AGRICULTURAL RESEARCH PRIORITY SETTING

INFORMATION INVESTMENTS FOR THE IMPROVED USE OF RESEARCH RESOURCES

EDITED BY BRADFORD MILLS

isnar
International Service for National Agricultural Research

KARI
Kenya Agricultural Research Institute

The International Service for National Agricultural Research (ISNAR) assists developing countries in bringing about lasting improvements in the performance of their national agricultural research systems and organizations. It does this by promoting appropriate agricultural research policies, sustainable research institutions, and improved research management. ISNAR's services to national research are ultimately intended to benefit producers and consumers in developing countries and to safeguard the natural environment for future generations.

To maximize the impact of its work in developing countries, ISNAR focuses on three objectives:

1. enhancing the capacity of agricultural research organizations to respond to their clients' needs and to emerging challenges

2. expanding global knowledge on agricultural research policy, organization, and management

3. improving developing countries' access to knowledge on agricultural research policy, organization, and management

ISNAR was established in 1979 by the Consultative Group on International Agricultural Research (CGIAR), on the basis of recommendations from an international task force. It began operating at its headquarters in The Hague, The Netherlands, on September 1, 1980.

ISNAR is a nonprofit autonomous institute, international in character, and apolitical in its management, staffing, and operations. It is financially supported by a number of the members of the CGIAR, an informal group of donors that includes countries, development banks, international organizations, and foundations. Of the 16 centers in the CGIAR system of international centers, ISNAR is the only one that focuses specifically on institutional development within national agricultural research systems.

Agricultural Research Priority Setting:
Information Investments for Improved Use of Resources

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AGROVOC Descriptors

agriculture; organization of research; research policies; resource allocation; investment policies; planning

CABI Descriptors

agricultural research; organization of research; research policies; resource allocation; investment policy; planning

Geographical Descriptors

Kenya

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Contents

Foreword

National agricultural research systems (NARS) continue to face serious financial and human resource constraints. As a result, they are pressed to do more with available resources and to demonstrate clearly the benefits that society can expect from continued investments in agricultural research. Ex ante research evaluation and priority setting can assist NARS in both these undertakings. The potential importance of improved evaluation and priority-setting procedures have led ISNAR and KARI to pursue active research agendas in these areas.

In 1991, KARI conducted an institute level priority-setting effort that resulted in the ranking of commodity and production-factor research programs for the country. The exercise was an important learning experience. It underscored the need for significant investments in information at the program level to further inform resource allocation decision making. In 1994, ISNAR and KARI embarked on a collaborative effort to develop methods for ex ante research evaluation and priority setting at the program level. A basic premise was that the methods should incorporate recent advances in information management technologies and economic theory.

The knowledge bases of both institutes have been greatly enhanced by this collaborative effort. This book shares many of the lessons learned. Its chapters provide important insight in areas ranging from the use of georeferenced data in the development of research alternatives to managing client and stakeholder participation in the priority-setting process. The experiences of the authors allow them to weave theory with practical applications that work in the field.

We hope that this book transmits the scope and nature of collaboration between ISNAR and KARI on this important research management topic. We thank the authors for this substantial contribution to increasing the efficiency of resource use in agricultural research.

Stein W. Bie	*Cyrus Ndiritu*
Director General	Director
ISNAR	KARI

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Acronyms

CBS	Central Bureau of Statistics (Kenya)
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro de Investigación Agrícola Tropical
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo
FAO	Food and Agriculture Organization of the United Nations
GIS	geographic information system
ICRAF	International Centre for Research in Agroforestry
IFPRI	International Food Policy Research Institute
ISNAR	International Service for National Agricultural Research
KARI	Kenya Agricultural Research Institute
Ksh	Kenyan shilling
NARO	national agricultural research organization
NARS	national agricultural research system(s)
NGO	nongovernmental organization
USD	United States dollar
TAC	Technical Advisory Committee (CGIAR)
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UNEP	United Nations Environment Programme
WRI	World Resources Institute
PRA	participatory rural appraisal
RRA	rapid rural appraisal

Introduction

Bradford Mills

Why set agricultural research priorities?

Broadly defined, agricultural research priority setting is the process of making choices amongst a set of potential research activities. Priority setting is not a new activity for most agricultural research managers. All functional agricultural research systems have followed either formal or informal priority-setting procedures to arrive at their current research agendas. However, formal procedures can improve both the quality and transparency of complex resource allocation decisions. By structuring information on client constraints and the potential of research to address those constraints. A clear and systematic presentation of priorities also assists national agricultural research organizations (NAROs) in taking a proactive role in soliciting government and donor support for areas identified as vital to agricultural development efforts. In addition, priority-setting exercises can be used to broaden participation in the formulation of the research agenda. They thereby increase a research organization's constituency base.

Target audience

Research managers who are charged with the design of priority-setting procedures for their organizations encounter a number of practical issues: Who will set priorities? What information will they use? And, what skills or tools will they need? Similarly, socioeconomists and others who implement priority-setting procedures need concrete guidance on how to undertake each step in a priority-setting process. The chapters of this book address both the process design issues facing research managers and the implementation issues faced by socioeconomists and others actually undertaking priority-setting exercises. The book is structured to lead the reader systematically through the major steps in the design and implementation of research priority-setting procedures. The materials in the book, including the exercises accompanying the chapters, may also provide a suitable guide for an applied workshop on agricultural research priority setting.

Other guidelines exist for the design and implementation of priority-setting procedures. For example, Collion and Kissi (1994) provide a practical, eight-step process for program planning and priority setting that is based on experiences in Morocco. Alston, Norton, and Pardey (1995) provide a thorough review of priority-setting methods and their economic underpinnings. This book builds on these volumes, but it also discusses important broader issues associated with the design of priority-setting procedures. These include institutional structures, information requirements, information management, tying priorities to resource allocation decisions, and developing human resource capacity. Each of these areas presents new opportunities for agricultural research organizations to improve the way they plan, prioritize, and implement their research agendas.

Procedures for decision making on resource allocations to research will always embody unique characteristics of an organization. They are, thus, situation specific. No generic procedures or methods for priority setting can be wholly recommended. However, a sound understanding of the procedures currently in use in research organizations and the various options available can help research managers identify areas for further improvement. In this book, examples from KARI demonstrate practical applications of some of the procedures and methods presented. The exercises at the end of each chapter are designed to help research managers review procedures that might be applied in their own organizations. The computer spreadsheet exercises developed in EXCEL for chapters five and six provide hands-on experience in implementing basic priority-setting methods.

Structure of the book

Chapter one examines the role of agricultural research priority setting in the broader context of research planning and resource allocation. The chapter also discusses the levels at which priority setting should occur and who should be involved at each level. In NARS, resource allocation decisions are made at the national, institute, program, and project levels. Program-level priority setting is the focus of much of the book. At the program level, priority setting attempts to increase the contribution of specific programs to a research organization's mandate and objectives. Broad client and stakeholder participation in priority-setting exercises is necessary, but it must be carefully managed.

Chapter two examines agricultural research objectives and how these objectives translate into criteria for evaluating research alternatives during priority-setting exercises. Research objectives are derived from national agricultural policy statements, which often present an array of development goals. For a set of objectives to be useful, they must translate into measurable criteria according to which research alternatives can be evaluated. The most common criteria used in agricultural research priority setting—efficiency, equity, sustainability, and food security— are reviewed, along with appropriate measures.

Chapters three and four discuss how to define the set of research alternatives that will be ranked during the priority-setting exercise. The choice of which research alternatives to evaluate is as, if not more, important than the subsequent ranking. Chapter three presents techniques for defining the spatial domain of research alternatives. Political boundaries as well as biophysical and socioeconomic criteria can play an important role in defining the spatial scope of research options. Geographic information systems (GIS) can greatly facilitate the classification of program-specific research zones.

Similarly, chapter four focuses on perhaps the most important piece of information in the development of research alternatives: information on client technology needs. Most public agricultural research institutes in sub-Saharan Africa have a mandate to address the agricultural technology needs of resource-poor farmers. Unfortunately, many such farmers have difficulty in articulating their research needs to formal research organizations. Rural appraisal techniques have been developed to bridge this communication gap. Participatory and rapid rural appraisal methods are discussed, along with the techniques of constraint-tree analysis to translate farmer constraints into research themes. While these techniques are valuable, human- and financial-resource constraints suggest they must be prudently integrated into priority-setting procedures.

Chapter five discusses methods for ranking research themes. The choice of method is often less important than the effort expended to develop well-defined research themes. Decisions on appropriate methods should be based on information and human-resource availability. The relative strengths and weaknesses of common priority-setting methods are presented in this chapter, along with the information and human-resource requirements.

Chapter six examines statistical data sources that can be used to improve the information base underlying research priority setting. Regionally disaggregated data on area, production, and price are collected in almost every country in sub-Saharan Africa. However, these potentially important sources of information are often not used in priority-setting exercises due to quality and accessibility constraints. The chapter identifies the type and resolution of data most frequently needed for research priority setting and suggests ways for minimizing the costs associated with data collection.

Chapter seven examines the important role that socioeconomists play in research priority setting specifically, but also in broader activities to develop information bases that inform program priority-setting activities. Unfortunately, many national research organizations have only recently begun to make significant investments in socioeconomic research capacity. And the demand for socioeconomic input far outweighs capacity. The chapter concludes with a discussion of KARI's efforts to cover the needs of a number of research programs with only a limited number of socioeconomists.

Chapters eight, nine, and 10, the last three chapters of the book, present program level priority-setting applications from KARI. These applications demonstrate many of the procedures and methods for priority setting that were discussed in the previous chapters. Chapter eight presents a commodity program priority-setting exercise for two horticultural commodities: snap beans and cabbage. Priorities for research on the two crops are set within the same geographic zones. However, the distribution of production across zones and the market structure of the two commodities varies dramatically. Snap beans are produced exclusively for export. By contrast, the cabbage market in Kenya is effectively closed to imports and exports. The results demonstrate how both the production base and market structure substantially affect the distribution of benefits both between zones and between producers and consumers within zones.

Chapter nine presents a similar commodity program priority-setting exercise for sorghum. Two major concerns with economic-surplus-based priority-setting exercises are that future nonresearch-induced growth and differential impacts on resource-poor households are not adequately captured in the analysis. The sorghum priority-setting exercise, therefore, goes beyond standard economic-surplus analysis to address these concerns.

Finally, chapter 10 presents a priority-setting exercise for a production-factor research program: the KARI soil fertility and plant nutrition program. Soil fertility interventions directly impact the soil base and, thereby, indirectly affect the yields of a whole range of commodities. The program's priority-setting application presents techniques for aggregating research impacts across multiple commodities and production systems.

References

Alston, J., G. Norton, and P. Pardey, 1995. Science under scarcity: Principles and practices for agricultural research evaluation and priority setting. Ithaca, N.Y.: Cornell University Press.

Collion, M. and A. Kissi, 1994. Guide d'élaboration de programmes et d'établissement de priorités. ISNAR Research Management Guidelines No. 2. The Hague: International Service for National Agricultural Research.

Chapter 1
The Role of and Levels for Agricultural Research Priority Setting

Bradford Mills and Adiel Mbabu

Introduction

Priority-setting exercises are not independent, one-time activities. When research organizations plan long-term investments in human and financial resources, formal priority setting can be used to clearly outline research options and to inform the allocation of resources across these options. Further, priority-setting procedures may be used at several levels within the research organization and involve external partners and stakeholders.

This chapter introduces three topics:

1. the role of priority setting in the broader process of research planning and resource allocation
2. different levels at which priorities are set in a NARS
3. the main participants in priority setting at each level

It concludes with an exercise to assist research managers in identifying levels for priority-setting activities in their organization and the appropriate participants at each level.

The role of priority setting in planning and resource allocation

The most common output of a priority-setting exercise is a ranked list of research programs or research themes within a program. Such lists are of little value, however, if they are not directly linked to broader procedures for research planning and resource allocation. Organizational charts usually depict priority-setting efforts as feeding directly into the planning process, which in turn, feeds into processes of budgeting and resource allocation (figure 1). In-

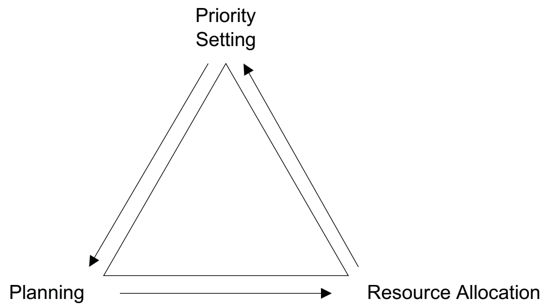


Figure 1. Linkages between priority setting, planning, and resource allocation

formation on current resource allocations then provide feedback to the organization on the congruence between priorities and resource use.

