in the vicinity of observed levels of research expenditures. It is further assumed that the research expenditures affect the supply function with an eight year time lag. Some literature suggests that the time lag might be much longer, and it is certain that the impacts of research will be felt over a number of years. The eight-year lag is chosen because it is a simple specification that performs well when confronted with the data (Norton, 1981; Zentner and Peterson, 1984). The relevant parameter values are $\sigma = 0.4$, $\delta = 0.5$, $\iota = 1.5$, and $\rho = 0.4$. Discussion of these choices can be found in Oehmke and Yao (1990).

Finally, it is important to combine these welfare measures accurately. Consumer's surplus and producer's surplus are usually added together to create social surplus, which is interpreted to be a measure of social welfare. The costs of generating the increase in social welfare are the tax costs of the programs. However, the budget expenditures on the program differ from the tax costs, primarily because of the welfare cost of raising tax revenue or other means of generating the necessary funds for the commodity and research programs. These welfare costs are generally thought to be in the 40 percent range. Consequently, a relevant measure of social welfare is the efficiency measure:

$$\Delta EFF = \Delta CS + \Delta PS - 1.4\Delta GB$$

where Δ represents the difference from before the programs and/or research to after, EFF is the measure of efficiency, CS is consumer's surplus, PS is producer's surplus, and GB is government budget. The marginal effects of research on social welfare can be obtained by differentiating ΔEFF with respect to research.

The marginal effects of research on producer's surplus, consumer's surplus, and the budget are presented in Table 1. When the observed programs are in place, increasing corn research expenditures by one dollar generates $1.8 of producer's surplus, $23.2 of consumer's surplus, and costs the taxpayer $6.73 in total budget exposure. Social welfare in-

Table 1. The Influence of Commodity Programs on Research Impacts.

	Corn 1989	Wheat 1989
Without Programs		
ΔP S	-5.80	0.44
ΔC S	26.97	7.40
ΔG B	2.14	2.14
ΔE F F	18.17	4.79
With Programs		
ΔP S	1.79	2.15
ΔC S	23.23	6.41
ΔG B	6.73	2.88
ΔE F F	15.60	4.56

creases $15.6, by the efficiency measure. While these numbers appear to be somewhat high, they are of the expected order of magnitude and will serve as a basis for comparison.

In the absence of the commodity programs, at the margin research would decrease corn producer's surplus by $5.8, increase consumer's surplus by $26.9, and the government budget by $2.1.[6] The efficiency measure is $18.1. Thus, the commodity programs have a negative impact of 15 percent on the measure of marginal efficiency of research.

The analysis of the wheat program provides similar results. Research has a positive marginal effect with or without the program. The program redistributes some of the research benefits away from consumers and to producers, and raises the marginal budget cost. It also reduces the impact of research on social welfare by about 5 percent of the efficiency measure.

These quantifications of the influence of commodity programs on research impacts are somewhat smaller than that found by Oehmke (1991a) for wheat in 1988. A possible explanation is that the program participation rates were very different, with over a third of 1988 wheat production grown under the commodity program, but only about 5 percent in 1989.

Extension to Africa

Almost all developing countries, and certainly most or all of those in Africa, intervene in agriculture. Thus, distortions are present. Evaluations of research impacts need to consider whether such distortions influence the impact of research, and account for such influences when they are relevant.

Two examples show this influence. Kenya imports all of its chemical fertilizers. Until recently, imports were restricted by a quota and fertilizer prices within Kenya were strictly regulated. Mazzucato (1991) posited that these policies restricted farmer access to fertilizers, thus diminishing the value of fertilizer-responsive, high-yielding varieties developed by agricultural research. Based on previous analysis by Karanja (1990), Mazzucato found that the influence of the fertilizer policies reduced the rate of return to Kenyan maize research from 60 percent to 58 percent. Although this drop is in the direction posited, it is also within the range of measurement error. Moreover, a 2 percentage point drop does not have an important impact on the conclusions to be drawn from a rate-of-return analysis. In this case, the influence of fertilizer policy on the returns to research seems to be minimal.

Through the late 1980s, the Malawi maize research program was largely focussed on dent maize varieties. Malawian subsistence farmers prefer to consume flint maize products, with dent maize sold to government purchasing agents. In the early 1980s, the government allowed the real price of dent maize to fall dramatically, resulting in a decline in hybrid (dent) maize area of over 30 percent (Oehmke, 1991b). In conjunction with a privatized national seed company and reinvigorated research program, price increases in the latter half of the decade led to an increase in area planted to hybrid dent varieties from about 3 percent of maize area in 1985/86 to 15 percent in 1990/91. While rate-of-return measures are not available, it is clear that the impacts of research are affected by the pricing policy.

Conclusion

This paper has presented the conceptual argument that agricultural policy interventions can influence the impacts of agricultural research. Evidence from the U.S. corn and wheat sectors indicate that this influence is negative, in these two cases. Evidence from Kenya indicates that the fertilizer policy probably had little influence on the returns to maize research, while evidence from Malawi indicates that maize-pricing policy seems to have an important influence on adoption of hybrid varieties. It is hard to make general statements from this limited number of examples. Nevertheless, it appears that the social science researcher would find it worthwhile to invest some time in deciding which policies influence research impacts, and if these influences are significant enough to change the results of an analysis.

For the CRSPs, policy distortions may be particularly important when calculating rates of return or other measures of benefits and costs. This is true in the context of quantifying impacts of previous research, perhaps in an effort to generate funding for ongoing projects and when projecting future benefits of research.

A second implication for the CRSPs is that they may wish to play a bigger role in the design and analysis of policy complementary to research. If, with Larry Busch (see paper in this proceedings), we view our role as one of modifying behavior, then these policy activities are certainly within the range of acceptable activities. It is well beyond the scope of the CRSPs to assist in implementation of the policies. Nevertheless, policy dialogues with Ministries of Agricultural, USAID-ADOs, and other relevant actors may be very useful in the implementation and success of more traditional CRSP research programs.

Notes

1. They may also send the wrong signals to researchers, consequently leading to a misdirection of research into areas of lower social value. However, this topic is not taken up in the current paper.

2. Supply and demand functions transform prices into quantities but, for historical reasons, are depicted with the argument on the ordinate and the image on the abscissa.

3. Effects on international producers and consumers are ignored. This simplifies the analysis without losing the focus on interactions between domestic commodity programs and domestic research.

4. In the simplest case, if the increase in social surplus (product plus consumer surplus) is larger than the increase in research costs, then the research is

deemed worthwhile. More realistically, research costs will be increased over a number of years before the supply shift is realized and the benefit of research will persist for a number of growing seasons. Consequently some type of present value model is appropriate. However, the purpose of this paper is not to calculate present value but, rather, to see how commodity programs may influence the benefits or costs of research.

5. The percentage decrease in quantity may vary due to the acreage reduction effects on farmer participation in the program.

6. This figure is the value of $1.00 spent in 1981 and brought forward to 1989 at a 10 percent discount rate.

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Impacts of New Technologies in Burkina Faso and the Sudan: Implications for Future Technology Design

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For almost a decade, Purdue has been involved in technology introduction and evaluation in the Sahel, principally in Burkina Faso and Niger. The initial research concentration was on the potential returns to a series of new technologies (for a review of this activity, see Nagy, Sanders, and Ohm, 1988; Shapiro, et al. 1993). More recently the Economics Program of INTSORMIL has become involved in looking at the association of new technology introduction with sustainability issues and within-household income distribution effects (Ramaswamy and Sanders, 1992a, 1992b). Outside the Sahel, a major effort has been made to evaluate the performance of a new sorghum hybrid in the rainfed and irrigated regions of the Sudan (Habash, 1990; Ahmed and Sanders, 1992).

Here we would like to present some of our principal results from Burkina Faso and the Sudan and why they are important for future technology development. Some methodological aspects of impact evaluation will also be briefly discussed. First, a general theory of cereal technology for semi-arid sub-Saharan Africa is presented. Secondly, methodology for measuring impacts will be considered from the perspective of how economists can respond to the requests of agricultural scientists and policymakers for more information on farmers' environments, objectives, and constraints relevant to research design.[1] This will be followed by two sections on the results and their implications for Burkina Faso and Sudan. Finally, some conclusions are presented.

A Theory of Cereal Technology Development for the Semi-Arid Sub-Saharan Africa[2]

In both national and international agricultural research centers during the last two decades, plant breeding has been the predominant discipline with other disciplines providing a supporting role. This stress on breeding results from the successes of the Green Revolution (wheat and rice in the predominantly irrigated regions of Asia, South America, and North Africa) and other breeding successes in the agriculture of developed countries. One common characteristic of the regions where breeding has been successful was the moderate to high utilization of improved agronomic practices, including water control and chemical-fertilizer utilization. In the United States, where sorghum yields tripled in 30 years from 1.2 metric tons per hectare in 1950 to more than 3.8 in 1980, the genetic contribution was estimated to be from 28 to 39 percent (Miller and Kebede, 1984:6, 11). Over 60 percent of these very large yield gains in the United States were due to improved agronomy practices, especially fertilization, herbicides, and water control (Miller and Kebede, 1984:7). The new cultivars are generally more responsive to higher input use. Thus, the technological-development strategy needs to include both breeding and improved agronomy (F. Miller, personal correspondence).