Figure 2 presents a more disaggregate set of activities associated with priority setting, planning, and resource allocation. Five basic priority-setting steps are depicted in the upper circle. Step one is the development of an information base. Step two is the establishment of research alternatives. Step three is the evaluation of the potential impact of research alternatives. Step four, often considered the final output of a priority-setting exercise, is the ranking of alternatives into research priorities. However, a fifth step, the development of guidelines for translating priorities into planning and resource allocation

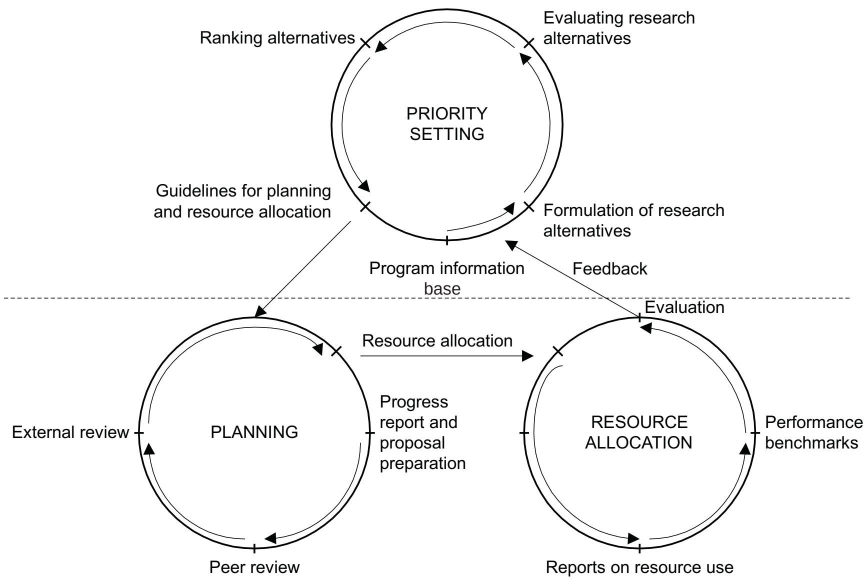


Figure 2. Disaggregated linkages between priority setting, planning, and resource allocation

decisions, is necessary to establish direct links with planning and resource allocation activities.

Basic planning procedures for translating priorities into a coherent research agenda are shown in the lower left corner of figure 2. First, annual reports and new proposals are developed based on the expected contributions of activities to priorities. Internal and external stakeholder reviews then occur. Research priorities and associated guidelines for planning and resource allocation play an important role in this review process. Finally, as shown in the lower right circle, resources are allocated to approved activities and their usage monitored. Organizations can then check if actual resource allocations conform with identified priorities. In few organizations are these functions well integrated. As a first step in the design of improved priority-setting procedures, research managers need to identify what priority setting, planning, and resource allocation activities are undertaken in their organizations, as well as linkages between these sets of activities.

Research system levels

Because priority-setting exercises support planning and resource allocation decisions, they are conducted on the same levels at which those activities occur. Research systems commonly plan and allocate resources at four levels: national, institute, program, and project.

National

A NARS is usually made up of a number of research organizations, each with its own unique mandate. Priority setting at the national level, therefore, addresses two crucial investment decisions: 1) what investment should be made in agricultural research versus other policy tools for agricultural sector development and 2) within agricultural research, how should funds be allocated across different components of the research system. The private sector, international agricultural research centers, and advanced research institutes may also make significant research contributions. Their role in the agricultural research system must also be examined. Figure 3 illustrates some of these dynamics.

Broad public-sector investment decisions are often made based on national development objectives, such as increased rural welfare, poverty alleviation, export growth, and food security. Rarely is formal analysis used to justify these decisions. However, agricultural research organizations should be acutely aware of how investment decisions are made so that they can lobby effectively for support.

Institute

An agricultural research institute is defined as a single research center with a national mandate or a collection of research centers with a shared mandate and set of resources. As such, priority setting at the institute level addresses two crucial investment decisions: 1) how resources are allocated across the

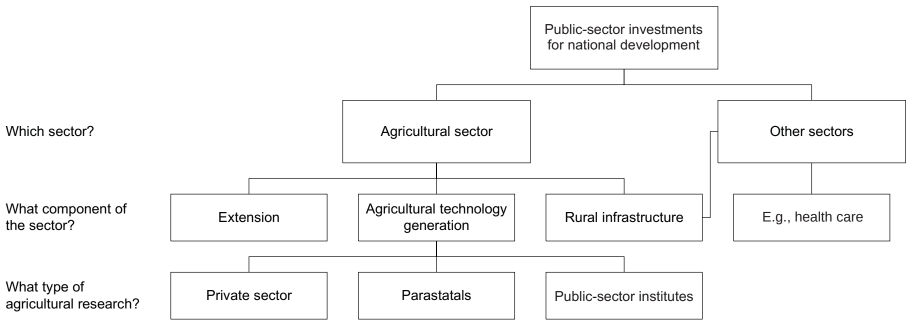


Figure 3. National public-sector investment decisions affecting agricultural research

institute's major research programs and 2) how resources are allocated across the major research zones within the mandate of the institute.

Institutes are usually required by government or donors to formally justify their resource allocation decisions on the basis of potential contribution of projects to their mandate. Formal priority-setting exercises can play an important role in this justification.

Program

A research institute's agenda is usually compartmentalized into research programs with commodity, production-factor, discipline, or geographic mandates. As such, program-level planning and priority setting can have a major impact on the research agenda of an institute. Priority setting at the program level should inform decision makers about the potential benefits that can be gained from resource allocations to major research themes and geographic areas. A research theme is defined here as a set of closely related research activities that addresses a specific constraint and has a specific output. A major portion of program-level priority setting is usually devoted to defining potential research themes.

Priority-setting procedures also differ by type of program. Commodity and production-factor programs usually have specific mandates defined in terms of an agricultural output or input (e.g., “maize” or “soil fertility” research). Narrow, topical mandates facilitate the comparison of research themes with programs. However, the needs of technology users are often specific to site, rather than commodity or production factor. Commodity and production-factor programs, therefore, divide their national mandate into geographic areas that are relatively homogeneous in environment or scope of technology user needs.

Disciplinary programs (e.g., socioeconomics or meteorology), on the other hand, have a national mandate that translates into research interventions across a range of commodities and production factors. Disciplinary programs also provide services to other research programs. The result is that the potential impacts of research themes in such programs are often difficult to define formally. In priority setting for disciplinary programs, less formal methods for comparing the benefits to be gained from alternative research themes are therefore often employed. This does not, however, reduce the need to carefully define the research alternatives to be ranked.

Finally, regional research programs have a definite geographic mandate based on either geopolitical boundaries or agroecological criteria. Within their mandate area, regional programs usually address the range of client constraints. As with disciplinary-based programs, in regional research programs research themes must be evaluated across multiple commodities and production factors.

Project

Projects are a collection of specified activities and experiments with a defined time frame, budgeted inputs, and an expected set of outputs. In a research system with well functioning priority setting, planning, and resource allocation processes, formal priority setting is not actually conducted at the project level. Rather, projects are designed to address the priority research themes identified through program planning and evaluation activities.

Participation

Participation is a crucial but often overlooked element of any priority-setting process. There are two basic groups of participants: clients and stakeholders. Clients are the intended users of the technologies that are developed by the research organization. Farmers are an important client group. However, processors of agricultural commodities and input manufacturers are also potentially important clients. Policymakers and even other research organizations may also be clients for certain types of research, for example, socioeconomic research. Stakeholders comprise a broader set of agricultural development actors. They include, for example, nongovernmental organizations (NGOs), farmers' organizations, extension services, input and output industry representatives, donors, and policymakers. Stakeholders may not actually use technologies developed by research. However, they have major interests in the role that research can play in agricultural sector development. Stakeholder participation in priority setting occurs primarily through information exchange and, less frequently, in decision making (figure 4). Information exchange usually involves client and stakeholder input in identifying technology needs, however participatory approaches discussed in chapter 4 promote joint client and researcher learning.

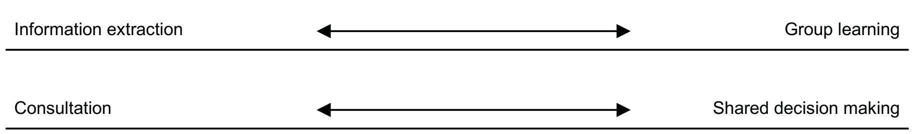


Figure 4. Continuums of participation

Both client and stakeholder groups must be carefully defined. That's because *who* participates in priority setting has a major influence on what the resulting priorities will be. As mentioned, potential participants range from farmers and other technology users to agricultural policymakers and politicians. All of these groups have valuable information to contribute to the formulation of the agricultural research agenda. However, the effectiveness of individual participation decreases as the number of those involved increases. Also, participation must be actively managed to ensure that the right people are involved at the most appropriate level. The composition of participants will also differ by level within the organization, as well as based on practical considerations, such as the financial resources available to support involvement.

Table 1 presents a list of participants commonly involved in priority setting at different levels. At the national level, major decisions on the mandates and resources of agricultural research organizations are made by senior government officials as part of a political process. Research organization directors, ministry of planning and finance analysts, and representatives of major stakeholders are often called upon to inform such debate through presentations to formal committees or boards. At the institute level, research

Table 1. Participants in Agricultural Research Priority Setting

Level	Mode
National	
1. Ministers and others involved in government budget allocation	Decision making
2. NARO directors	Information providers
3. Analysts from the ministry of planning and finance	Information providers
4. Representatives of major stakeholders	Information providers
Institute	
1. Research institute board of directors	Decision making
2. Senior research managers	Decision making
3. Heads of programs	Information providers
4. Scientists	Information providers
5. Major stakeholders	Information providers and decision making
Program	
1. Heads of programs	Decision making and information providers
2. Scientists	Information providers and decision making
3. Program stakeholders	Information providers and decision making
4. Program technology users	Information providers
Project	
1. Same as program level	Information providers

boards, institute directors, and senior managers are usually involved in decision making. Program heads, scientists, and major stakeholders, including private-sector representatives, provide information to these decision makers, but normally play a limited role in actual decision making. Participation is generally formally managed through an agricultural research board or other, similarly vested, formal body. There, distinctions between the roles of the clients providing information on their technology needs and of stakeholders participating in the actual setting of priorities, becomes blurred. Program stakeholders are also often called upon to evaluate the performance and contribution of projects to program-level priorities during the planning, monitoring, and evaluation of program-level research.

Designing and managing priority-setting procedures

Like any complex task, responsibilities for planning and implementing priority-setting exercises must be assigned to specific actors (table 2). Most im-

Table 2. Actors in Agricultural Research Priority Setting and their Responsibilities

Actor	Responsibilities
Senior research manager	Manages the priority-setting process Ensures that adequate resources and technical assistance are available
Head of program	Ensures that the exercise is implemented and that resources are properly utilized Organizes meetings of priority-setting working group and stakeholders Assists the program socioeconomist in collecting information for the priority-setting working group
Priority-setting working group	Identifies research program target zones Identifies research alternatives Provides initial assumptions of the potential for technology generation and adoption
Facilitator	Assists the head of the research program and the program socioeconomist in the design and implementation of the process
Stakeholder group	Reviews and modifies the priority-setting working group's assumptions to achieve a broad consensus on program priorities Establishes resource allocation guidelines Reviews the program's adherence to resource allocation guidelines

portantly, a senior research manager must be mandated to manage the process. For program-level priority setting, the manager will want to delegate responsibility for implementation to the appropriate program head. Along with this responsibility, program heads must be provided with sufficient resources and technical assistance to conduct the exercise. The program heads must also be held accountable if they fail to complete the exercise.

Four basic groups collect information and carry out the analysis associated with a program-level priority-setting exercise:

- A priority-setting working group composed of 10 to 14 key research and extension personnel with a strong regional and disciplinary mix is responsible for identification of research alternatives, as well as the initial evaluation of those alternatives.
- A program socioeconomist, together with the program head, is given the task of synthesizing available information on client constraints and relevant agricultural statistical data. The socioeconomist also takes a lead role in implementing the method chosen to rank research alternatives.
- A facilitator with previous experience in conducting priority-setting exercises should be available to assist the program head and socioeconomist. The facilitator cannot, however, be given the primary responsibility for implementing priority-setting exercises in all programs.
- A stakeholder group composed of 30 to 40 representatives of organizations with interests in the performance of the research program should be involved. This group will review and help to modify working-group assumptions and contribute to achieving broad consensus on the final priority ranking. Major stakeholders include farmer group representatives, processing industry representatives, input and output industry representatives, commodity or production-factor policy analysts, extension service specialists, and NGOs. In order to increase the probability that the priorities set within the research program actually affect resource allocation decisions, the stakeholder group should also translate priorities into resource allocation guidelines and review projects annually for adherence to those guidelines.

Finally, it may be useful to establish two other groups at the institute level to design the priority-setting process. First is a working group composed of senior managers, scientists, and expected implementers. This group will review the options available for priority setting and prepare a position paper with recommendations on the most appropriate procedure. Second is a priority-setting committee chaired by the institute director. This committee will review the recommendations and ensure that the process is mandated from the highest level in the institute.

Maximizing benefits to be gained through priority setting

In practice, a formal priority-setting exercise produces a number of benefits in addition to a ranked list of research themes. These include learning, consensus building, and increased credibility. A well implemented priority-setting exercise is a learning process. Significant investments are made to obtain and share information. This information can influence the opinions of researchers, managers, and stakeholders on resource allocation. Consensus on research priorities is also an important output. Individuals involved in priority setting will be committed to implementation in subsequent planning and resource allocation steps if they feel the identified priorities will increase the effectiveness of the research organization and if they feel that their interests were adequately represented in the process. Finally, credibility is an important leverage point for resource allocation. Credible priority-setting exercises clearly and transparently identify and justify how priority rankings were developed. The results can then be used by the organization to bolster efforts to gain greater control over external sources of funding, as well as to establish internal mechanisms to account for the use of resources.

Where to invest?

Most would agree that priority-setting processes must be linked to simple and transparent procedures for planning and evaluating research projects' contributions to program priorities. Priority setting must also be linked to procedures for budgeting and allocating resources. This leads to the question of whether procedures for program planning and evaluation, budgeting, and resource allocation must be strengthened concurrent with the conduct of priority-setting activities. Or can significant gains can be made from investment in priority setting alone? A crucial, but often overlooked, component of this debate is the capacity of the research organization's current staff to absorb simultaneous investment in these areas. Most organizations have a limited pool of individuals to implement the various research management functions. Capacity-building efforts in each area must complement activities in related areas of research management and without overloading the existing capacity.

Exercise 1.1
Simple Steps

This exercise leads research managers through some simple steps that they can take to strengthen linkages between priority setting and resource allocation decisions within their organization.

In a small working group, discuss and prepare responses to the following questions:

1. What are the current procedures for program planning, priority setting, and resource allocation in your organization? How can linkages between priority setting and these other sets of activities be improved?
2. Have priority-setting exercises in your organization resulted in a firm set of guidelines for resource allocation decisions? Provide an example of priority-setting guidelines that would significantly influence resource allocations.
3. How can "secondary" benefits of priority-setting exercises, such as learning, consensus building, and increased credibility, be used to influence resource allocation decisions?

Exercise 1.2
Designing a Priority-Setting Process

Form a small working group and discuss the following issues:

1. At what levels do planning and resource allocation occur in your organization?
2. Who is involved in making planning and resource allocation decisions at each level? Do the people involved also differ by program type?
3. Review the function of each type of participant in priority setting. Do they provide information, do they decide priorities, or do they allocate resources?

Chapter 2
Research Objectives and Priority-Setting Criteria

Bradford Mills and Steven Were Omamo

Introduction

A successful research organization must have a clear set of research objectives that translates its mandate into concrete interventions for target groups. For example, a research organization may be charged with developing agricultural production technologies. The associated objective may be to increase the welfare of producers and consumers of agricultural commodities. The choice of objectives is crucial for the ensuing steps in the priority-setting process. Clear objectives make it easier to identify appropriate criteria for evaluating alternative research themes. Well defined criteria that are logically linked to research objectives, in turn, lead to credible measures of the potential contribution of research themes.

This chapter has three main objectives:

1. to discuss appropriate research objectives at different levels within research organizations
2. to examine criteria for measuring the contribution of research themes to research objectives
3. to outline how objectives and criteria can be identified based on national development goals, organization mandates, and consultations with major stakeholders

Where appropriate, examples from KARI are used to illustrate crucial points. The exercise at the end of the chapter assists research managers in identifying major research objectives and operational criteria in their own research organizations.

Research objectives at different levels

Research objectives are likely to vary across the different levels of a research system or organization. Aggregate objectives of NARS are usually based on broad national and agricultural development goals as stated in national policy documents and development plans. Examples of such goals are economic growth, poverty reduction, employment creation, and protection of natural resources. In Kenya, where agriculture remains the principal source of employment and income for most citizens, central tenets of agricultural and overall economic policy are food self-sufficiency and cash-crop expansion, especially in small-scale agriculture. As shown in box 2.1, these goals are found in an array of policy statements and are reflected in KARI's mission. Historically, support for agricultural research has been based on its potential contribution to achieving these policy goals.

Ideally, a research organization's objectives should be as specific as possible, without excluding major components of the mandate. National policy statements and a research institute's mandate can, however, give rise to very broad objectives. These objectives may require refinement to more closely match the core functions of the organization. For example, the broad objective of improving household welfare might translate—within the mandate of a research institute—to an objective to enhance agricultural sector productivity in ways that lead to increased household welfare. Similarly, a research organization's objective to design improved agricultural technologies for specific agroecological conditions might be linked to a national objective to increase food security.

Public-sector research organizations are also increasingly challenged to distinguish between research topics that could be addressed by the private sector, or in partnership with the private sector, and topics where the private sector cannot be expected to undertake research on its own. Explicit attention is devoted to the increasingly important role of the private sector in agricultural technology development when outlining the organization's mandate and translating that mandate into objectives. Two criteria are commonly used to identify research areas that are inherently "public goods:" 1) limited potential to appropriate revenues from the sale of technologies associated with the research topic and 2) limited ability to exclude initial users from passing generated technologies to others. For example, it may be impossible for a private-sector firm to appropriate benefits associated with a new crop spacing recommendation because they cannot exclude one farmer from passing information on to other farmers. The development of hybrid seed, on the other hand, is a research area with significant potential for private-sector involvement, because benefits associated with variety development can be incorporated into the sale price of the seed. Strategic partnerships with other countries' NARS, international agricultural research centers, and advanced research institutes can maximize the flow of improved technologies and minimize potential duplication of research activities.

At the program level, objectives focus the organization's mandate on specific commodities, production factors, or regions. In KARI, national and regional research programs have different mandates. The mandate of national programs is to conduct applied strategic research on issues of national scope. For example, maize is produced throughout Kenya in a wide range of production systems that reflect varying agroecological and socioeconomic conditions. KARI's maize research program, thus, undertakes activities in

Box 2.1. National and Agricultural Development Objectives and KARI's Mandate

National development objectives
Sustainable income growth
Employment generation
Poverty alleviation
Food security
Foreign exchange generation and savings

Agricultural development objectives
- Internal self-sufficiency in basic foods—i.e., maize, sugar, wheat, sorghum, finger millet, rice, pulses, tubers, oilseeds, fruits and vegetables, meat and meat products, dairy products, poultry and eggs, fish, and honey.
- Maintenance of strategic reserves of maize, the main staple food.
- Enhanced production for export of traditional crops—e.g., coffee, tea, pyrethrum, sisal—and newer items—e.g., cut flowers, fruits, and vegetables.
- Expanded production of agro-industrial raw materials.

KARI's mandate
To carry out research in agriculture and veterinary sciences so as to achieve the following:
- Protect, conserve, and upgrade the basic resources upon which Kenya depends for agricultural development.
- Improve the quality of food and other farm products thereby increasing domestic and foreign demand for Kenyan agricultural products.
- Enable farmers to produce adequate food supplies and other farm products at decreasing real production costs.
- Protect crops and livestock from pests and other production hazards and protect consumers from health hazards that may arise through the use of agro-chemicals.
- Help raise the income base and quality of life in rural areas through improved farming technologies.
- Develop a Kenyan scientific capacity for generating and disseminating new knowledge and technologies for the solution of current and future problems.
- Cooperate with other research bodies within and outside Kenya that are carrying out similar research.

KARI's core objective
Increase the welfare of Kenyan agricultural producers and consumers through improved technologies.

Sources: National development plans 1989-93 and 1994-96; Sessional Paper No. 4 of 1981 on National Food Policy; Sessional Paper No. 1 of 1984 on Economic Management for Renewed Growth; Sessional Paper No. 1 of 1992 on Development and Employment in Kenya; KARI annual reports 1990-94.

most parts of the country with the objective of increasing the welfare of maize producers and consumers. Similarly, the objective of the national soil fertility and plant nutrition research program "to raise agricultural sector productivity through improved soil fertility" spans a wide geographic area. KARI's regional research programs, by contrast, are mandated to conduct adaptive research on the production systems of a particular region. The regions are defined according to official administrative boundaries. For example, the national dryland farming research program is charged with developing integrated technologies suited to Kenya's arid and semiarid areas in five districts. Additionally, it has the associated objective of improving rural welfare in those areas.

Criteria

Priority-setting criteria help specify the contribution that a set of potential research activities can be expected to make towards the objectives of the research organization. Good criteria have two attributes:

1. They are logically related to the stated objectives of the research organization.
2. They are supported by measures that credibly discriminate between research alternatives.

The most commonly used criteria for agricultural research priority setting are efficiency, equity, sustainability, food self-sufficiency, food security, foreign exchange, and public good.

Efficiency

The efficiency criterion relates to the impact of research on societal welfare. The primary goal of agricultural research is often to improve the welfare of citizens. Because resources for research are limited, they must be allocated to generate the largest possible benefits for both agricultural producers and consumers.

Equity

The equity criterion relates to the distribution of welfare benefits. While the efficiency criterion assumes that the monetary value of research benefits is the same for all producer and consumer groups, the equity criterion places a higher weight on welfare gains achieved for certain target groups (e.g., the poor). This is because research targeted to these groups may result in greater social welfare gains than similar monetary gains to other groups.

Most people agree that government has a moral imperative to address equity objectives. However, agricultural research is often a weak mechanism for changing the distribution of welfare in a society. In fact, research may have greater impact on the distribution of social welfare by providing policymakers with information on the potential welfare impacts of nonresearch policy measures, than through technology-related research. The equity criterion must be defined as a trade-off with the efficiency criterion. If no trade-off is involved in differentially targeting a specific group, then there is no need to use an equity criterion.

Sustainability

Broadly, sustainable development meets the needs of the present generation without compromising the ability of future generations to meet their needs. As a priority-setting criterion, sustainability examines the contribution of research to the objective of protecting the resource base for future use. Since current agricultural production almost always affects the resource base and potential future production, the sustainability criterion must evaluate how society trades present benefits for potential future benefits.

A sustainability criterion can be applied at many different levels within the agricultural production system. Technologies that are sustainable at one level may not be sustainable at a higher or lower level. For example, sustainable agricultural technologies at the plant level may not be sustainable at the household or farming-system level. In practice, choice of the level of analysis partly depends on the quality of information that is available. That, in turn, is determined by the kind of information that scientists generate in the course their activities.

Food self-sufficiency and food security

These two criteria are often grouped together incorrectly. The underlying objective of food self-sufficiency is to produce enough food in a defined geographic area to feed the population in that same area. The pursuit of this objective may lead to the production of a commodity for which the country has no comparative advantage (i.e., the commodity could be imported and internal resources used to produce other commodities with greater benefits to society). Because trade often buffers swings in domestic production, food self-sufficiency policies that erect trade barriers in order to ensure that local populations consume only locally produced agricultural products may result in increased variation in food availability.

On the other hand, food-security objectives attempt to increase the stability of staple food availability. The pursuit of food-security objectives has two important related components: 1) to reduce market variability in the supply of staple foods and 2) to decrease the probability of production shortfalls in staple foods. The first component is best addressed through agricultural market policies. The second can be addressed by research aiming to produce technologies that reduce the impact of shocks on agricultural production (e.g., soil and water management or agronomic technologies to reduce production variability in marginal environments). Like equity, the food-security criterion must be clearly defined as a trade-off with efficiency in its differential targeting of specific groups.

Foreign exchange

Perhaps the most diffuse of all these criteria is research’s contribution to increasing foreign exchange earnings. In liberalized economies with free exchange rates, it is not clear exactly how, or why, foreign exchange earnings contribute to agricultural research organizations’ objectives differently from other earnings. In fact, criteria aimed at increasing foreign exchange are often really equity criteria aimed at targeting research benefits to export-oriented farmers. If the major benefit of research on an export-oriented crop is to increase comparative advantage or profitability on the world market, the gain will be fully captured in the producer surplus measure of the efficiency criterion. By the same token, if research has a large impact on a crop that is an import substitute, the impact on the balance of trade will also be large. The efficiency criterion will, again, fully capture these benefits.

Public good

Publicly supported research organizations often wish to avoid crowding out private-sector agricultural research investments. They therefore concentrate their research in areas that promise a high payoff to society but that would not be undertaken by the private sector. Research on technologies for which the benefits can be appropriated by the developer are more likely to be undertaken in the private sector or in a public-private-sector partnership. The public good criterion measures the extent to which restrictions on the appropriability and excludability of research results may limit private-sector involvement in the research area.

Measures

Priority-setting criteria must be logically consistent with research objectives. Criteria are, however, of practical use only if they are evaluated with measures that credibly and transparently differentiate between the potential contributions of research alternatives. Similarly, measures cannot be developed without a very clear definition of the criteria to be employed. These definitions, in turn, depend on the set of research alternatives under evaluation. In light of this interdependence, some broad guidelines for measures of efficiency, equity, sustainability, food security, and public good criteria are provided.

Efficiency

The ease of measuring the contribution of research to the efficiency criterion, as well as the strong links between efficiency and many of the basic objectives of agricultural research, make the criterion a cornerstone of many priority-setting exercises. Significant advances have been made in the development of benefit/cost and economic surplus research evaluation methods that discriminate between the potential contributions of alternative research themes to economic efficiency. These methods are discussed in detail in chapter five.

Equity

The trade-off between aggregate efficiency and benefits targeted to specific groups is captured in equity measures (box 2.2). Formal measures of the contribution of research to equity require two basic political decisions be made in consultation with major stakeholders:

Box 2.2. Potential Trade-offs between Efficiency and Equity Criteria

Figure 5 depicts a set of potential trade-offs between targeting research benefits predominantly towards resource-poor farmers in a semiarid environment or aiming them towards other farmers in a high-potential area. The total benefits that can be gained by alternative allocations of resources between farmers in the two areas is depicted by the curve. In the example, moving from the efficiency position to the equity position involves a decrease of 200 units of the benefit that could be gained by farmers in the high-potential area so that farmers in the semiarid areas can gain 150 units of benefits. Shifting the allocation of research resources to this point implies that a political decision has been made, in effect, that benefits to farmers in the semiarid area are worth 4/3 times the benefits to farmers in the high-potential area.