The central problem of agricultural technology development in sub-Saharan Africa is that too much has been expected of the breeders. In contrast with those regions of the world where breeding activities have been successful, semi-arid sub-Saharan African agriculture takes place in an extremely harsh environment. Rainfall is low and irregular; there are multiple soil-fertility problems, including very low levels of the two basic nutrients, nitrogen and phosphorus; and there is minimal purchased input utilization. Asking breeders to resolve all these problems of inadequate water and nutrient availability prior to basic improvements in agronomic conditions is unrealistic.[3] Moderate improvements in the agronomic environment of sub-Saharan Africa would enable breeders to concentrate on developing cultivars for an improved and less variable agronomic environment.

The first task then is to identify these principal agronomic and other constraints. There has been much debate on the constraints to increasing cereal productivity in sub-Saharan Africa. Seasonal-labor scarcity has been advanced as the major constraint to agricultural output increases and most sub-Saharan African countries have had programs to subsidize the introduction of animal traction, some for 30 to 40 years. Still, the introduction of animal traction has been minimal, estimated at less than 15 percent of the farmers in semi-arid West Africa in the mid-eighties (Matlon, 1990:30).

The importance of the water-availability constraint is obvious from the definition of the region as semi-arid. Unfortunately, increasing soil moisture when the nutrient levels remain low does not markedly increase yields. Even at slightly higher fertility levels, cereals will quickly mine the available nutrients if they are not replaced. Applying fertilizers (organic or inorganic) without an assured water supply is economically risky since the response to fertilizer is dependent on the availability of water at critical stages of plant development. Combining the two, increased water availability and utilization of moderate fertilizer levels, has been shown to result in large and consistent increases of sorghum yields (Nagy, Sanders, and Ohm, 1987:39–46). These innovations have also been shown to be highly profitable at low levels of yield risk to farmers.

There also are two secondary constraints which often become important in implementing strategies to overcome the dual water-availability/soil-fertility constraints. First, many methods of water retention require a substantial labor input during the crop season. In this case, seasonal-labor availability can become a binding constraint. However, animal-traction mechanization can resolve this problem. A tractor implement utilized for furrow diking on the Texas High Plains has been adapted, field-tested, and marketed for Sahelian conditions of animal traction (Nagy, Sanders, and Ohm, 1988; Anon., 1984:24).

Price as a secondary cereal-productivity constraint became obvious in 1986. After the second year of predominantly good harvests of sorghum, millet, and maize production in the West African semi-arid tropics and with the low international prices of rice and wheat, the sorghum/millet price collapsed in both Niger and Burkina Faso in 1986 (Adesina and Sanders, 1991).[4] At these low cereal prices, there is minimal interest by cereal producers in adopting new technologies or by public officials in increasing cereal productivity.

Another secondary constraint is the low level of infrastructure, especially secondary roads. The poor state of transportation and communication substantially increases the cost of locally produced cereals (Delgado, 1991:106) and would be expected to reduce competition between truckers, thus making it more difficult to export sorghum and millet to other countries or other regions of the country. The commonly overvalued exchange rates, as in the CFA zone, also subsidize the price of the imported cereals, shifting demand from domestic to imported cereals. (Delgado, 1991).

A strategy for technology introduction in semi-arid sub-Saharan Africa needs to focus first on improving the agronomic environment through simultaneous improvements of water availability and soil nutrients. Clearly, with the soil and climatic variation in semi-arid sub-Saharan Africa, there will be substantial regional variation in the appropriate technologies and technological development strategies.

In spite of the constraints of the harsh environment, there have been numerous introductions of new technology across the semi-arid zone (Table 1). Are these introductions consistent with the above theory? Cotton and maize yield increases are a dramatic success in the higher rainfall Sudano-Guinean zone. Cotton yields increased from 75 kilograms per hectare in 1952–54 to 1,124 kilograms per hectare in 1984–87 (Savadogo, 1990:30, 31). The basis of these yield increases has been increasing fertilizer use, new cultivars, and improved agronomic practices. More recently, similar gains have been made in corn yields in this region with the same research combination. There has also

Table 1. Rainfall by Region and Technologies Successfully Introduced in the Three Principal Agroecological Regions for Crop Production of the Semi-Arid Tropics in West Africa.

Zones	Expected Rain-fall at 90% probability (mm)	Technologies	Responses to Principal Constraints	
			Water Availability	Soil Fertility
Sudano-Guinean	800-1100	New cotton and corn cultivars with chemical ferilizer and improved agronomic practice. Improved agronomy and fertilization on corn and sorghum	Sufficient rainfall in most years in this zone.	Fertilizer utilized in the combined-technology package.
Sudanian	600-800	Contour dikes and organic fertilizer. Early cereal and cowpea cultivars.	Holds the runoff water. Earliness gives drought escape.	Organic fertilizer. Selected for low soil-fertility conditions.
Sahelo-Sudanian	350-600	Supplementary irrigation.[a] Early cereal and cowpea cultivars. Contour dikes and organic fertilizers.	Full water control. Drought escape with earliness. Holds the runoff.	Rice heavily fertilized. Selected for low soil-fertility conditions. Organic fertilizers.

[a]Only small area of supplementary irrigation (< 1 ha) provided by government to farmers; these are a type of income stabilization for dryland farmers.

Source: Adapted from J.H. Sanders, S. Ramaswamy, and B.I. Shapiro (1992: Ch. 3).

been a spinoff to sorghum of increased fertilizer utilization, principally with the residual fertilizer effect in the rotations. This is a region in which there is generally sufficient rainfall, hence the combined water-retention/fertilization strategy is not necessary in most years.

Moving farther north toward the Sahara, attention to water availability becomes critical. The rapid introduction of the combined contour dikes and organic fertilizers has been documented for the Sudanian zone.[5] The main cultivar success stories have been the early sorghum, millet, and cowpeas. Here the drought-escape activity of earliness is substituted for the increased water availability.

In this summary of observed technology introduction, the theory seems to be performing well. The gains were especially impressive for cotton and corn and, to a lesser extent, sorghum in the Sudano-Guinean higher rainfall zone. However, this is not a strong test of the theory since water-retention techniques are not critical here. Nevertheless, it is important to emphasize the rapid technological change in this region to offset the prevailing gloom-and-doom outlook of the conventional wisdom toward agricultural development in sub-Saharan Africa. Technological change in this higher rainfall region is an outstanding success story. Moreover, results of the technologies being introduced in the lower rainfall regions, while not as dramatic, are also consistent with the above theory. Elsewhere, the programming evidence of potential technological introduction is also marshalled to evaluate this theory (Sanders, 1992).

Evaluating the Impact of New and Potential Technologies

Funding agencies appreciate studies of successful technology introduction because their investment decisions in agricultural research can have very high returns. These high returns to agricultural research are a well-known phenomenon to agricultural economists. Measurement of the economic impact of a successfully introduced technology is straightforward, requiring only observed prices of the new technology, the costs of research development and of the new technology, and estimates of demand and supply elasticities. However, a methodological problem exists of whether to use the economic variables faced by the farmers or the real costs and prices faced by the society if all distortions are removed and products and inputs are valued at their social costs. Both types of analyses are relevant but they respond to different behavioral and policy questions. An example of both types of analysis will be presented in a later section of this paper reporting the results from the Sudan.

Another important economic analysis is to estimate the potential impact of new technologies not yet introduced and help identify the constraints to their introduction. This type of analysis is generally not undertaken in developed countries but is very important for developing countries. Why? The rest of this section responds to this question.

Agricultural scientists in developed and developing countries are continually turning out new technologies. In developed countries, these technologies are often promoted to other scientists, the extension service, and even directly to media or farmers. Sometimes these technologies are promoted too soon and they fail, or they are successful but have unexpected consequences, or they are successful in places where they are not expected to be successful.

In developed countries, there are a series of internal checks protecting farmers from poor technological advice. First, there is a long, scientific tradition with its internal checks of competition and journal verification. Second, there is a well-educated and skeptical extension service through which new technologies are often channeled to farmers. Third, most farmers have at least a high school education and often university training. They can filter information; make small trials of divisible technologies; or inspect their neighbor's larger, more indivisible (new-machinery) technologies. They can also afford to take moderate losses on small experiments or even survive a bad year or unexpected failure. Thus, developed countries with substantial public support for agriculture and many off-farm alternatives to labor can handle adjustments from inappropriate technologies or adverse secondary effects.

In contrast, in low-income developing countries, few of these conditions exist. The extension service often has poor links to the scientific community. Farmers' educational levels are low and their cultural distance from the scientific community is often great. Farmers' abilities to filter information or even to obtain it or to experiment with innovations is minimal. Small losses can have much more serious implications than in developed countries.

Hence, to maintain credibility of the agricultural institutions, some filtering devices of the new technologies being evaluated at the experiment station need to be implemented. The most well-known filtering device is on-farm technology testing. Regional trials for testing site-specific technology effects are common in developed and developing countries. Agronomists in developed countries often try out new practices on farms. This on-farm testing is frequently more of an extension activity than a research activity. The farming systems research movement attempted to make a science of the different types of farm tests and other farm-level information gathering in developing countries. This movement and testing never really caught on in developed countries although it has been partially resurrected in the United States as part of the sustainability movement. Farming systems research was more successful in establishing itself as part of agricultural research institutions in the developing countries.

The farm testing in developing countries has been useful for further analysis of regional and farm-specific effects and constraints. It has pushed scientists, including social scientists, to work together. It has helped broaden communications among scientists, extension agents, and farmers. It has helped concentrate scientists' attention on delivering a final product to farmers and on responding to constraints identified by farmers. Now many countries have institutionalized this process in their agricultural research institutions.[6]

Most statistical evaluation of technologies coming off the experiment station or out of farm trials begins with analysis of variance. This is the standard quality-control device of agricultural scientists. At some level of probability, analysis of variance tells scientists which treatments are significantly greater than the control representing present farmers' practices.[7] For many agricultural scientists, this is the extent of their involvement in the arcane world of statistics. Some can be convinced that farmers do not maximize yields and will let economists put in costs and prices to do partial budgeting. Most will not touch this type of inexact data themselves. Some will resist this simple profitability analysis, arguing that these were data from only one season so economists should wait a few seasons. Moreover, some would argue that since costs and prices vary substantially within the year and between years, so really only yield differences should be analyzed.