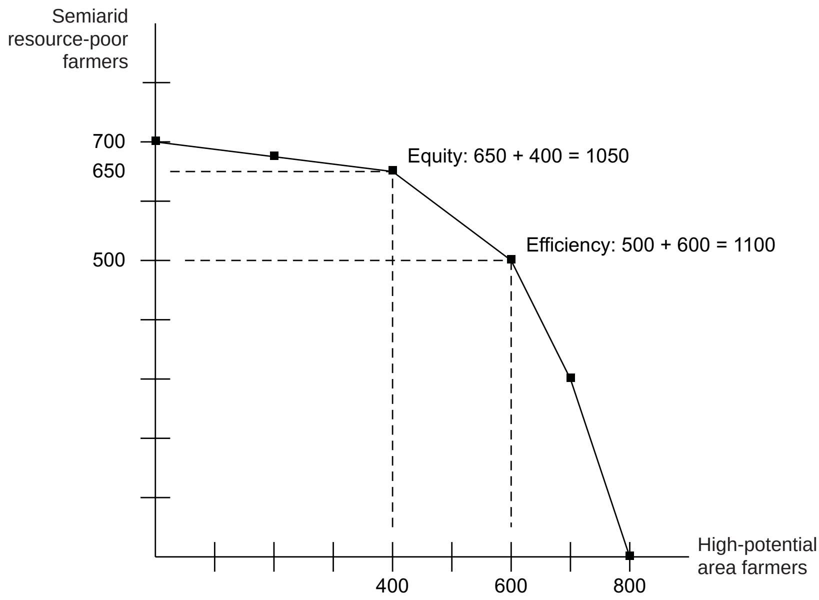


Figure 5. Trading efficiency benefits for equity benefits

Unfortunately, trade-offs in the form of reallocation of resources to research that will benefit target groups is very difficult to specify empirically. Equity is therefore often included in multiple-criteria scoring models based on the subjective assessment of experts about the differential impact of research alternatives on the target groups. Scoring models are discussed in chapter five. Even with the scoring approach, groups targeted because of equity concerns must be clearly identified if the criterion is to be properly employed. Research alternatives can then be assessed based on the provision of benefits to the targeted group. Unfortunately, the scoring approach does not directly capture the central trade-off between efficiency and equity.

1. Which groups are to be disproportionately targeted by agricultural research in pursuit of equity considerations?
2. What level of potential benefits will be taken from other groups in order to provide additional benefits to a targeted group?

Sustainability

Difficulties in defining a sustainability criterion translate into difficulties in measurement. Definitions of research's contribution to sustainable agricultural systems differ based on both the time frame used and the scale at which the production system is examined. If sustainability criteria are clearly defined, emerging links between biophysical and economic modeling of agricultural production systems offer the possibility of formally measuring the contribution of research themes to desired future states of agricultural production systems. However, to date, such research efforts have been very site specific. They are also human-resource intensive. Across a broad array of research themes, few models provide accurate approximations of such future states in production systems.

The most comprehensive empirical measure of sustainability is total factor productivity, which is the ratio of all outputs to all inputs of a production system. That's because central to the notion of sustainability is that the outputs of any production system include not only marketed commodities but also nonmarketed "services" to the environment. Similarly, inputs include not just labor and purchased items, but also any costs of natural resource depletion and damage to the environment. Sustainability of an agricultural production system, thus, is measured in terms of changes in total productivity. This accounts for the broad array of market and nonmarket inputs and outputs. However, it is not only very difficult to identify and quantify values of all inputs and outputs of production, but the extent to which these valuations can guide actual resource allocations in agricultural research organizations is unclear.

Given the limited resources in most NARS, returns to investments in data- and analysis-intensive measures of sustainability may not justify costs. As a result, sustainability criteria have been little used in priority-setting exercises outside of subjective assessment in scoring models.

Food security

Like equity, food security must be viewed as a trade-off with aggregate efficiency. Successful agricultural research usually increases commodity supply. The value of these increases is well captured by efficiency measures. Commodity prices in a geographic area generally reflect the scarcity of a good. However, food deficits may result in greater losses of social welfare than is reflected in commodity price averages. Hence, additional weight may be attached to research benefits generated in food-insecure regions.

The general approach to measuring trade-offs between food security and efficiency considerations is the same as for equity. First, food insecure areas or target groups must be clearly identified. Second, the political weight of benefits to the identified groups, relative to the general population, is clearly established. Finally, the trade-offs inherent to alternative allocations of research resources to target and nontarget groups is measured. Again, few organizations devote resources to formally measuring these trade-offs. In practice, food security is usually included as a criterion in a scoring model and measured based on the subjective assessment of experts on the relative contribution of research alternatives to specific food-insecure groups.

Public good

The public good criterion measures the feasibility of alternative combinations of public- and private-sector research activities. It's largely a screening mechanism for the use of public-sector funds. Like other criteria, full-blown economic analysis of the feasibility of research alternatives under all public- and private-sector combinations of resource sharing are rarely undertaken.

Final lessons on criteria and measures

Two basic lessons can be drawn for establishing priority-setting criteria and measures:

1. All agricultural research priority-setting criteria must be carefully and formally defined. Criteria must be logically linked to the research organization's objectives and supported with credible and discriminating measures of the potential contribution of the various research alternatives.
2. The choice of measures depends on a number of factors, including the type of research alternatives under evaluation. The decision also depends on the desired level of investment in information and the methods available for organizing the information. Many of these issues are revisited in chapter five in a discussion of methods for priority setting.

The process of determining objectives and criteria

Agricultural research objectives should be developed at the system, institute, and program levels through a systematic process of discussion and consultation. Relationships among stakeholders are central to an agricultural research organization's efforts to identify research objectives. Viewed broadly, this group ranges from farmers in the most remote regions of a country, to traders who link farmers to domestic and international markets, to agricultural policymakers. It is often difficult to reconcile the inherently different concerns of these groups. With regard to agricultural research, where do these groups' interests meet or diverge? How do research activities potentially further each stakeholder's interests?

De facto, the exercise of defining objectives, selecting criteria, and measuring impact answers these questions. The more open the process is, the greater its complexity as different interests collide. At the same time, the more open the process is, the wider the scope for arriving at compromises in order to reflect the varied interests. Some appropriate institutional structures for this process were mentioned in chapter one. Four basic steps can assist organizations in developing coherent research objectives for institute and program priority setting:

1. A working group reviews national agricultural development goals and the research organization's mandate.
2. The working group formulates recommendations on objectives for the organization as a whole, as well as for the research programs.
3. A priority-setting committee consisting of senior research managers and scientists reviews and modifies the working group's recommendations.
4. The organization's board or another formally vested body of major stakeholders reviews the objectives that are recommended.

Similarly, criteria and measures are identified through three basic steps:

1. The working group translates objectives into a basic set of criteria.
2. The working group determines what is the information and analytical capacity required to implement alternative criteria measures. In some cases pilot exercises may be undertaken to test potential methods.
3. The working group presents its recommendations to a priority-setting committee for approval and implementation across the organization.

A KARI example

A priority-setting working group based at KARI headquarters initiated efforts to clarify the institute's objectives and to identify program-level criteria for measuring the contribution of research themes to those objectives. The working group, composed of some 10 members, first reviewed government policy statements on agricultural development objectives, as well as KARI's corporate plan. The major institute objective that emerged from this synthesis was "to increase the welfare of Kenyan agricultural producers and consumers through improved agricultural technologies." However, the need to develop technologies suitable for smallholders was also recognized, as was the need to increase the sustainability of agricultural production systems. These objectives could be translated, respectively, into three common priority-setting criteria: efficiency, equity, and sustainability.

Further, the working group felt that initial priority-setting efforts at the program level should focus on developing ways to measure the core criterion: efficiency. Because the equity criterion is most applicable for cross-program priority setting and the sustainability criterion is notoriously difficult to define and measure, these were excluded from pilot exercises to develop an "efficiency"-based process appropriate for program-level priority setting. One of the four national commodity program pilot exercises, sorghum, is presented in chapter nine.

A working group synthesis and lessons learned from the pilot exercises were presented in a priority-setting position paper. Guidelines and a plan for implementing the process in the remaining national commodity programs were also developed. The position paper was formally presented during a one-day meeting to a priority-setting committee composed of the KARI director, deputy directors, and assistant directors for discussion and approval. The committee approved the initial focus on the efficiency criterion, but mandated the group to explore the possibility of including a well defined equity criterion in future rounds of program-level priority setting. The guidelines and implementation plan were also approved. Further, the working group was asked to develop similar sets of guidelines and plans, through pilot exercises, for setting priorities in regional research programs and natural resource management research programs. The natural resource management pilot exercise that arose from this request is presented in chapter 10.

Exercise 2.1
Defining Objectives, Criteria, and Measures

Form a small working group. Discuss and prepare short responses to the following questions:

1. What are the objectives of your research organization?
2. What process was used to arrive at those objectives?
3. Does your organization have a set of criteria for evaluating the contribution of research themes to those objectives? If so, how were these criteria developed?
4. What measures are used to evaluate the contribution of research to these criteria?

Chapter 3 Spatial Targeting of Program Research

Bradford Mills, Daniel Kilambya, and Stanley Wood

Introduction

Agricultural production and the environment are intimately related. Most agricultural production, particularly in sub-Saharan Africa, still occurs under rainfed conditions with high environmental variability. Cultural practices, transport costs to input and output markets, and unequal distribution of household assets add further variability, even within relatively homogeneous biophysical environments. As a result, technology needs and potential research impact tend to be location specific. Research organizations struggle to develop technologies that address specific client needs but are still applicable across a broad enough base to justify the research effort.

A spatial framework for research evaluation can help research managers explore both the local relevance and broad applicability of potential research alternatives. Specifically, a formal spatial framework can assist in organizing existing information bases and in the collection of additional information, particularly on technology user needs. A formal spatial framework can also be used to control major sources of variation (particularly biophysical) when evaluating the potential impact of research alternatives. It can also help researchers examine the potential spillover of technologies developed in other locations. This chapter discusses two main issues related to spatial targeting of research programs:

1. approaches and information bases for developing spatial classifications
2. the potential role of GIS and other tools in spatial classifications

The KARI soil fertility and plant nutrition program provides an example of how such target zones can be delineated and classified. The exercise at the end of the chapter helps research managers identify tools and information bases that might be used for targeting the research programs in their organization.

Approaches to spatial classification

The choice of a classification scheme for research evaluation should be based three issues. First is the scope and scale of research management issues to be addressed. Second is the availability of georeferenced information based on key criteria. Third is the desired role of expert opinion in the classification process.

Scale and scope

Spatial classification entails making reasonable trade-offs between specificity and scope. Classifications used for research priority setting and planning must be broad enough to inform resource allocation decisions but site specific enough to serve as a meaningful framework for identifying client constraints and evaluating potential impact. Inclusion of even a fraction of the myriad criteria that influence the spatial distribution of agricultural technologies will quickly produce an extremely disaggregated classification scheme. Such a scheme will be of little use for research program planning and resource allocation (figure 6).

The art of spatial classification is to demarcate areas that show reasonable homogeneity with respect to the set of research alternatives being evaluated. Classification schemes for commodity programs with a national mandate will generally be more aggregate than those for regional research programs with very specific geographic mandates. From a practical point of view, planning and resource allocation will become difficult if it is based on a scheme with more than six separate research target zones.

Information availability

The choice of criteria for a classification scheme is also influenced by the availability of information. Potential criteria include geopolitical boundaries (country, division, district, location, sublocation political boundaries), climatic conditions (monthly average rainfall, monthly average minimum and maximum temperature), topography (elevation, slope, soil structure), current land use, market structures and transaction costs (distance from roads or major retail centers, the distribution of input and output prices), and human conditions and preferences (population density, measures of household welfare, prevalent cultural practices).

A first step in setting up a spatial classification scheme is to determine the availability of georeferenced information bases. Existing classification schemes can be a valuable reference point when developing a new scheme specific to the set of research alternatives under analysis. Sometimes existing schemes can be used without modification. However, with the rapid development of GIS software and datasets, the technology exists to quickly create classifications specific to programs and even research themes.

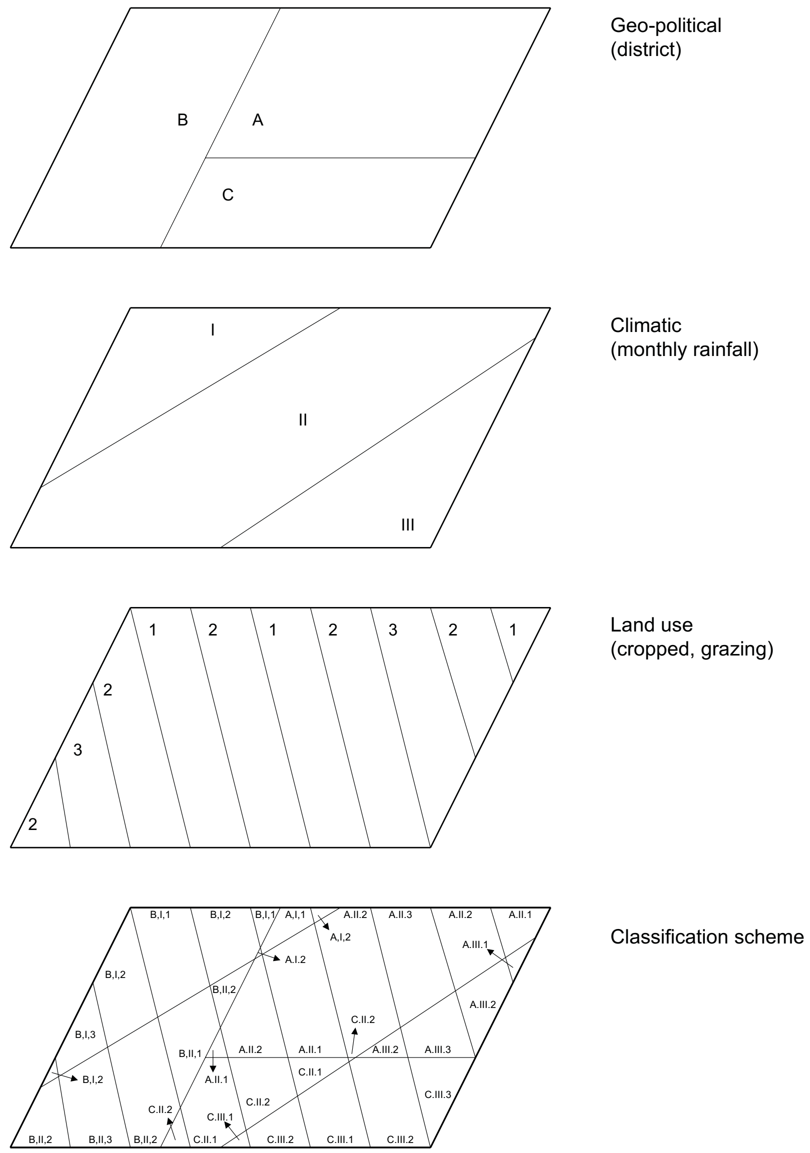


Figure 6. Rapidly increasing complexity of a spatial classification scheme

A wide range of international and national agencies use georeferenced data. Many have proceeded to develop their own spatial databases using “digitized” maps and remote sensing data (table 3).[1] Most international and some national agencies make this information available for a modest fee to cover the cost of computer materials and shipping. Increasingly, spatial

1. Earth observation data collected using a wide range of sensor devices aboard manned or unmanned airborne platforms, for example, aerial photographs, radar, LANDSAT.