The next stage of analysis, after simple profitability, is the fit into farmers' systems of production. Several research questions should be addressed at this stage of analysis: With several technologies (treatments) being profitable and many combinations available, which will be chosen and at what levels? Are there on-farm or off-farm constraints preventing the adoption of the new technologies? How sensitive is technology adoption to off-farm resource availabilities and to economic policies (actual or potential)? Will adoption levels be affected by more complicated objective functions than profit maximization? These and other questions regarding the potential impact of new technologies can be responded to with mathematical programming analysis of the farm. The principal outputs of this analysis are the expected income effects, farm-level constraints to the introduction of new technologies, and the potential contribution of supporting agricultural and economic policies to technology introduction and expected farm incomes. The next two sections will illustrate some of this output.

Results and Implications for Burkina Faso

Two recent questions about the potential impacts of new technologies are especially relevant in Burkina Faso: (1) When will farmers shift from extensive (area-increasing) or traditional technologies to intensive (yield-increasing) technologies? (2) Will the new technologies have adverse effects on the income (welfare) of women?

In the more heavily populated and severely degraded regions of Burkina Faso, there has been rapid adoption of new water-retention/soil-fertility technologies.[8] Approximately 60,000 hectares have been put into earthen dikes and another 6,500 hectares into stone dikes. Dikes on the contour slow down water runoff, resulting in higher returns to the organic fertilizer placed immediately behind the ridges (1 to 2 meters). The yield effects are small but the diffusion is impressive (Sanders, Nagy, and Ramaswamy, 1990:6–8). The new water-retention technique is highly labor-intensive but it can be accomplished outside the crop season.

The next stage in technology evolution would be a water-retention technique, such as tied ridges and/or improved land preparation. These techniques need to be undertaken during the crop season but offer the potential of much higher yields and profits (Sanders, Nagy, and Ramaswamy, 1990:9, 10). On the areas traditionally growing sorghum, combined activities of tied ridges and moderate chemical fertilization were estimated to increase yields over 100 percent. This was a conservative estimate made for the modeling. Note the data summarized in Table 2 includes averages of farm trials from different villages and over two years.

Despite very impressive yield increases and high profitability recorded with partial budgeting analysis, there has been minimal adoption in Burkina Faso of this combined technology of tied ridges and chemical fertilizer. Why? One hypothesis is that as long as farmers have

Table 2. Yields and Percent of Farmers Taking Cash Losses[a] from Fertilization and/or Tied Ridges in Sorghum Production in Farm-Trial Villages in Burkina Faso, 1983 and 1984.

Year/ Village	No. of Farmers	Traction Source	Treatments	Control	Tied Ridges	Fertili-zation	Tied Ridges & Ferti-lization
1983:							
Nedogo	11	Manual	Yields	157	416	431	652
			% Farmers who would have lost cash	---	0	27	9
Nedogo	18	Donkey	Yields	173	425	355	773
			% Farmers losing cash	---	0	50	0
Bengasse	12	Manual	Yields	293	456	616	944
			% Farmers losing cash	---	0	8	17
Dissankuy	25	Ox	Yields	447	588	681	855
			% Farmers losing cash	---	0	0	0
Dispangou	19	Manual	Yields	335	571	729	1006
			% Farmers losing cash	---	0	26	0
Dispangou	19	Donkey	Yields	498	688	849	1133
			% Farmers losing cash	---	0	21	0
Dispangou	19	Ox	Yields	466	704	839	1177
			% Farmers losing cash	---	0	5	0
1984:	3	Manual	Yields	430	484	547	851
Nedogo			% Farmers losing cash	---	0	56	0
Nedogo	11	Donkey	Yields	444	644	604	962
			% Farmers losing cash	---	0	58	42
Bangasse	12	Manual	Yields	406	493	705	690
			% Farmers losing cash	---	0	21	17
Diapangou	24	Manual	Yields	363	441	719	753
			% Farmers losing cash	---	0	8	8
Diapangou	25	Donkey	Yields	481	552	837	871
			% Farmers losing cash	---	0	12	16
Diapangou	25	Ox	Yields	526	578	857	991
			% Farmers losing cash	---	0	20	12

[a]Cash expenditures were only for the chemical fertilizer. The only additional input for tied ridges was substantial increases in family-labor utilization. Note also that expenditures were paid by the project so that the farmers did not actually lose those expenditures on chemical fertilizer.

Source: J.H. Sanders, J.G. Nagy, and S. Ramaswamy (1990:10).

abundant bush-fallow land, there is little incentive to intensify production by increasing yields. Rather, the preferred technology would just be further area expansion with animal traction. Extensification by animal traction pushes cultivation into marginal lands previously used for communal grazing and reduces crop yields that are already being affected adversely by increasing population density in the Sahel (Broekhuyse and Allen, 1988; Vierich and Stoop, 1990). Intensive or yield-increasing technological change is necessary to reverse land degradation and to increase crop yields.

Results from a representative farm-programming model indicate that the new sorghum technologies are adopted even with abundant bush-fallow land available. but on a small scale, 0.6 hectares. Full adoption on the entire 1.4 hectares of

Table 3. Cropping patterns and input use with traditional and improved technologies as the supply of Bush-Fallow Land (BF) becomes more inelastic.

	Supply of Bush-Fallow Land PERFECTLY ELASTIC		Supply of Bush-Fallow Land MODERATELY ELASTIC		Supply of Bush-Fallow Land HIGHLY INELASTIC	
	Traditional Technology[a]	Improved Technology: Extensive Option[b]	Traditional Technology[a]	Improved Technology: Extensive Option[c]	Traditional Technology[a]	Improved Technology: Extensive Option[c]
Total Area (Ha)	**5.82**	**6.47**	**5.35**	**5.67**	**4.95**	**4.95**
Maize	0.15 CL	0.15 CL,TR,DT	0.15 CL	0.15 CL,DT,TR	0.15 CL	0.15 CL,TR,DT
Sorghum	---	0.6 HQ,DT,TR,F	---	0.7 HQ,DT,TR,F	---	1.4 HQ,TR,DT,F
Sorghum/Cowpeas	1.4 HQ	0.8 HQ,HT 0.1 BF,HT	1.4 HQ	0.7 HQ,HT 0.5 BF,HT	1.4 HQ	---
Millet/Cowpeas	4.0 BF	3.2 BF,HT 1.2 BF,DT	3.6 BF	3.2 BF,HT	3.0 BF	3.0 BF,HT
Peanuts	0.27 BF	0.25 BF,HT 0.17 BF,DT	0.2 BF	0.42 BF,HT,DT	0.4 BF	0.4 BF,HT
Urea (kg/farm)	---	30	---	38	---	70
Compound Fertilizer (kg/farm)	---	60	---	73	---	141

[a]Hand tillage, no chemical fertilizer or tied ridges.
[b]Use of animal traction.
[c]Tied-ridging on sorghum and maize, fertilization on sorghum, utilization of animal traction. This chemical fertilizer is known as cotton fertilizer in Burkina Faso and has the composition of 14:23:15 of N:P:K. The standard level utilized with the tied ridges on the sorghum land was 100 kg/ha of this cotton fertilizer and 50 kg/ha of Urea.
Key: BF=bush-fallow land; CL=compound land; D=donkey traction; HQ=high-quality land; HT=hand traction; F=fertilizer activity; TR=tied-ridge activity.
Note: The moderately inelastic supply of bush-fallow land was modeled with a "time cost" of travel to outlying fields of one hour per day. In the highly inelastic case, the farmer had access to only 3.5 ha of bush-fallow.
Source: S. Ramaswamy, and J.H. Sanders (1992a).

Table 4. Income levels per farm and per hour associated with different technologies as the supply of Bush-Fallow Land (BF) becomes more inelastic.