Table 3. International Sources of Spatially Referenced Data for Agricultural Research Applications

Theme	Resolution or Scale	Responsible Institution	Remarks
Climate data	1:5000000 19 km grid	FAO CIAT	Thermal zones and LGP Monthly maximum and minimum temperature and rainfall in Africa and Latin America and the Caribbean
Soil or terrain type	1:5000000	FAO	Based on FAO/UNESCO Soil Map of the World (FAO/UNESCO)
Terrain/Land use Elevation (m) Land use/cover	1km grid 1km grid	USGS/NOAA	
Administrative boundaries	1:1000000	ESRI	
Demographics, population density	10km grid	NCGIA	
Infrastructure		DCW	
Regional datasets		WRI CIAT/UNEP IFPRI/CIAT	African Data Sampler (WRI 1995)
Metadata contacts		UNEP Edinburgh Univ.	

datasets can be found on the Internet for downloading free of charge, although GIS files tend to be large even when compressed.

International datasets often have much less spatial resolution than do equivalent national datasets in countries where such data exist. Data from international sources may be used to start a national dataset, however. Later, thematic layers (such as soils, temperature, forest reserves, etc.) can be systematically replaced with higher resolution national data as they become available. Further, the international datasets may often be useful for NAROs in their search for technological options that can be “borrowed” from neighboring countries.

If data is desired on variables that are not supported by existing datasets, a decision must be made on whether the information is worth collecting. The collection and processing of georeferenced data is resource intensive. Such investments should only be made with a clear understanding of the costs and potential benefits to be gained from the information.

Role of expert opinion

Once the appropriate scope and scale for the classification scheme is agreed upon and the availability of information bases is reviewed, important choices must be made on the criteria to use in the scheme. There are four basic approaches: generic schemes, deductive schemes, clustered schemes, and production geography schemes (figure 7). Expert opinion plays a different role in each approach. A more detailed description of approaches to spatial classification for research evaluation is found in Wood and Pardey (1998).

If an adequate generic classification scheme already exists, expert opinion is restricted to deciding which research themes apply in which zone or combination of zones. By contrast, in the specific-zone approach, experts are directly involved in the choice of criteria and criteria ranges. This is usually done by a group of experts iteratively mapping alternative criteria ranges with the aid of a GIS until a scheme emerges that sufficiently represents areas with homogeneous potential impact for the research themes under evaluation. The third approach, cluster analysis, relies on expert opinion to establish initial criteria and a target number of clusters. A statistical algorithm then defines clusters that minimize variance over the chosen criteria. Expert opinion is again used to combine the clusters into zones that show sufficient homogeneity with respect to the set of research themes under evaluation. The final approach, production geography, uses detailed information on the current location of production, as well as associated agroecological, socioeconomic, and institutional characteristics of the location, to identify similar areas in other locations. This last approach allows for specific characterization of production zones, but is very information intensive.

In summary, the choice of an appropriate spatial classification scheme should be based on the scope and scale of research alternatives to be evaluated, as well as information bases currently available. If an available generic scheme is not employed, the capacity to classify (or reclassify) georeferenced information must also exist. The following sections briefly review the minimum computer hardware, software, and analytical capacity needed to use GIS tools to support spatial classification activities.

GIS alternatives

There are essentially two GIS data formats and corresponding families of software to manage them. The original GIS format is based upon *vectors* and is used in software packages such as ARC/INFO, MapInfo, and Atlas GIS. These systems represent spatial entities, such as points, lines, and closed shapes, as a single or string of *x, y* coordinates. Many separate vector themes can be overlayed on a printed map or computer screen. They can also be intersected to create new shapes (mapping units). For example, a map of rainfall isohyets (a line map) can be intersected with a map of soil units (a

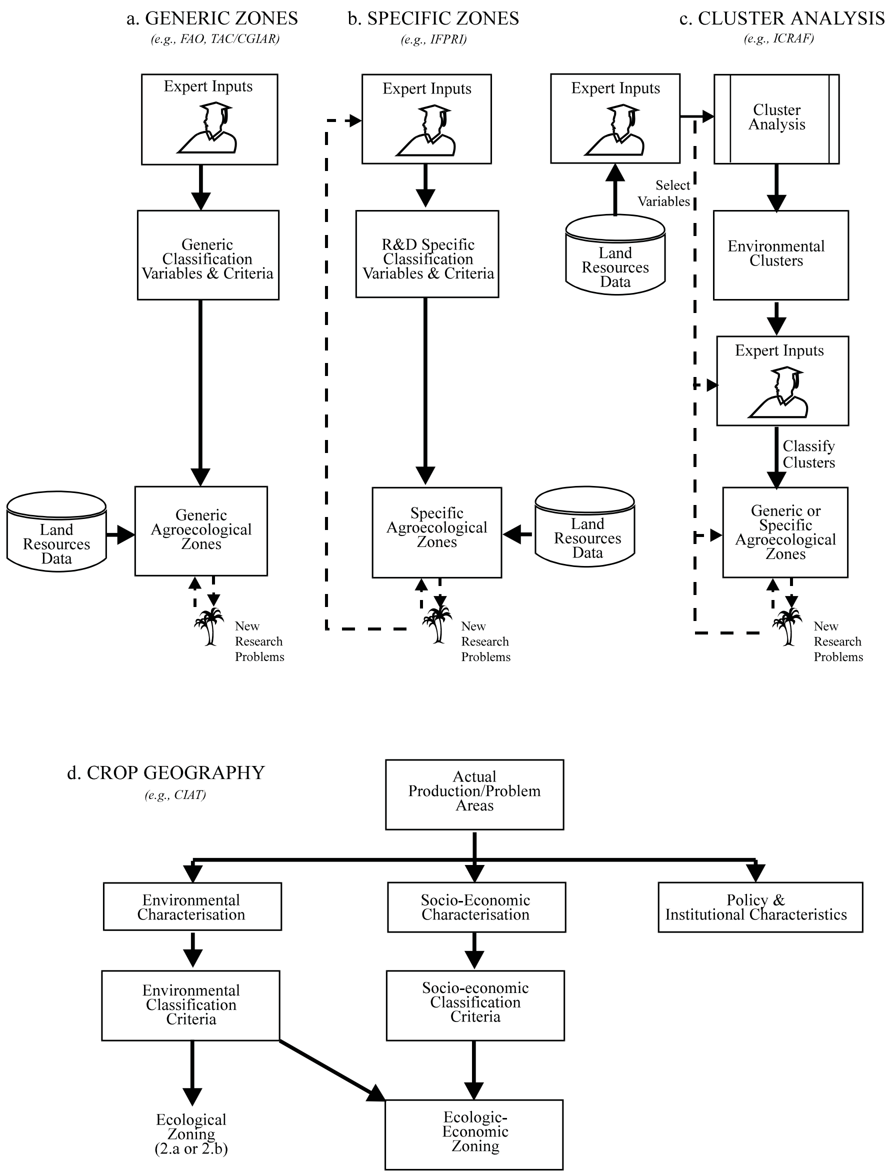


Figure 7. Some approaches to agroecological zoning within the Consultative Group on International Agricultural Research (CGIAR)

polygon map) to create a new polygon map that depicts simple agroecological zones. The GIS not only creates the new map but also automatically labels the agroecological zones, calculates their area, and stores their unique combination of properties, in this case, rainfall and soil type, in a database permanently associated with the new agroecological zone map.

The second GIS format is based on *rasters* and is used by software systems such as Erdas, Idrisi, and Spans. Here, geographic space is represented by a rectangular image made of up equal-size grids (pixels), whose number is based on the number of rows and columns contained in the image. Thus, an elevation image of 1000 rows by 600 columns contains 600,000 individual pixels. Each has its own value in, for example, meters of the geographic area that the pixel represents. The image is depicted on the screen or on a printed raster map by assigning colors to specific values or ranges of the thematic variables. Since each thematic image (equivalent to one computer file) must contain a numeric value for each pixel, it is not possible to visually overlay these images in the same way as vector files. However, they are better suited to mathematical manipulation. For example, a new image of annual rainfall can be made by adding the corresponding pixel values of 12 monthly rainfall images.

In reality, the traditional distinction between these two types of GIS is becoming blurred as new systems combine the ability to handle both types of data. For example, most raster systems allow the overlay of images by suitably formatted vector files. And vector-based systems allow raster images to be used as a background to a vector map. Both systems also offer raster-vector and vector-raster conversion. As with any other computer-based technology, the power, flexibility and user friendliness of GIS software has advanced greatly in recent years. Purchase prices have also fallen significantly. For under US $1000 it is possible to purchase a Windows-based system such as ESRI's ARC/VIEW or Clark University's IDRISI. Furthermore, discounts are often available for organizations in developing countries and in teaching and research institutions. To be most flexible it is preferable to have both systems in order to manage and interface both vector and raster data.

In terms of computer hardware, several of the GIS packages referred to above—ARC/INFO, ARC/VIEW, and ERDAS—have both workstation and personal computer (PC) versions. However, GIS databases need a lot of hard-disk space. It is not uncommon for a single raster file to occupy 30 to 50 megabytes. A two to three gigabyte hard disk is a minimal requirement. A computer with a minimum of 166 MHz Pentium processor and a 17 to 19 inch color monitor is also recommended. A CD-ROM, too, is essential. Not only is most GIS software now sold on CD-ROM, but much GIS data is published (commercially or publicly) only in CD-ROM format. A color printer is also essential. Options range from ink-jet color printers to color laser printers. A final hardware issue is that of a "digitizer." A digitizer is a flat table on which a map or photograph can be manually traced to capture new spatially-referenced information in vector formats. The purchase of this type of equipment must be considered in relation to the critical issue of whether technicians are available with the skills necessary to manage, operate, and use the GIS systems in cost effective and creative ways.

An example from the KARI soil fertility and plant nutrition program

This section presents a "specific zone" approach to spatial classification that was used by the KARI soil fertility and plant nutrition research program in its priority-setting exercise. The program's mandate is to develop improved fertilizer and plant nutrition technologies for all of Kenya's crop-growing regions. However, it does not have enough resources to address the whole range of clients' soil fertility technology needs under all soil and climatic conditions in the country. Priority research zones, therefore, had to be identified and resources concentrated in those geographic areas.

A priority-setting working group composed of a regionally representative mix of researchers and extension workers was first appointed. This group identified key environmental determinants of the potential impact of technologies. These were rainfall, elevation, and population. The resulting criteria ranges are presented in table 4. A map of the zones that emerged from the analysis is in figure 8.

Rainfall: Areas where moisture availability is a serious constraint to agriculture production are identified as receiving between 200 mm and 900 mm of rainfall per year. All other primary areas for agricultural production receive more than 900 mm of rainfall per year.

Elevation: Elevation is included to demarcate major differences in production systems in the medium and higher elevation areas. Medium elevation areas (400 - 1800 m) with more than 900 mm of annual rainfall are traditional smallholder systems located in the Lake Victoria basin and on the lower slopes of Mt. Kenya. High elevation areas (greater than 1800 m) comprise the traditional grain basket of Kenya. Much of the land in these areas was organized into large-scale farms during the colonial era.

Population: Human population density is included to capture different pressures on the soil base. Lower rainfall areas southeast of Mt. Kenya and in

Table 4. Research Target Zones of KARI's Soil Fertility and Plant Nutrition Program

Zone	Elevation (meters)	Rainfall (mm)	Population (density per km^2)
Coast	< 400	> 900	> 20
Low Rainfall			
low population	—	200 - 900	20 - 80
high population	—	200 - 900	> 80
Medium Altitude			
high population	400 - 1800	> 900	> 80
High Altitude			
low and high population	1800 - 3000	> 900	> 20

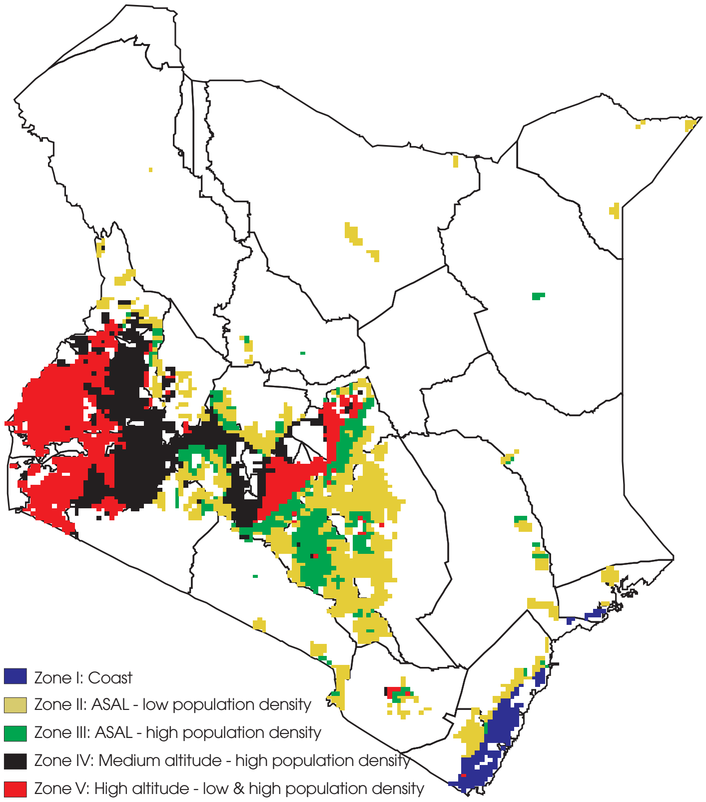


Figure 8. Soil fertility and plant nutrition program research target zones

the lower elevation areas of the Rift Valley have dense settlement patterns (greater than 80 persons per square kilometer) and face the difficult challenge of developing suitable production systems under continuous cultivation with low annual production of biomass. Other low-rainfall areas still operate as extensive agricultural production systems (characterized by population densities between 20 to 80 persons per square kilometer).