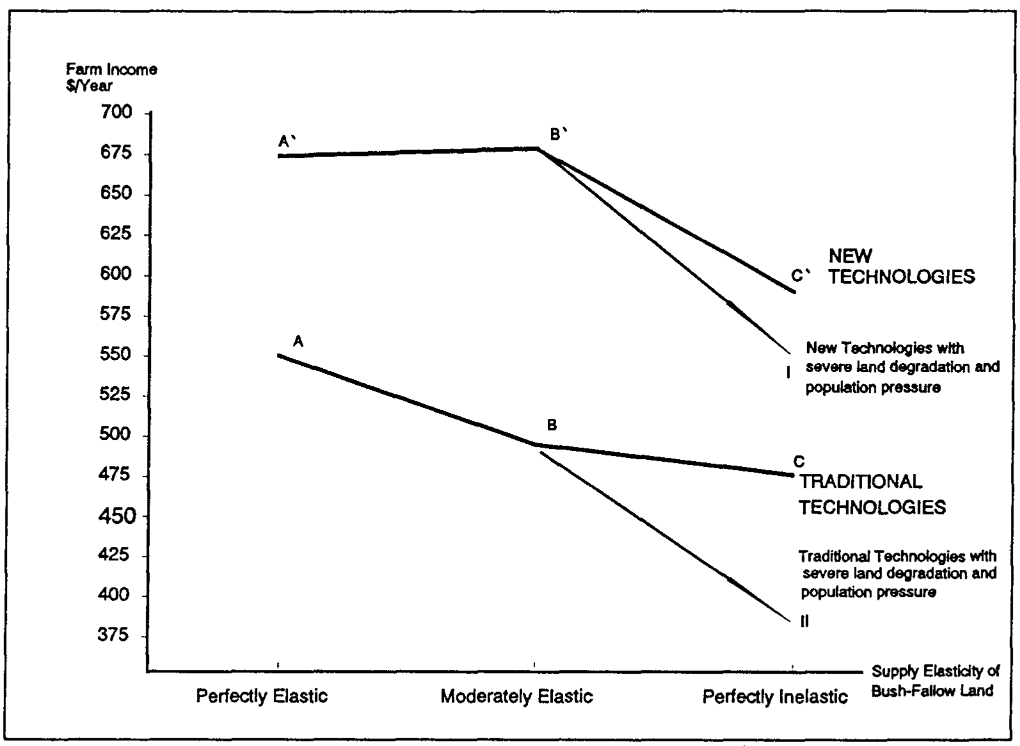
	Supply of Bush-Fallow Land PERFECTLY ELASTIC		Supply of Bush-Fallow Land MODERATELY ELASTIC[a]		Supply of Bush-Fallow Land HIGHLY INELASTIC[b]	
	Traditional Technology[a]	Improved Technology: Extensive Option[b]	Traditional Technology[c]	Improved Technology: Extensive Option[d]	Traditional Technology[c]	Improved Technology: Extensive Option[e]
Net Farm Income[f] $/year	$ 558	$ 674	$ 495	$ 679	$ 476	$ 590
Implicit Wage[g] $/Adult Hour	0.15	0.17	0.13	0.18	0.13	0.16
(FCFA/Adult Hour)	(41)	(46)	(35)	(50)	(35)	(44)

[a]The land supply of bush fallow land above 3.5 ha. also required the additional time costs of travel for one hour each work day.
[b]In the perfectly inelastic case only 3.5 ha. of bush fallow land was available to farmers.
[c]Hand tillage, no chemical fertilizer or tied ridges.
[d]Use of animal traction.
[e]Tied-ridging on sorghum and maize, fertilization on sorghum, utilization of animal traction.
[f]Includes market value of home consumption of cereals.
[g]To estimate the hourly wage for males, the net farm income is divided by the number of adult male equivalents in the household (6), the number of working days in the season (98) and the average daily hours worked on the farm (6). Females are 0.75 equivalents and children 10 to 14 are 0.5 male equivalents. The average wage rate for this region is 50 FCFA/hr (Jaeger, 1987). For a more detailed description of the model, refer to Roth et al. (1986).
Exchange Rate: 273 FCFA/U.S.$ (IMF, 1990).

Source: S. Ramaswamy and J.H. Sanders (1992a).

sorghum land occurs only when the bush-fallow land becomes more scarce (Table 3). In Table 4, the income effects of the introduction of new technology does offset the declines in land availability presently being experienced in this region. On the Central Plateau and in other heavily populated regions of the Sahel, such as the peanut zone of Senegal, the land is already severely degraded. Thus, population pressure leads to a breakdown in the fallow system and in declining yields, resulting in chronic poverty. In Figure 1, this is represented in the more land-supply inelastic cases, as in the Central Plains, with further yield declines ranging from a third to a half over the nondegraded case (points I and II). Nevertheless, the more intensive technologies are still able to increase farm income 36 percent to $540 per year (shift from point II to I). But even with these new technologies, farm incomes are lower than the original scenario of bush-fallow land surplus without new technologies (Figure 1, point A). Thus, the region is expected to be in-

Figure 1. Farm incomes with traditional and new technologies as the supply of bush-fallow land becomes more inelastic.



Note: Farm income includes the market value of home consumption. The moderately inelastic land supply was modeled by introducing a time-cost of travel of one hour per day. The perfectly inelastic land supply was modeled by fixing the supply of bush-fallow land at 3.5 ha/farm. The exchange rate in 1988 was 298 FCFA/U.S. dollar (IMF, 1988). (Source: S. Ramaswamy and J.H. Sanders, 1992a.)

creasingly receptive to these combined agronomic changes. Moreover, the addition of a new cultivar into this moderately improved environment is expected to further increase the profitability of these practices and to accelerate the breeding and diffusion processes by making the breeding requirements less difficult. The breeders can then orient some of their activities to producing new cultivars for a moderately improved agronomic environment. Some drought and nutrient stress research will undoubtedly benefit any new germplasm for the region. Meanwhile, it is important to introduce what is presently available and does have a substantial yield effect, that is, the improved agronomic technologies.

The next logical question is why is there not more adoption of these combined technologies on farmers' field? First, in regions where these technologies have been observed by farmers on other farmers' fields, there has been adoption of the combined technologies (Sanders, Nagy, and Ramaswamy, 1990:15). Secondly, farmers and researchers have trouble evaluating technologies involving several new inputs (see Byerlee and de Polanco, 1986, for a Mexican example). The combination here included tied ridges, chemical fertilizer, and animal traction. All have been available in Burkina Faso for more than two decades, but there has been little emphasis on their complementarity by either extension agents or applied researchers.[9]

Starting with the principle that in semi-arid regions new technologies will build on the combined activities of water-retention/soil-fertility improvement and finally overcome seasonal-labor availability constraints is the most basic concept of the programming and field analysis. Once these improvements are in place, putting a new cultivar into this improved environment will have a substantial yield impact.

A more discordant note than the predominant pessimism of conventional wisdom about increasing yields in semi-arid sub-Saharan Africa is the challenge from the women-in-development literature. One basic question raised by them is: Are women made worse off by the introduction of new technologies? The evidence is that agricultural technological changes are introduced almost exclusively to the men. The yield-increasing or intensive technologies increase the demand for labor. Household women are then generally observed reducing the time worked on their private plots and increasing the time spent on the communal-land area where the new technologies are introduced (Gladwin and McMillan, 1989; Kumar, 1987; Sen, 1990; Buvinic and Mehra, 1990; and the classic Boserup, 1970).

The available detailed empirical studies indicate that women are compensated for this increased activity to introduce new technologies. Jones' fieldwork documents that women were paid their opportunity costs for this additional labor but the income they received was only one-fourth of the income generated by this additional work on the communal area. A second very important point is that land productivity is frequently lower on their private fields than on the collectively farmed or communal fields (von Braun and Webb, 1989; Jones, 1983, 1986).[10]

Farm modeling was undertaken for a zone of rapid, recent introduction of technological change in Burkina Faso, the Solenzo region. Technological change has principally been concentrated on cotton production with new cultivars and chemical fertilization. Some chemical fertilizer has been utilized on the cereals, specifically on corn and in the rotation with sor-

Table 5. Household incomes and female worker incomes from new technologies and the availability of off-farm employment in the Solenzo Region of Burkina Faso.

	Traditional Technology and Animal Traction	New Intensive Technologies on Communal Fields[a]	New Intensive Technologies on Private Fields Only[b]	New Intensive Technologies on Communal & Private Fields	Improved Off-Farm Employment and Improved Technologies Available on Both Types of Fields
Farm Income from Comunal Fields (U.S.$)[c]	922	1,556	805	1,414	1,106[d]
Income of Adult Female Worker (U.S.$):					
Private Plot	36	14	68	68	—
Communal Field					
Compensation	—	71	—	45	125
Off-Farm	—	—	—	—	71
Total: Female Worker	36	85	68	113	196

[a]Here the new technologies are introduced on the more productive fields. The household head must pay more to the female worker for the increased labor on the communal field. The private field available is only 0.75 ha.
[b]Here the land available to the female worker is increased to 1.75 ha and the technology is introduced first on the private fields in spite of the lower productivity. This is done by forcing the model in the programming. It is equivalent to a preferential policy of directing the technology first toward the female farmer (and increasing her land area). These policy measures are frequently advocated in the women's literature.
[c]This is family income including the value of home consumption of food. This includes only crop income from the communal land. Note that as technologies change so do family sizes. The traditional farm with animal traction includes seven adult equivalents.
[d]Note that besides the household head, there are six adult workers on the farm, all with private plots.

Source: S. Ramaswamy and J.H. Sanders (1992b).

ghum. This is a high-rainfall region so the water-retention technique is not necessary in most years.

Since the cited detailed empirical studies of household-income distribution indicate that women are indeed paid for their increased labor activities, a bargaining model was applied. With the bargaining technique, each side in a cooperative/conflict situation calculates its threat point of not dealing with the other.[11] In this case, the two parties are the household head and one of the household wives. The household head can either hire family members or seasonal labor off the farm. The wives can either work for the household head or work more on their private plots or, in some cases, outside the farm. The bargaining rule then decides upon the intermediate point between the two threat points. The simplest type of bargaining rule—the Nash rule—then splits the difference between the two threat points (Nash, 1953; McElroy and Horney, 1981).

With farm modeling, the introduction of new technologies and various policies to benefit women were considered (Table 5). When new technologies were introduced in the communal lands, women reduced their time on the private plots but were paid for their labor on the communal area and increased their incomes from $36 to $85. In this scenario, farm income increased from $922 to $1,556. Both the household and the individual woman farmer were better off. These model results are in line with preliminary results from field surveys which indicate that women's (and men's) participation rates on private plots in Solenzo have declined in comparison with other settlement regions. Furthermore, total farm income in Solenzo has been rising rapidly and women's discretionary income is reportedly higher (Savadogo, Sanders, and McMillan, 1989).

As the next step, the model was used to evaluate the potential impacts of various policy suggestions from the literature. Forcing the new technology to be introduced only on the private fields made the women's income and overall farm income lower (Table 5, cols. 2 and 3). The explanation for this decline is the lower use of inputs and lower productivity of the private fields. If the bargaining process within the household is functioning, the women and the family farm would have higher incomes when technologies are introduced only on the communal fields.

However, if the household head is exploiting the women by forcing them to work on the communal fields and not paying them compensation for this additional labor, then the female preferential policies for technology introduction would make the women better off. The farm household, however, would be substantially worse off and there would be considerable pressure on the household head to negotiate more with other members of the family.

When women have more off-farm activities, their opportunity costs increase and the household head has to increase their wages on the communal fields. In this case, even with the option to utilize new technologies on their expanded private fields, the women did not take that option. Rather, if the women worked off-farm and on the communal field (Table 5, col. 5), the household incomes went down substantially with the higher wages paid, but the women were made much better off.

While the model results emphasize solely the potential income gains that could be realized by women (and the household), attention must be paid to a possible decline in the quality of life for the women within the household. The increasing commercialization of women's labor, in addition to all the housework and child care they perform, places a double burden on the women. One way of improving their welfare is to improve the efficiency of household activities. Efficient wood stoves, hand-pump sets to deliver water, and less time-consuming methods to process cereals would have substantial effects on women's welfare by alleviating the high and fairly inflexible household labor demands.

One important implication from this modeling (and fieldwork) is that economic policies to force the increased utilization of less productive resources can make both the household and the women worse off. There are two ways to increase women's incomes without reducing allocative efficiency on the farm: First, future technological change could increase the productivity of their private plots. A more viable alternative presently may be facilitating the growth of nonfarm employment, which is expected to help the women in the bargaining process. This is still only a hypothesis because the modeling above only roughly estimated private benefits and did not explicitly consider the cost side. However, the potential for technological change to benefit both the household head and the women with some reasonable assumptions about within-household decision-making has been shown.

The basic working hypothesis of this analysis was that with the introduction of new technologies, households move away from a preoccupation with acquiring sufficient grain consumption for the year. They become concerned with the monetized sector of the economy. The household head will then have to negotiate with the household wives to obtain their collaboration in new technology utilization. Moreover, the wives will obtain a share of the increased income flows corresponding to their opportunity costs, that is, their market value working on their private fields or off the farm. Both the decision-making mechanism and the division of increased incomes are important empirical issues requiring more detailed case studies. Meanwhile, it appears that there is sufficient evidence to proceed with introduction of technological change as rapidly as possible with relative confidence that household women will also benefit and that improving the off-farm labor market and the technology of household-production activities would benefit women even more.

Results and Implications for the Sudan

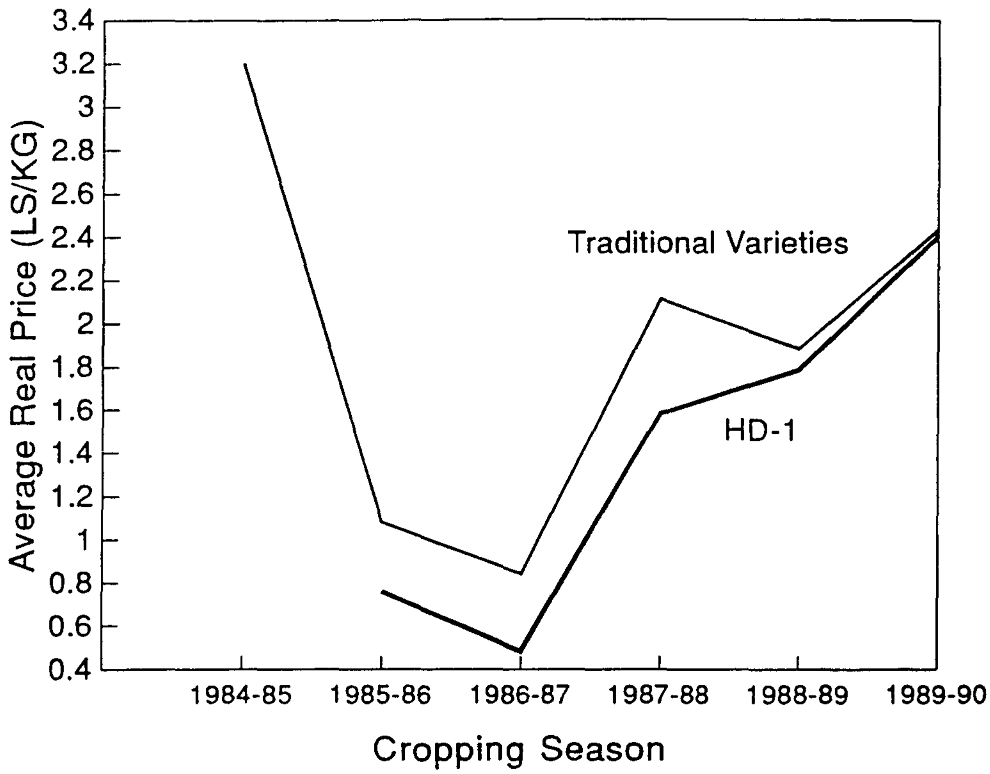
A new sorghum hybrid was commercially released in the Sudan in 1983.[12] Public agencies and 11 private companies rushed into seed production of HD-1 in response to the high sorghum prices after the drought year of 1983–84. The sorghum area in the mechanized rainfed sector increased from 2.1 million hectares in 1984–85 to 3.7 in the 1985–86 season. A substantial output-response and an inelastic demand resulted in a sorghum-price collapse. A large price differential for HD-1 compared with locally preferred sorghums (40 to 50 percent) was then observed. The Sudanese development bank stopped purchasing HD-1 when the sorghum price collapsed that year.

Most farmers then refused to buy HD-1 seeds for the 1986–87 season. Hence, public seed-producers (National Seed Administration [NSA], Gezira Scheme, and Rahad Scheme) drastically reduced their seed production. The private seed companies initially reduced the area planted in certified seed production and then stopped production one year later. Over the period 1986–88, the Sudan Gezira Board was unable to sell even 20 percent of its HD-1 seed stocks.

However, in the Gezira Scheme, there were some farmers who had substantially increased their sorghum yields with HD-1 (Interviews, 1990). They discovered a number of characteristics they liked about HD-1. They continued to buy seeds from the Sudan Gezira Board (SGB). In response to higher sorghum prices since 1988–89, diffusion of HD-1 accelerated and the demand for seeds expanded. Hence, the public seed-producers increased HD-1 seed production in 1990–91. The Rahad Scheme also resumed HD-1 seed production in 1990–91. One of the 11 private seed companies that had stopped seed production after the 1986–87 season began to plant HD-1 again in the 1990–91 season.[13]

The price differential that opened up between HD-1 and traditional varieties in 1985–86 has almost disappeared in the Gezira during the 1989–90 season (Figure 2). There are two hypotheses to explain this price differential. One hypothesis links the price differential to low sorghum prices in good rainfall years. When sorghum prices are high and the output is low, varietal price differentiation is hypothesized to decline. However, real sorghum prices declined substantially between 1986 and 1988 while the price differential narrowed. The second hypothesis is that farmers' (and other consumers') tastes are expected to be gradu-

Figure 2. The price differential of HD-1 relative to traditional sorghum varieties, 1985-1990.

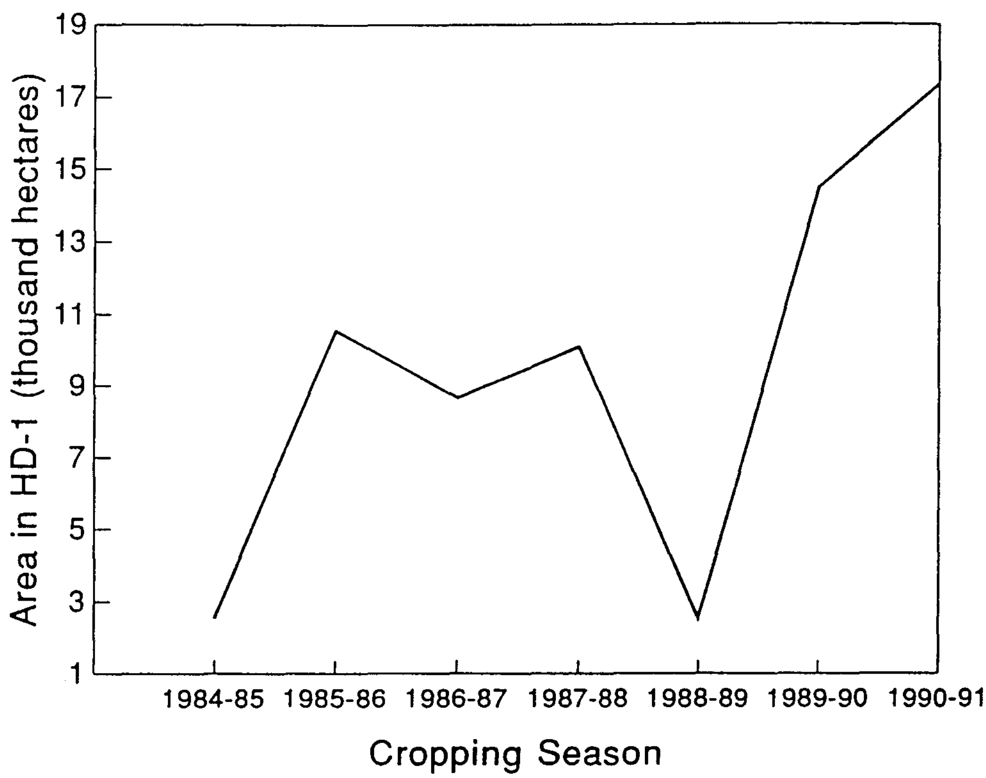


ally responsive to economic factors over time. In the field surveys of 1990, almost all farmers surveyed reported that they either preferred or were indifferent to "Kisra" of HD-1 relative to their traditional sorghums. Apparently, tastes evolved in the Gezira in response to the very high yields of the new cultivar and the consequent reduced per unit production costs. There is only fragmentary evidence but this taste evolution would be analogous for consumers to the induced innovation concept for firms.