Medium elevation areas with high rainfall show uniformly high population density (greater than 80 persons per square kilometer). These areas also face the challenge of maintaining the soil base under continuous cultivation, although with more available biomass. Higher elevation areas show a less uniform distribution of population density. As mentioned, these areas were developed as large-scale farm enterprises during the colonial era. Many large farms have been subdivided in the post-colonial era to produce the current mix of high and medium population density areas. Chapter 10 discusses further the priority-setting exercise of the soil fertility and plant nutrition research program.

Reference

Wood, S. and P. Pardey. 1998. Agroecological aspects of evaluating agricultural R&D. *Agricultural Systems* 57(1): 13-41.

Exercise 3.1
Examining Spatial Classification Schemes

Form a small group. Discuss and respond to the following:

1. Identify spatial classification schemes currently used for planning and implementing agricultural research within your organization.
2. Are current schemes sufficient for program-level priority-setting efforts? If not, what variables might allow more refined targeting of technology impacts?
3. Identify existing georeferenced databases that might be used in the development of program-specific classification schemes.

Chapter 4
Translating Farmer Constraints into Research Themes

Patrick Audi and Bradford Mills

Introduction

Farmers and other clients of agricultural research have a large number of technology-related constraints. Only a few of these can be addressed effectively through agricultural research. Once zones are identified where new technologies can be expected to have a relatively homogeneous impact, the needs of farmers and other technology users must be translated into research alternatives. These research alternatives are referred to here as research "themes." Research themes should be as specific as possible. But because they represent both current and potential future activities, themes are not synonymous with the list of existing research projects.

A research program can focus on any number of problems. However, research will only result in technologies with a realistic possibility of being adopted if it addresses problems of importance to the eventual users of technology. Only a limited number of research themes can be evaluated in a priority-setting exercise. This set of potential themes is derived from the intersection of the needs of agricultural technology users and the technical problems that can be addressed effectively by agricultural research (figure 9).

Identifying the agricultural technology needs of users, and translating those needs into research themes is an essential component of any priority-setting exercise. If properly done, a clear set of specific themes will emerge for ranking. If not properly undertaken, ambiguity about the set of alternatives to be compared is magnified in all subsequent steps of the priority-setting process. This stage of priority setting often requires significant investment of human resources for several reasons. First, many clients, particularly resource-poor farmers, are unable to formally articulate their tech-

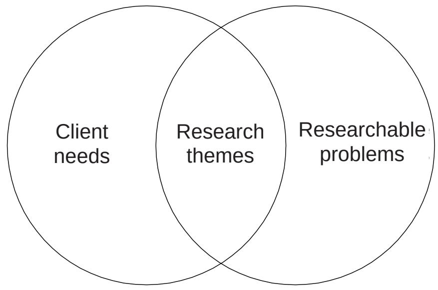


Figure 9. Research themes are the intersection of client needs and researchable problems

nology needs. This necessitates time and resources being devoted to techniques like participatory rural appraisals (PRA) to understand the constraints and technology needs of these groups. Second, client constraints and technology needs, once identified, are often difficult to translate into research themes.

Tools like constraint-tree analysis, which is introduced in this chapter, can also help priority-setting working groups to systematically translate client constraints into specific researchable objectives. These objectives must, in turn, be translated into research themes that are underpinned by activities and outputs. A considerable degree of creativity and consensus building is required in these steps and appropriate time should be allocated to each.

In short, the distance from client needs to research themes for ranking in a priority-setting exercise can be rather far and require considerable effort to bridge. In this chapter three basic stages of that journey are examined:

1. identifying client constraints
2. translating client constraints into research objectives
3. translating research objectives into research themes, activities, and outputs

An example from the KARI Katumani regional research program’s priority-setting exercise accompanies the discussion of each step. An exercise at the end of the chapter assists research managers and implementers of priority-setting exercises in reviewing the potential for applying such techniques in their own organization.

Identifying client constraints

There is no single “best” method for identifying client constraints and research needs. A review of the mandate and objectives of the research organization or program (as discussed in chapter two) helps to clearly identify who are the program’s clients. Many research programs will already have collected a tremendous amount of information on the needs of these client groups. Unfortunately, this information is rarely kept in one place. Even more rarely is it synthesized into a useable form. An important first step in identifying client constraints is, therefore, to identify existing sources of information and distill relevant past findings on client constraints. Here are a few important sources of information:

- rapid rural appraisal (RRA) or PRA surveys of areas within the program mandate
- formal surveys of farmers, processors, or other potential technology users and their production constraints
- reports on client assessments of previously released technologies
- expert opinion of extension workers and NGOs working closely with clients in technology testing

In practice, a team of two or three persons (e.g., the program coordinator, a socioeconomist, and a research assistant) needs between one and two months to collect and synthesize this information. The output is a list of identified client constraints and technology needs. However, the team must also identify gaps in existing information. Potential gaps include geographic or thematic areas that were not covered in previous survey work but that are within the program mandate (e.g., marginal environments or food processing activities), as well as needs of important client groups that are not adequately represented in previous surveys (e.g., women and peri-urban farmers). Short- and long-term strategies for addressing these information gaps should be developed. In the short run, additional information on major client constraints may need to be collected prior to further priority-setting activities. Long-term information needs can be noted and addressed as part of future research efforts.

The most commonly used techniques to obtain additional information on client constraints are RRAs and PRAs (box 4.1). A good review of these methods is in Okali, Sumberg, and Farrington (1994) “Farmer Participatory Research: Rhetoric and Reality.” The discussion here is restricted to three points related to the use of these techniques in identifying client constraints for research priority setting:

1. Rural appraisal techniques, in practice, require a significant commitment of human resources, both during field activities and in writing up results. Any field activities that are not properly documented are quickly lost from the program information base. Loss of such information represents a major impediment to long-term program development. Rural appraisal should only be undertaken once information gaps have been clearly identified.
2. Complete PRAs collect a wealth of information, only a small portion of which directly touches on client technology needs. Researchers may want to restrict the focus of generic appraisal methods to the discussion of issues directly related to agricultural technologies.
3. Rural appraisal techniques should be seen as an imperfect short-term substitute for sustained in-depth interactions with technology users. When conducted as one-time events by large teams of researchers and extension agents, the information collected may have little influence on perceived research needs.

Box 4.1. The Use of Participatory Rural Appraisals by the Katumani Regional Research Program

The mandate of the Katumani regional research program is to develop improved agricultural technologies for farming systems in five districts. Agroecological conditions vary greatly in these districts. So as a first step in the priority-setting process, five relatively homogeneous agroecological zones were identified. The priority-setting working group then decided to focus initial activities on identifying client constraints in the high-population zone with two rainfall seasons. This accounted for the largest number of inhabitants in the mandate area. Further, this area had not been a major focus of previous program activities. Two PRA sites were chosen from a population-weighted, fixed-interval random sample of areas within the zone.

PRAs were conducted over a two-week period at both sites. The community and the PRA team used a number of tools:

- community sketch of agriculture and land use
- transect walk
- agricultural activities calendar
- trends analysis
- household interviews
- daily activities calendar by gender
- community institution diagram
- livelihood mapping
- problem listing and analysis
- problem ranking
- opportunity and options assessment

The results of the PRA were compiled into a report and verified in other villages in the zone.

Translating client constraints into research objectives

Research themes denote specific sets of research activities that address farmers' priority constraints. However, the set of farmer constraints is not equivalent to the set of researchable problems. Priority-setting working groups are thus left with the difficult task of translating farmer constraints into researchable problems. The simplest approach for doing this is to first list all identified constraints and then group common constraints as research problems. Given the lack of structure to this approach, the set of research problems emerging will almost always directly reflect the current research agenda. A real danger exists that important problems will be excluded from the analysis. A second approach, constraint-tree analysis, systematically relates farmer constraints to their direct causes and effects in order to identify critical entry points for research (box 4.2).

Box 4.2. Construction of a Constraint Tree for KARI's Katumani Regional Research Program

During PRA exercises, farmers identified and ranked production constraints. They then merged related constraints, after which, 12 core constraints remained. These were then comprehensively analyzed by the priority-setting working group using the constraint-tree approach. Starting from the core problem, direct and substantive causes were deduced and placed in flow-chart style immediately below the core problem. This process was repeated until the group of scientists and extension staff reached consensus that the analysis was exhaustive and that they had reached the lowest levels of the "tree" relevant to research. The group checked for consistency within each "problem tree" by examining whether removing or reducing the effects of lower level problems would also reduce the effects of the higher level problems. For example, in figure 10, when the problem of high runoff is reduced, the core problem of inadequate soil moisture will also decrease.

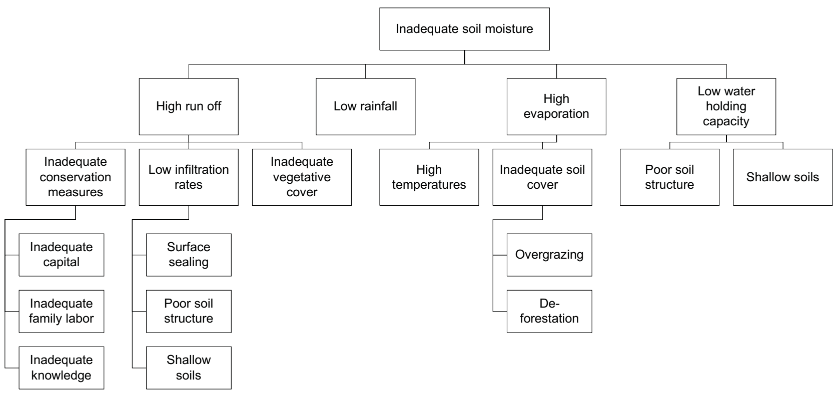


Figure 10. Problem tree for the core problem of inadequate soil moisture

Translating objectives into research activities, themes, and outputs

Research activities must address specific objectives. Normally, research activities should be associated with an objective at the lowest level of the objective tree (box 4.3). Sometimes, however, agricultural research cannot contribute to objectives at that level and the most appropriate entry point for research is at a higher level. In short, expert opinion is needed to identify the most appropriate level for translating objectives into research activities. That's because a clear, one-to-one correspondence does not always exist. It is

Box 4.3. Construction of an Objective Tree for KARI's Katumani Regional Research Program

After completion of a comprehensive analysis of problems and their causes and consistency checks, constraints were transformed into research objectives. This was done by translating the negative statements to positive ones. Figure 11 shows the "solution tree" corresponding to the "problem tree" in figure 10. A consistency check in the objective tree is done by ensuring that when one fulfills the lower level objectives, the higher level ones are met. For example, when the objective of reduced surface sealing is achieved, the higher infiltration rates and, subsequently, adequate soil water objectives are met. If objective trees are not consistent, then the problem and causes analysis probably needs to be revisited.

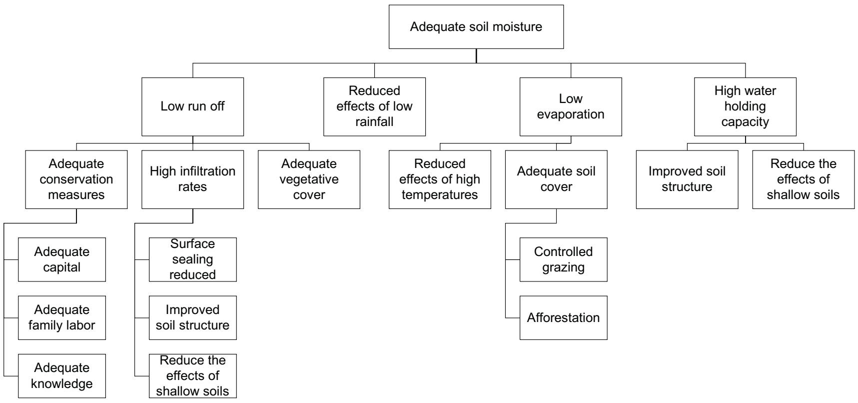


Figure 11. Solution tree for adequate soil moisture

important, however, for research activities to address very specific objectives. Otherwise, it is very difficult to develop meaningful research themes and associated outputs.

Translating objectives into research activities: the Katumani example

In KARI's Katumani regional research program, after constructing objective trees, research activities that met the lowest level objectives relevant to research were listed by the scientists. It is important to remember that these objectives were derived directly from the constraints defined by the clients. For example, the activities in table 5 were developed to meet the objectives defined in figure 11 with respect to soil moisture.