HD-1 diffusion started rapidly in 1985–86 in response to the high sorghum prices of the drought year (Figure 3) but due to the low prices in the 1987–88 season, the area in HD 1 collapsed in the 1988–89 season. With the recovery of sorghum prices since late 1988 and the apparent developed preference for HD 1 "kisra" in the Gezira, diffusion of HD-1 once again accelerated reaching 17,336 hectares in the 1990–91 crop year.

Early in the 1990–91 season, both the NSA and the SGB sold all their seed stocks. In the summer of 1990 many Gezira farmers complained about their inability to obtain HD-1 seeds and chemical fertilizer. In spite of considerable expansion of public seed production of HD-1 in 1990–91, the ability of the input markets

Figure 3. Diffusion of HD-1 in the Gezira Scheme, 1984-1991.



(seeds and fertilizer) to respond adequately to high sorghum prices is a principal constraint to increased HD-1 diffusion in the Gezira presently according to farmers (Interviews, 1990).

HD-1 responds well to better management, including fertilizer, good land preparation, sufficient irrigation, higher density, and thinning. Without these treatments, the farm yields of HD-1 are substantially reduced and are approximately equal to the yields of traditional varieties at low input levels (Interviews, 1990). Farmers who utilized high levels of fertilizer and provided these other inputs obtained 3.28 metric ton per hectare from HD-1 as compared to 1.13 metric tons per hectare for the traditional varieties without fertilizer or 1.45 metric tons per hectare for traditional varieties with 47 kilograms per hectare of Urea.

The introduction of HD-1 is associated not only with increased demand for fertilizer and other improved agronomic practices but also with increased marketed surplus. With traditional sorghum cultivars, consumption for home and hired workers were the principal outlets for the low sorghum-output levels. Those farmers producing local cultivars purchased substantial quantities of sorghum, 12 to 25 percent of their production, over the period 1984–90. In contrast, farmers producing HD-1 sold 25 to 33 percent of their production.

Table 6. Present and potential financial returns to the introduction of HD-1 with different diffusion rates and fertilization levels.

	Internal Rates of Return[a]		Net Present Value of Returns (Mil. U.S. $, 1989)[a]		Annual Flow of Returns (Mil. U.S.$, 1989)[a]	
	η=-0.25	η=-0.8	η=-0.25	η=-0.8	η=-0.25	η=-0.8
Present Returns						
9% Diffusion Low Fertilization	23	22	6.944	6.615	1.535	1.462
9% Diffusion High Fertilization	31	31	21.821	20.618	4.826	4.559
Potential Returns						
35% Diffusion Low Fertilization	29	29	32.346	30.094	7.152	6.655
35% Diffusion High Fertilization	37	36	85.089	75.708	18.816	18.229
50% Diffusion Low Fertilization	31	30	44.906	41.081	9.929	9.084
50% Diffusion High Fertilization	39	38	123.892	17.064	27.397	23.675

[a]These estimates were calculated for the range of elasticities of demand of -0.25 to -0.8.

Note: For calculation of benefits and costs of the research, the following assumptions were made: The price elasticity of supply is 0.29; discount rate of 13% was utilized; the time period of analysis is the seven years before release and then benefits occur from 1984 until 2013. The exchange rate for converting to 1989 U.S. dollars was 12.1 S.P./U.S.$; this was the official rate in the spring of 1989.

Source: M. Ahmed and J.H. Sanders (1992).

With HD-1, there is more production of sorghum, so farmers are marketing more. This will make the irrigated regions an even more significant safety valve of available cereals in poor rainfall years. Moreover, Gezira producers of HD-1 are selling their surpluses over the entire crop year. This should help eliminate the substantial within-year sorghum price variation. There are numerous benefits to the introduction of HD-1 in the irrigated area, including increased utilization of fertilizer and better management, increased marketed surplus, reduced price variation within the season, and substantial increases in sorghum yields. In calculating the benefits, only yield increases were included. The other indirect benefits from the marketed surplus and price stability are difficult to quantify and, hence, were not incorporated in this study. This omission would bias downward the estimates of benefits.

The economic results for present and potential diffusion of the new cultivar are summarized in Table 6. These are reasonable results, including—for the most conservative assumptions about diffusion and fertilizer use—an annual return of $1.4 to $1.5 million for the next 30 years. When all the distorted prices, including the exchange rate overvaluation, are eliminated, the internal rates of return decline slightly from 29 percent to 25 percent for the potential diffusion of 35 percent of the Gezira sorghum area in the new cultivars (Table 7).

Table 7. Rates of return to HD-1 research under alternative policy regimes and traded conditions with lower yield advantage and fertilizer utilization.

	Trade Status of Grain Sorghum		
Trade Regimes	Exportable[a]	Nontradeable[b]	Expected Value[c]
Current Policy	—	—	29.23
Reforms in Trade Policy	15.20	26.87	20.35
Reforms in Trade Policy and Exchange Rate	24.15	26.14	24.80

[a]Evaluated at export price parity.
[b]Evaluated at domestic price.
[c]With 0.7 probability for export and 0.3 for nontradeable.

Source: M. Ahmed, W. Masters and J.H. Sanders (1992).

In the irrigated region, moderate to high levels of chemical fertilizer were profitable on new sorghum cultivars. Fertilizer use on the traditional sorghum cultivars was minimal in the irrigated zone. On the rainfed vertisols where there were neither water-retention techniques nor chemical fertilizer application, there also was no diffusion of the new hybrid (Habash, 1990). To date, the diffusion results for HD-1 in the Sudan seem to be consistent with the theory of cereal technology development presented earlier in this paper.

The apparent changes in consumer tastes and marketing practices with the introduction of a high-yielding cultivar also give an insight into the technology-introduction process. At the beginning of the diffusion process, consumers often call attention to taste differences of new cultivars. These farmer interviews in the Gezira indicate an apparent evolution of tastes in response to the high production potential of the new cultivar. Evaluating the dynamics of the diffusion process of new technologies over time and between regions seems to be an especially important area of research in the future for improving the feedback from social scientists to agricultural scientists and to national policymakers.

Conclusion

The theory of first introducing agronomic improvements to overcome the water-availability/soil-fertility constraints in semi-arid sub-Saharan African agriculture seems to be consistent with observations of the successful technologies introduced. The theory also offers an explanation for the failure of strategies focused only on breeding solutions for the harsh, low-input conditions of these agricultural systems. Once the prerequisite agronomic improvements are made, a large impact from improved cultivars can be expected. The disciplinary mix of commodity research programs is a continuing multi-disciplinary issue and social scientists need to provide field inputs into this decision-making process.

There also needs to be awareness among social scientists on the degree to which they can program or even anticipate the pace of scientific discovery. Similarly, among social scientists, there is often a romantic notion that best farmer practices can substitute for the expensive, institution-demanding adaptation of scientific principles to the solution of farm problems. Best farmer practices can give researchers ideas about farmer constraints. Most yield increases will need to come from the adaptation of scientific concepts to developing-country problems, as has been the process in developed countries.

Soil degradation and decreasing availability of land have been going on for some time in the Central Plateau and in other high-population zones of the Sahel, such as the peanut zone of Senegal. Moreover, the shortage of quality land is expected to rapidly become a constraining factor in much of semi-arid sub-Saharan African agriculture. According to the modeling, new yield-increasing technologies are adopted by farmers as the land supply becomes more inelastic. The continued rapid development and adaptation of these intensive, yield-increasing technologies is expected to be critical for future agricultural development in most of sub-Saharan African agriculture. When and where land supply becomes more inelastic is an important empirical issue for field research.

Other empirical studies and some modeling results here indicate that women are not made worse off by the introduction of new technologies even when that introduction is concentrated on the communal lands. The most cost-efficient method to increase the incomes of women may be by increasing their opportunity costs off the farm and by introducing new technologies for household-production activities to reduce these time-intensive demands rather than implementing specific policies to focus the agricultural technologies for them. The alternative of ensuring equal access by women to technologies apparently requires greater access to a number of outputs, including purchased inputs and better quality land. Further empirical work is necessary but these are important preliminary results.

Evaluation of the success stories of new technology introduction shows that there are high returns to agricultural research. Problems at the start of the process, such as price collapse and price differentials between new and traditional cultivars resulting from taste differences, were apparently overcome in the case of HD-1 introduction in one irrigated region of the Sudan. The introduction of HD-1 is one case study and further studies of the dynamics of the technology-introduction process are required.

Market distortions are frequently indicated as a principal explanation for the slow adoption of new technologies in developing countries. The distortions introduced on export crops from direct taxes and the indirect tax of overvaluation of the currency have been serious problems in sub-Saharan African agriculture (World Bank, 1986:61–84). In this case, comparatively little distortion was experienced for a nontradable agricultural product, sorghum; hence, eliminating these distortions would not result in a substantial effect on output growth. In other countries and commodities, these distortions may be substantial and result in larger impacts.

Social scientists can help present information from farmers (and consumers) to the agricultural scientists and policymakers. To the extent that social scientists concentrate their evaluation on the new technologies being produced by agricultural scientists, there will be more immediate interest in these results. Since many of these technologies are still only potential new technologies, developing methodologies to evaluate them is considered to be a critical input into the technology-generation process. Mathematical programming and simulation models will become increasingly important to give insights on constraints and to facilitate the planning and policy processes. To many agricultural scientists, these are still black boxes, so more effort on communication between disciplines is necessary.

Notes

For critical comments and observations, we are indebted to Milton Coughenour, Ousmane Coulibaly, Pareena Gupta, and Tennassie Nichola.

1. Most disciplinary methodology problems within economics are considered to be largely outside the scope of this conference. See References for more detail on disciplinary concerns.

2. The following section draws substantially from Sanders (1989:141–144).

3. In India, the situation was different. Here moderate yield increases were obtained from the introduction of new sorghum and millet cultivars, generally without supporting agronomic improvements for increased water availability or soil-fertility amendments (Andrews, 1986). The introduction of hybrid sorghums increased national yields from 0.4 to 0.7 metric tons per hectare (cited in Hosenay, Andrews, and Clark, 1987:398). The extent of diffusion of these new cultivars is dramatic, from 1.1 percent and 0.5 percent of the area in 1966–67 to 32.5 percent and 49 percent of the area in 1984–85 for sorghum and pearl millet, respectively. This was over 5 million hectares for each of the two crops (Jansen, Walker, and Barker, 1990:654).

There are two hypotheses to explain the greater successes of breeding activities in India. First, there was more population pressure on the land, hence, a greater supply inelasticity for extending the land area. The pressure on the available land area results in a greater demand for yield-increasing technologies, such as these new cultivars. Many regions of sub-Saharan Africa are now reaching this stage of land supply inelasticity. Second, India has more trained scientists and a longer history of development of their research institutions.

Nevertheless, these yield gains are still small and the next round of breeding improvements will undoubtedly require improvements in the agronomic environment. The Jansen, Walker, and Barker (1990:659–662) study emphasized the region-specific requirements of agroclimatic and edaphic variation but still put a principal emphasis on breeding. One breeder said in his projection for millet in West Africa: "The first priorities for most millet regions are to improve soil and water retention and create higher fertility levels" (Andrews, 1992). This recommendation for West Africa is probably also applicable in India.

4. The primary factor in the price collapse was the inelasticity of demand. The food-aid system set up in response to the drought of 1984 did reduce their imports with a lag in response to domestic prices.

5. In the seventies, 60,000 hectares were put into earthen dikes in the Yatenga region of Burkina Faso. In the early eighties, 6,500 hectares were put into stone dikes in this same region (Sanders, Nagy, and Ramaswamy, 1990:8).

6. Many observers believe that the above concepts of farm testing have been more objectives than accomplishments. Farming-systems projects have tried to obtain these interactions but have often failed and seldom have been institutionalized. (We are grateful to Ousmane Coulibaly for this point.)

There is a very large difference in the ability to identify the farm-level constraints by a scientist raised on a farm and still with farm contacts, as is frequently the case in a developed country, and a scientist raised in the urban area of a developing country so that he can get an education. The developing-country scientist is often very sensitive to the large cultural and economic differences between the farm community and himself.

7. Type II error of the cost of rejecting an improved technology is rarely formally considered by agricultural scientists. This is a really critical source of error. The Type I error cost with quality control of airplane parts, for example, is very serious. The Type I error cost of making a wrong recommendation about planting densities is much less serious. The Type II error of the experiment station of not recommending a practice that is better may delay the output of useful products from the station. This delay can result in a lack of appreciation of agricultural research with a consequent impact on publicly funded research support.

8. This section draws heavily upon Ramaswamy and Sanders (1992a) and Sanders, Nagy, and Ramaswamy (1990).

9. The complementarity effects of combined inputs are well known to agricultural researchers but these effects make their traditional experimental design and statistical analysis substantially more complicated. In the harsh environment of the Sahel, analyzing one factor at a time, when yields are low and inputs have interactive effects, is expected to waste public money and have little payoff. For an indication that agronomists have known about this problem for a long time, note the following quote from an article on English wheat yields in the 1920s: "No aphorism is more frequently repeated in connection with field trials than that we must ask Nature few questions, or, ideally, one question at a time. The writer is convinced that this view is wholly mistaken. Nature, he suggests, will best respond to a logical and carefully thought-out questionnaire, indeed, if we ask her for a single question, she will often refuse to answer until some other topic has been discussed" (Fisher, 1926, as cited in Dillon, 1977:xiii).

10. Clearly, this is not a universal principle, but the lower quality land worked by women has been observed in the two above cited cases in Gambia and Cameroon and in our research (Ramaswamy and Sanders, 1992b). In Mali among some ethnic groups, the private fields of the women are around the village where the land is more fertile (O. Coulibaly, personal observation).

11. Cooperative-conflicts are a general class of intrahousehold problems of which the "bargaining problem" is a special subclass. The members of the farm household have to decide simultaneously about cooperation (adding to total availability) and conflict (dividing the total availabilities among the various members).

12. The following draws extensively from Ahmed and Sanders (1992).

13. In the second half of the 1980s and in the early 1990s, the demand for irrigated production of sorghum was increased by several low-rainfall years and because the continuing civil war disrupted agricultural production in the south, increasing the refugee population.

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Session 9

Summarizing the Future CRSP Research Agenda

- Issues Related to CRSP Research Agendas: Responses of the CRSPs
- Response to Social Science Research and the CRSPs

Session Chair: David G. Cummins

Speakers: David G. Cummins
Nina Renee Bowen and
Pamela Stanbury

Issues Related to CRSP Research Agendas: Responses of the CRSPs

David G. Cummins

On behalf of the CRSP Directors and investigators I would like to express our thanks to the presenters for enlightening us, a group predominated by biological scientists, on the complementary role of the social and biological sciences in the developmental process.

During the workshop, we have reviewed some of the issues of social science research in the development of a strategic research agenda. These social science issues impacting development reflect the needs of people and included the following:

Household food security,
Gender, class, and ethnicity,
Aspects of consumer tastes,
Commodity markets,
Implications of Biotechnology,
Food policies,
Sustainability,
Indigenous knowledge,
Land tenure,
Risk,
Farmer participation in research,
Researcher-extension-farmer linkages,
Impact measurement, and
Impacts of new technology.

The biological sciences will impact development when they improve the well being of people without depleting and even enhancing our environment.

The CRSPs were developed with a goal of enhancing the capabilities of developing country and U.S. scientists and institutions to do research, and to focus these capabilities, particularly the human resources, on the development of needed technology and better resource management to enhance food production, processing, and use.

The CRSPs are constraint driven. We all focus on the resolution of a series of global constraints in our particular commodity or natural resource area. These constraints were identified and selected by a range of people from the researcher to the beneficiary. The constraints selected were perceived as having the greatest potential for resolution during a defined time period with a potential of having a positive impact on developments.

The continuing validity of these constraints are reviewed annually by our scientists, technical committees, and boards of directors as we develop annual work plans.

Objectives of research to solve problems contributing to these constraints may change during the annual planning processes or through recommendations of our external evaluation panels during major reviews, usually every five years.

Therefore, the CRSPs are dynamic, not static, processes and the collaborative research mode is recognized as one of the best processes conceived to date for identifying and solving technical problems constraining development (at least in some circles).

I would like to expand on a particular point. Socioeconomic concerns were identified as constraints in several of the CRSPs. Some CRSPs had independent socioeconomic projects, while some had socioeconomics as components of multidisciplinary projects. Socioeconomic research helped to define and focus research objectives in projects, follow concerns and objectives such as gender throughout the program, and to measure impacts of developed technologies.

All the CRSPs face different dilemmas. All are in different stages. All are faced with establishing and maintaining a viable and effective research agenda. Establishment and maintenance of a research agenda requires the marriage of the biological and social sciences.

After listening to you all, we realize the importance of the social sciences before, (ex ante) during, and after (ex post) the development of CRSP technologies cooperative efforts in (1) identifying & prioritizing appropriate research areas, (2) impact assessment, and (3) evaluation.

In response to what we have heard this week, I would like to offer a number of observations, statements, and concerns expressed by a crossection of the CRSP participants in the Workshop. I realize this may be a bit skewed since many comments came from the CRSP biological scientists rather than the CRSP social scientists present.

1. In one of the breakout groups that contained most of the biological scientists present, this statement was made by one in response to the question, what does what you have heard mean to you?, and I paraphrase "Much of it went over my head." What does this say. First, the biological scientists need to learn how to communicate with the social scientists and understand how their respective roles merge in the development process. Second, the social scientists need to better understand the biological process and the products produced to help the biological scientists make their research and products more appropriate for the user.

Another said he was confused, but not sure whether confused over what he heard or how to apply what he heard. Surely this workshop has helped in our coming to a better "meeting of the minds." We must work together as partners in light of combined budget reductions and reduced emphasis in agriculture.

2. The gender issue has been addressed. We can see that there are times when gender has an impact on the types of technology we would develop. There are times we do not see how gender impacts type of technology we would develop. We need to know how to discern these differences and better understand how gender of the beneficiaries affects the design of our research programs.

3. Discussions on the farming systems approach to research strikes a chord. Constraints addressed by CRSPs are by design global in nature so as to have broad application and maximum impact. We cannot always afford to fund research with a farmer specific "problem solving" framework but must select broader, global issues to address.

This results in the question of participation in the setting of research agendas—to what extent should farmers, extension workers, and others be involved in establishing the CRSP agendas? How much involvement can we afford?