Table 5. Research Objectives and Activities Identified to Achieve Adequate Soil Moisture

Objective	Activity
Increased knowledge	Demonstrate improved soil-water management practices on pasture and crop fields
Reduced surface sealing	Test and adapt tillage methods such as deep ploughing and early ploughing; test and adapt tillage implements suitable for land preparation, weeding, and water harvesting and evaluate their economic benefits
Improved soil structure	Demonstrate improved use of farm-yard manure and compost
Reduced effects of shallow soils	Demonstrate improved use of farm-yard manure and compost; demonstrate the use of suitable crop types
Adequate vegetative cover	Test, adapt, and transfer appropriate stocking rates; test and adapt appropriate cropping patterns
Reduced effects of low rainfall	Test and adapt suitable crop varieties; test and adapt suitable water harvesting and conservation methods and evaluate their economic benefits
Reduced effects of high temperatures	Test and adapt suitable crop types
Controlled grazing	Test, adapt, and transfer appropriate stocking rates and forages
Afforestation	Demonstrate suitable agroforestry techniques

Grouping activities into research themes

A research activity focuses on one constraint. However, some constraints are best addressed by an integrated agenda of several research activities. Further, medium-term resource allocation decisions are often based on combinations of closely related or logically sequenced activities. These are research themes.

Themes must not, however, be defined too broadly, or evaluation of their potential impact becomes very difficult. An examination of the outputs associated with a theme can help managers judge whether a theme is too broadly or narrowly defined. If a theme has a number of outputs that are only loosely related, the theme can most likely be subdivided into sets of activities with more sequentially related sets of outputs. On the other hand, if the theme yields an output, or a collection of several outputs, which by themselves are unlikely to result in an impact at the farm level, then the theme may be too narrowly defined. Again, considerable subjective judgment is involved in deciding what is the most appropriate level of aggregation. In practice, the best level of aggregation also depends on the purpose of the priority-setting exercise. If the purpose is to allocate resources among a current set of program activities, themes may show a one-to-one correspondence with current activities. If the goal is to develop medium- and long-term human and financial resource capacity in the program's key research areas, themes should represent a broader level of aggregation of both current and potential research activities.

Grouping research activities into themes and expected outputs: the Katumani example

Following on the Katumani example, after activities were defined for each objective tree, they were grouped into research themes. Outputs were then defined for each theme. Table 6 shows how activities to improve the efficiency of soil moisture use were aggregated into research themes. Most of the activities fell under the theme of soil surface management for optimization of water use. However, several activities were allocated to crop improvement, crop husbandry, and feed research themes. The expected outputs from each theme were then determined. Table 7 shows expected outputs for the soil surface management theme. The outputs of the other 12 themes identified by the program were developed in the same manner.

The Katumani example clearly demonstrates the difficult choices that often must be made in aggregating activities into themes. In the case illustrated in tables 6 and 7, strong arguments can be made to subdivide the activities into tillage and cropping systems research themes. The counter-argument is that these two sets of activities are very interrelated and must be simultaneously addressed through an integrated set of research activities.

Summary

A link must be established between the users' technology needs and research themes. There are three crucial components of that link:

1. a sound understanding of client constraints and technology needs in specific research zones
2. identification of technology needs that can be effectively addressed by research
3. grouping of related research activities into research themes with clear activities and outputs

Tools and techniques exist for each step. Rural appraisal tools for understanding client constraints are often human resource intensive and need to be incorporated into a priority-setting exercise only cautiously and after a thorough review of existing information. Constraint-tree analysis can assist

Table 6. Activities Sorted into Research Themes

Activity	Research Theme
Demonstrate soil-water management practices	Soil surface management
Test and adapt tillage methods	Soil surface management
Test and adapt tillage implements	Soil surface management
Evaluate the economic benefits of tillage methods and implements	Soil surface management
Demonstrate improved farm-yard manure and compost use methods	Soil fertility improvement
Demonstrate the use of crop types that are suitable in shallow soils	Crop improvement
Test and adapt appropriate stocking rates	Improved feeds for increased productivity
Test and adapt cropping patterns that enhance soil surface cover	Improved crop husbandry
Test and adapt early-maturing and drought-resistant crop varieties	Crop improvement
Test and adapt water harvesting and conservation methods for crop production	Soil surface management
Evaluate the economic benefits of improved water harvesting and conservation	Soil surface management
Test and adapt crop varieties that are tolerant to high temperatures	Crop improvement
Test and adapt productive and drought-resistant forages	Improved feeds for increased productivity
Demonstrate suitable agroforestry techniques	Soil surface management; improved soil fertility

priority-setting working groups to systematically understand core client constraints and translate those constraints into objectives and research activities. In the final analysis, however, the establishment of research themes is a subjective process. The techniques mentioned above do not substitute for creativity and consensus building during the formulation of research themes. Techniques can, however, assist in incorporating disparate pieces of informa-

Table 7. Activities and Expected Outputs for the "Soil Surface Management" Research Theme in Katumani's Regional Research Program

Activities	Expected Outputs
Demonstrate improved soil-water management practices on pasture and crop fields	Farmers who are more knowledgeable in suitable soil-water management practices
Test and adapt tillage methods to reduce surface sealing	Use of suitable tillage methods and implements
Test and adapt suitable tillage implements for weeding and water harvesting	Improved water harvesting and conservation methods
Evaluate economic benefits of improved tillage and water harvesting methods and implements	Cropping systems that minimize run-off
Test and adapt suitable water harvesting and conservation techniques for crop and livestock	
Test and adapt suitable cropping systems	

tion and viewpoints in a structured manner. For further discussion of such techniques, see the ISNAR (1997) training module on research program formulation available on the ISNAR Internet site (www.cgiar.org/isnar/).

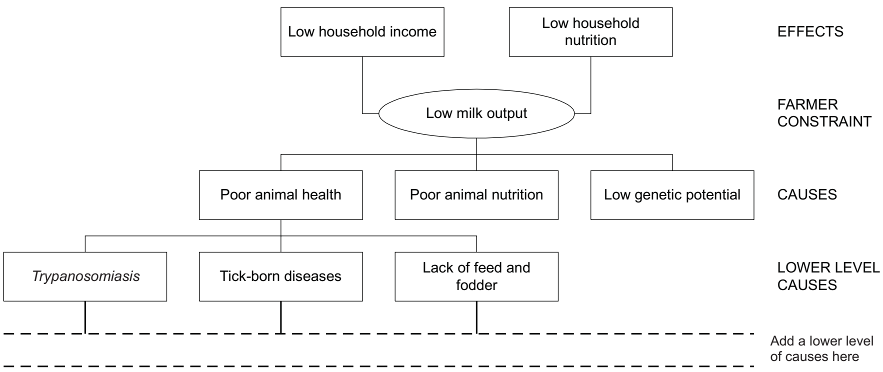
References

Okali, C., J. Sunberg, and J. Farrington. 1994. Farmer participatory research: Rhetoric and reality. London: Intermediate Technology Publications.

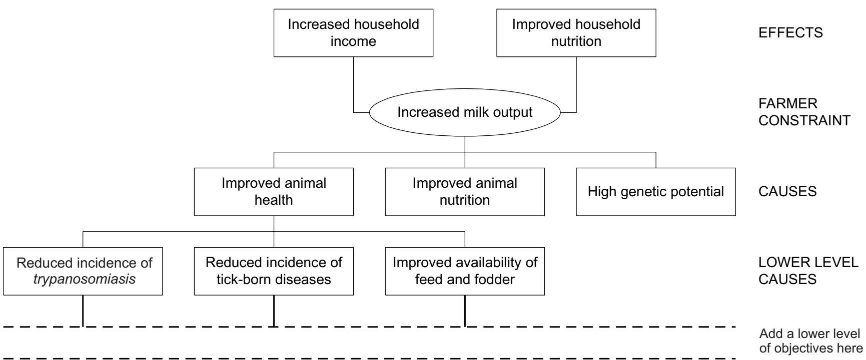
ISNAR. 1997. Research program formulation. ISNAR Training Module. The Hague: International Service for National Agricultural Research.

Exercise 4.1
Formulating Research Themes

1. For the following constraint tree, specify another lower level of causes below trypanosomiasis, tick-born diseases, and lack of feed and fodder. Add these lower level causes to the problem tree below.



2. Transform these new constraints into objectives.



3. Translate these objectives into a set of research activities, then group the activities into themes with specific outputs.

Chapter 5 Methods for Prioritizing Research Options

Bradford Mills and Mercy Kamau

Introduction

The previous two chapters examined procedures for identifying research themes. Priority-setting methods rank the themes. While no single priority-setting method is appropriate for all situations, the best method for a specific case will include the following three characteristics: 1) efficient use of the information available, 2) compatibility with the human resources available in an organization, and 3) result in outputs that are clearly understood by decision makers and used to allocate resources between research themes.

This chapter discusses various priority-setting methods. It has three main objectives:

1. to review the four most common methods for agricultural research priority setting (congruency, benefit/cost, economic surplus, and scoring)
2. to discuss the information and analytical capacity required to implement these methods
3. to demonstrate how each of these methods are used in agricultural research organizations

Computer-based exercises at the end of the chapter give readers practical experience with some of the methods presented.

Congruency

Description

The congruency method ranks research themes according to the value of a single measure. The measure used most often for commodity research priority setting is the value of production. Other measures that can be used are total population and the number of the poor impacted. For example, table 8 ranks four maize research regions based on two different measures: value of

Table 8. Priority Ranking Based on Value of Production and Consumption

Commodity	Value of Production		Value of Consumption	
Maize	**US dollars**	**Rank**	**US dollars**	**Rank**
Region 1	400,000	1	200,000	2
Region 2	300,000	2	500,000	1
Region 3	200,000	3	160,000	3
Region 4	100,000	4	140,000	4
Total	1,000,000		1,000,000	

production and value of consumption. Region 1 receives the highest ranking based on the value of production. When ranked by the value of maize consumption, however, region 2 receives the highest ranking.

Issues

The choice of measure is of paramount importance in using the congruency method. An appropriate measure should be derived logically from research objectives and criteria. The value of production is commonly used as a measure because the most valuable commodity groups often have the largest potential impacts. At the commodity level, the ranking derived from this simple measure will often hold true during the application of more complex benefit-cost and economic surplus analysis, if the potential impact of research does not differ dramatically across commodities. Value of production as an indicator of potential is, however, usually heavily biased towards historically important commodities and against commodities of emerging importance, or with greater potential for technological advances.

On the positive side, the congruency method is simple to apply and very transparent. The method is often effectively used as a "first cut" to reduce the number of research commodities, zones, or themes examined using more rigorous priority-setting methods. An example of the use of congruency analysis to sift out research zones for further evaluation is provided by the KARI horticulture program case study described in chapter eight.

Information requirements

The information required for congruency analysis depends on the measure chosen. Measures like value of production require disaggregated commodity price and production data. Population and poverty measures require population census and household welfare survey data, respectively, as well as a good understanding of the geographic domain of research themes.

Benefit/cost

Description

The benefit/cost priority-setting method is based on a standard economic framework for project analysis. The criteria used in the analysis is the potential economic value (efficiency) generated by each research theme. Benefit/cost analysis is done in three steps. In step 1, the potential for generation and adoption of technologies under each research theme is estimated. In step 2, the stream of economic benefits and costs associated with the research theme is clearly identified for each year on the planning horizon. In step 3, yearly benefits and research costs are discounted to calculate the net present value of each research theme.

Step 1: Estimating research potential

Agricultural research, even adaptive research, is a long-term investment. Moreover, a tremendous amount of uncertainty is associated with a research organization's ability to generate technologies that address client constraints. Even if technologies are successfully generated, further uncertainty exists over the rate at which those technologies will be adopted by clients. Despite this uncertainty, research themes usually have different inherent potentials to address the needs of diverse technology users. Research potential can be divided into two distinct components: technology generation and technology adoption. We discuss these two components separately.

Technology generation, by the nature of the research process, is uncertain and thus is best represented as a distribution of possible outcomes. For individual research themes, outcomes are most commonly conceptualized in terms of yield increases (or avoided yield losses). However, such yield increases often require additional inputs, which lower the effective value of yield gains. Simple commodity budgets can be used to translate gross yield gains and associated additional inputs into minimum, most likely, and maximum net yield gains.

In certain cases, it is appropriate to measure gains over a multiyear time horizon. For example, a new variety or tillage technique may result in significant yield gains under climatic conditions that occur once every four years. However, net gains are slightly lower in the other three years. This technology is more appropriately evaluated based on average net gains over the four-year period.

The potential for technology generation will also vary with the level of resources allocated to the research theme. Usually the current level of program, human, and financial resources is used as the basis for evaluating future outcomes. However, some priority-setting exercises also examine the change in the potential for technology generation associated with higher and lower resource levels.

Box 5.1 illustrates a partial commodity budget that can be used to translate gross yield gains and associated additional input costs into net yield gains. Expected net yield increases can be simply calculated at three levels based on minimum, most likely, and maximum estimated gross yield gains.

Box 5.1. A Partial Commodity Budget

		Minimum	Most Likely	Maximum
a)	Elicited expected gross yield gains (kg)	100	200	300
b)	Current average farm yield (kg/ha)	1000	1000	1000
c)	Commodity price per metric ton (USD)	10	10	10
d)	Elicited additional input costs with technology (USD per metric ton)	1	1	1
e)	Input costs in equivalent commodity weight (kg) [(d/c)*b]	100	100	100
f)	Net yield gain (kg) [a-e]	0	100	200
g)	Expected net yield gains (%) [(f/b)*100]	0	10	20

Further, the resulting estimates can be assumed to represent minimum, most likely, and maximum points on a triangular distribution of net yield gains (figure 12).