4. How do we bring about the proper marriage of social and biological scientists in the CRSPs to assure that appro-

priate technologies are developed? Does each CRSP need a formal socioeconomic subproject or subprogram?

Should most projects contain both social and biological components? Could economic components be inter-CRSP in nature to avoid duplication of efforts during times of budget constraints—a pool of resources?

5. There appears to be a preponderance of emphasis on preharvest socioeconomic problems. We need information beyond the farm gate, like the subsector approach that was discussed.

6. How far can the CRSPs go in evaluating benefits or impacts of research? Such activities can be costly, time consuming, and often duplicative. Financial constraints will limit these activities. Can the social scientists develop simpler, less costly procedures to evaluate impacts that will be scientifically sound?

7.Broad issues were alluded to in some presentations, i.e., such as policy, ethical, political, and institutional changes. Should CRSPs study these non-technical options for achieving development.

8. I would like to speak to the training aspects of the CRSPs that have a goals of building local research capabilities and human resource development

Who are we training--just scientists, farmers to be researchers, researchers to understand farmers, drivers to be technicians? CRSPs have a primary responsibility to improve research capability, and increase the inherent capability to solve problems in the future.

9. We are struggling with the problem of research—our mandate—and the extent we are involved in outreach. As we re-evaluate the role of outreach in research programs, we appreciate the comments we heard on a greater emphasis on farmer participation research.

In conclusion, I mentioned that some biological scientists were confused in how to apply some of the things we have heard. In a long-term perspective, some of these theoretical musings (such as knowledge is imperfect, ideas about risk, ethics) can help bring about a change in how the biological/natural scientists view the social sciences, and the connection between science and society.

Response to Social Science Research and the CRSPs

Office of Women in Development
Agency for International Development

Stronger and more cost effective linkages between researchers and farmers need to be developed if the production problems of small resource-poor farmers are to be solved. One of the difficulties is that technology is frequently seen as neutral to differences between users. It is not. The diversity of microenvironments requires equally diverse technologies and the research and development associated with them. While the CRSPs have a global mandate, research cannot be done in isolation from reality of production systems. Attention must be paid to both the sociocultural and socioeconomic as well as the physical dynamics of agrobiological systems.

As the papers presented at the conference pointed out, social science research is critical in establishing and carrying out agricultural research agendas by providing information and methodologies which take into account the socioeconomic characteristics of farming through (1) the consultation of different types of users in project design, (2) making distinctions between technology users and technology owners and operators, and (3) investigating the allocation of time and labor. This process determines the domains for research in a particular geographical area.

Who are these farmers? How, and with whom do they make decisions? It is here that intrahousehold relationships, and the gender and generational division of labor is crucial. Gender analysis draws on a number of disciplines within the social sciences—economics, anthropology, sociology, and geography. Gender analysis is a call for greater efficiency of resource use and greater efficiency in technology development. It is, essentially, a refinement of the user, or "client," perspective and calls for changing the way production problems are identified.

Several of the papers presented made mention of gender differences. It is, however, important to distinguish the difference between awareness of gender issues—indicating concern—and incorporating gender as an analytical variable in the research and development paradigm. This means not just looking at gender differences but, rather, gender relations. Such relations include the need to look at power relations; that is, who exerts authority over certain kinds of decisions. As Anne Ferguson's paper points out, it is not enough to know that bean production is done by small farmers when, in fact, it is done mostly by women who are also primarily subsistence producers. Researchers need to know whether or not this requires any changes in the research agendas, methods, or technologies. Social science research, and the incorporation of gender analysis in it, makes the link between technology development and the varying technical needs and constraints of different potential users of a new technology.

Gender as a variable cannot be isolated from consideration of other socioeconomic factors; gender does not stand alone as a determinant of behavior or access to resources. The impact of new technologies on men or women will depend on their socioeconomic status, ethnicity, age, or race. Research priorities should be the result of a holistic approach that combines detailed gender analysis with other analytical approaches. Income level, household structure, and gender of household head interact to affect development outcomes. Gender analysis must be an integral part of the larger socioeconomic analysis. In turn, the socioeconomic analysis must be an integral part of the biological or technical analysis.

Research conducted under the Bean/Cowpea CRSP demonstrates that breeding strategies need to be designed with class variables in mind. It has identified differing priorities and constraints of smallholders versus medium to large landholders. Within this class framework, gender issues are also of concern. Women as food producers, processors, and preparers often have concerns overlooked in male-focused research agendas. Breeding strategies must incorporate storage, processing, and cooking issues; consumption and nutrition issues; and domestic organization and work roles (labor organization and utilization).

Experience had shown that successful projects try to gradually modify or work with traditional roles and cultural beliefs regarding gender rather than ignoring or attempting to change them outright. In addition, planners cannot assume that gender roles will remain static. Research programs must remain flexible to adapt to changes in women's and men's roles and responsibilities, which respond, in turn, to changes in the economic and social environment. Examples are labor migration and changes in demand for cash and food crops. This advocates for incorporating the social sciences throughout the research process, not just at the preliminary agenda-setting stage. The impact of new varieties, techniques, and technologies must be monitored, and the information must be fed back into the technology development process to improve future research efforts and outcomes. Gender issues should be incorporated into mainstream research activities, rather than addressed in special women's projects, which might isolate both the problem and the solution.

A recent FAO study showed that incorporating gender frameworks into the work of research and development organizations is linked to five conditions: making changes in policy mandates; having senior management and leadership support and involvement; implementing gender-explicit evaluation and monitoring mechanisms; having sufficient professional staff with gender expertise; and enhancing overall human resource capacity through training.[1] These findings should be taken into account when considering the future of social sciences in the structure of the CRSPs.

The Office of Women in Development encourages adopting an explicit perspective and incorporating gender analysis into the research agenda of the CRSPs. External reviews of the CRSPs should pay explicit attention to gender issues, and evaluation teams should include individuals with expertise in gender analysis. CRSP review committees should explicitly emphasize the importance of gender issues in reviewing scopes of work for research. Clearly included in the mandate of the CRSPs is capacity building. We also need to continue building national agricultural research systems' capacity to increase gender expertise in national agricultural research and development programs.

Priority must be given to identifying methodologies and developing proxy measures that will overcome the high financial and time costs of household-level data collection; are interdisciplinary; can help identify significant variations in microenvironments and associated farmer practices; and above all, actively incorporate farmers and other clients—end users of a new technology—into key stages of the research process.

Notes

The Office of Women and Development was represented at the conference by Ron Grosz, Robin Kosloff, and Pamela Stanbury.

1. Susan Poats and Sandra Russo. 1989. Training in WID/Gender Analysis in Agricultural Development: A Review of Experiences and Lessons Learned. Prepared by Tropical Research and Development, Inc., Gainesville, Florida, for the Women in Agricultural Production and Rural Development Service of the FAO.

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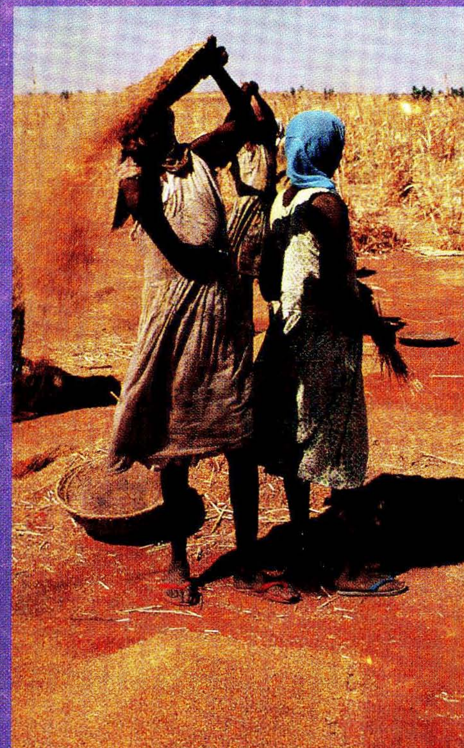

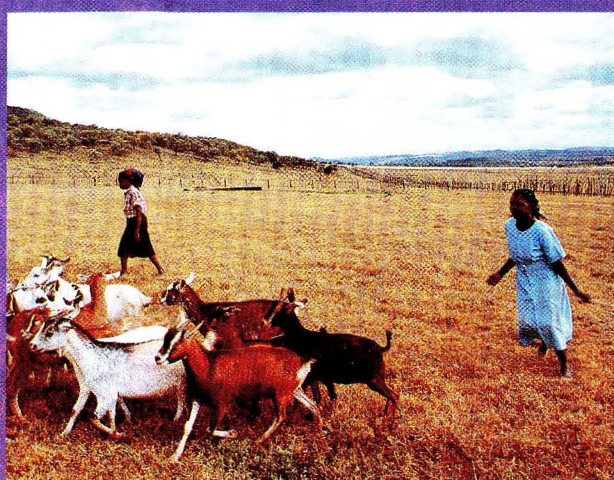

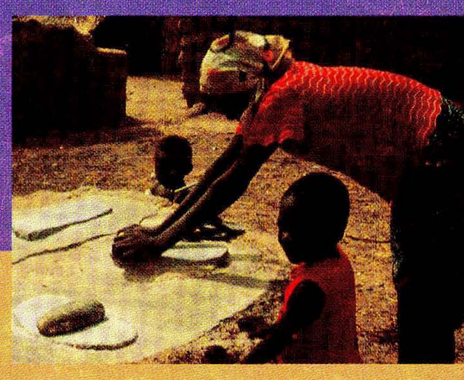

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