A more rigorous definition of what is commonly referred to as the "probability of research success" can also be incorporated into the elicitation

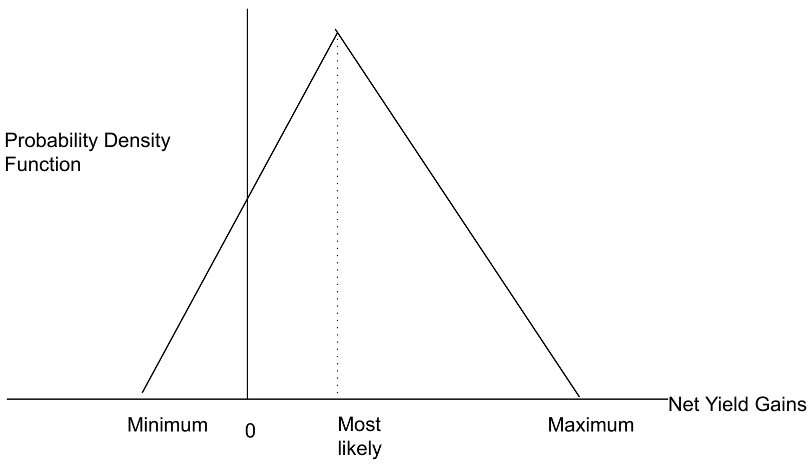


Figure 12. Minimum, most likely, and maximum net yield gains

process in order to account for research outcomes with no possibility for dissemination. Farmers, particularly resource-poor farmers, will adopt technologies only if net yield increases are significantly greater than zero. Where this "threshold level" for adoption lies depends on factors such as farmer perception of technology risk and the additional labor and capital investments associated with the technology. Technologies with net yield gains not exceeding this threshold will not successfully pass through the on-farm testing and evaluation phase of the research cycle, and will not be released for dissemination. The dissemination threshold is defined after reviewing these factors for each major research theme and zone (figure 13).

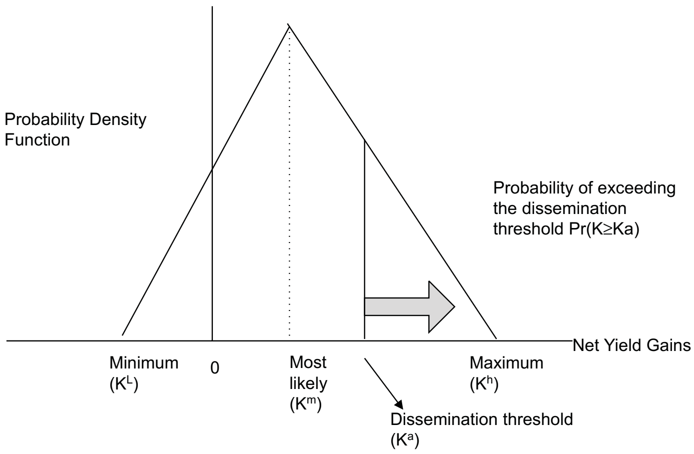


Figure 13. Probability of exceeding the dissemination threshold

The expected percentage net yield gains is then calculated as the product of two parameters derived from the triangular distribution of net yield gains: 1) the probability of exceeding the net yield gain dissemination threshold and 2) the expected net yield increase conditional on the dissemination threshold being exceeded (box 5.2). Formulas for these calculations are given in appendix 5.1 and are also provided in the spreadsheet accompanying exercise 5.2.

Alternatively, many benefit/cost studies directly specify a "probability of successful research" parameter and multiply it by the net yield gain calculated through the partial budget analysis (see Collion and Kissi for a description of factors associated with the probability of success parameter). This approach has the advantage of simplifying the calculation of expected gains while controlling for the fact that not all research efforts result in successful technologies. However, a considerable degree of subjectivity is introduced about what constitutes successful research relative to the definition imposed by the dissemination threshold. Further, when the probability of success is multiplied by the net yield gain, research outcomes with no possibility of occurrence on farmers' fields are given a positive weight. Under either ap-

Box 5.2. Measuring Expected Net Yield Gains

The minimum, most likely, and maximum net yield gains, as well as the dissemination threshold above which the technologies emanating from the research will be released, are specified for one research theme in table 9. The probability of exceeding the dissemination threshold is then calculated (assuming a triangular probability distribution) using the formulas in appendix 5.1. In this case, the parameters suggest there is a 12.5 percent probability that the net yield gains achieved will be sufficient for the technologies under development to be adopted by farmers.

Expected net yield gains, conditional upon exceeding the threshold, are then calculated using the corresponding formula in appendix 5.1. The adjusted net yield gain is simply the product of the probability of dissemination and the conditional expected net yield gain (in this case, 12.5 and 16.5 percent, respectively).

Table 9. Expected Net Yield Gain

Net Yield Gain		
Minimum = 0%	Most likely = 10%	Maximum = 20%

Dissemination Threshold	Probability of Dissemination (calculated)	Conditional Expected Net Yield Gain	Adjusted Net Yield Gain
15%	12.5%	16.5%	2.1%

proach, the concepts employed must be clearly defined in order to logically justify ensuing parameter estimates.

Research impact also depends on the rate and extent of technology adoption (box 5.3). Thus, it is essential to include an assessment of the likely adoption profile in estimates of research potential. Such a profile has some standard characteristics:

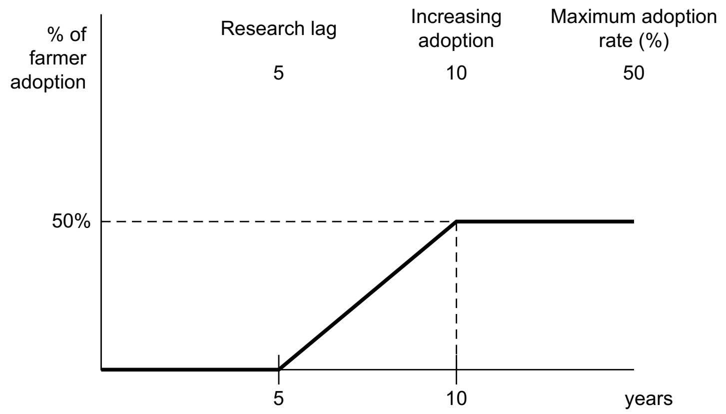
1. a research-development lag, which ends with the release of the new technology
2. an initially increasing adoption rate as growing numbers of farmers become exposed to the technology
3. an adoption plateau where most target-group farmers have been exposed to the technology and have decided whether or not to adopt
4. a declining adoption rate as the technology becomes obsolete and is abandoned by farmers.

Combined, these characteristics determine the speed and frequency with which research results are adopted by farmers in their fields (or into the production procedures of other clients). Note that adoption profile parameters also depend on the magnitude of the net yield gain embodied in the technology being disseminated. Expected net yield gains, conditional on the dissemination threshold being exceeded, are usually an appropriate benchmark for estimating potential adoption profiles.

No conceptual framework can fully capture the complexities of technology generation and adoption. In this respect, two valid concerns with the framework described in boxes 5.2 and 5.3 should be noted. First, net yield gains often do not fully capture the direct impacts of agricultural technologies. For example, research on soil and water management techniques has a primary impact on the soil base, and a secondary impact through the soil base on commodity yield gains. This indirect impact may even be spread over a number of commodities. Hence, care must be taken in representing the im-

Box 5.3. Estimating the Adoption Profile

A linear approximation of the first three components of a basic adoption profile is presented in figure 14. No adoption occurs in the five-year research lag, during which time the technology is under development. The estimated rate of adoption is then zero. During the phase of increasing adoption, the rate of adoption increases by 10 percent per year between year five and year 10. Finally, at year 10 most potential users have been exposed to the technology and have opted to adopt or not to adopt. The rate of adoption levels out at 50 percent for years 10 through 15. No disadoption phase is included in the example profile. Either the technology is not expected to become obsolete during the period under evaluation or the technology is expected to be replaced by another that embodies the technological gains made through the research theme under evaluation. If the technology is expected to become obsolete rapidly, the disadoption phase should also be modeled as a decreasing percentage of clients using the technology over time.



	Year 1	2	3	4	5	6	7	8	9	10	11-15
Yearly adoption rate (%)	0	0	0	0	0	10	20	30	40	50	50

Figure 14. Linear approximation of a basic adoption profile

pacts of non-commodity-based research in terms of net yield gains. On the other hand, if no impacts from an intervention can be linked to increased profitability of agricultural production, then serious doubt must be raised as to whether such technologies would ever be adopted by farmers. Chapter 10 presents an example of estimates of research impacts for a soil fertility research program that must aggregate its impact over multiple communities.

The second concern relates to the accuracy of information provided on the potential for technology generation. As with any forecast, a degree of uncertainty exists. Designers of the priority-setting process must decide if the information provided (even with its associated errors) is more useful for resource allocation decisions than the alternative assumption that all research themes have similar potentials. (This is essentially the assumption made in the congruency method.)

The most knowledgeable information sources for estimating technology generation and adoption parameters are often program experts with vested interests in the outcomes of the priority-setting exercise. Priority-setting procedures can attempt to control for the bias inherent in these subjective estimates of interested parties through three steps. First, the program coordinator and socioeconomist can collect benchmark information on historical yield and production growth trends in the target zones, along with available information on yield gains and adoption of previously released technologies. This benchmark information then serves as a reference point when examining the ex ante potential for technology generation and adoption. Second, the priority-setting working group reviews the potential research impact of addressing these constraints through a structured elicitation process. The group controls potential bias to some extent. If an individual scientist behaves too strategically, the rest of the group (with other vested interests), will challenge the information being provided and develop a consensus on more realistic assumptions. Finally, the working group should present its assumptions on the potential for generation and adoption of technologies to a larger group of research stakeholders, including representatives of input and processing industries, as well as farmers, for review and in some cases modification. The process of client review serves as a further check on unrealistic assumptions.

Step 2. Identifying the economic benefits and costs

In step two, information on the potential for technology generation and adoption is combined with value of production information to generate estimates of yearly research benefits. The potential for technology generation is represented as the expected percentage net yield gain (accounting for additional inputs) associated with the research theme: (K). However, this net gain will only manifest when the technology is adopted by the intended user group. The rate of adoption varies over time and is represented for period *t* as A_t. The total percentage shift in quantity due to a research theme is simply represented by $k_t = A_t * K$ (figure 15). Accompanying research benefits are represented by price (P) times the net change in commodity production due to research $B_t = Pk_tQ_0$.

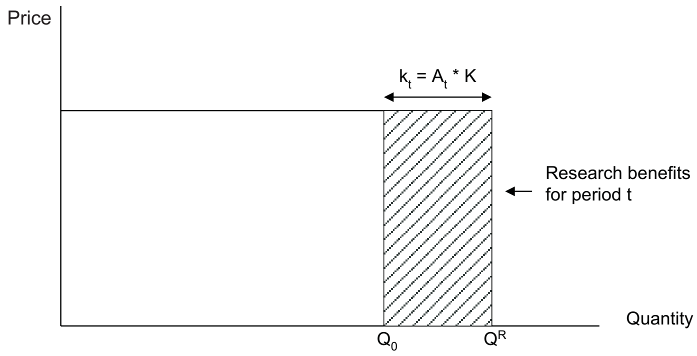


Figure 15. Research benefits in period *t*

Research benefits can be calculated for each year in this simple fashion. The example in table 10 calculates benefits over 15 years for a simple commodity, based on the technology generation and adoption parameters specified in figures 13 and 14, a production base of 1000 metric tons, and a price of US $10.00 per metric ton.

Significant costs in both human and financial resources are associated with technology development, particularly during the research lag period. Often, scientists are the major expenditure in developing-country agricultural research programs. Therefore, full-time-equivalent researcher years can be used as the basis for comparing per-unit benefits of research themes. An example is given in table 11.

Step 3. Discounting yearly benefits and costs

Table 12 presents the net present value for the research theme in the example. First undiscounted costs are subtracted from undiscounted benefits in each

Table 10. Research Benefits for 15 Years

	Year														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
a) Expected net yield gain (%)	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
b) Period rate of adoption (%)	0	0	0	0	0	10	20	30	40	50	50	50	50	50	50
c) Price (USD/MT)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
d) Base production (MT)	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
e) Total benefits (a*b*c*d)	0	0	0	0	0	21	42	63	84	105	105	105	105	105	105

Note: MT = metric ton.

Table 11. Research Costs over 15 Years

	Year														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Number of full-time-equivalent researchers	2	2	2	2	2	1	1	5	5	0	0	0	0	0	0
Unit cost of a full-time-equivalent researcher	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Estimated cost of research	20	20	20	20	20	10	10	5	5	0	0	0	0	0	0

year to give undiscounted net benefits. The net present value of benefits are then calculated for each period based on the following formula:

$$NPV_t \frac{NetBenefits(t)}{\left(1+r\right)^t}$$

where r is the real rate of interest. In the example, five percent is used as the rate of interest based on the interest rate on government loans to support agricultural research. Finally, a net present value for the whole period can be calculated by summing the period-specific net present values. In the example, this sum equals US $397.00. Alternatively, an internal rate of return can be calculated to determine the rate of interest at which the stream of benefits would equal the stream of costs. In our example, the rate of return of the theme is estimated at 29.8 percent per annum.

Issues

Benefit/cost analysis provides a measure of the economic (efficiency) benefits associated with research themes. Trade-offs in efficiency benefits across areas and groups within a population can also be explored within the framework. However, some research managers feel that the benefit/cost framework focuses too narrowly on measurable economic benefits. It is important to note that benefit/cost estimates only provide information which, in turn,

Table 12. Present Value of Net Agricultural Research Benefits with a Five Percent Discount Rate over 15 Years

	Year														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**1**	**12**	**13**	**14**	**15**
Undiscounted benefits	0	0	0	0	0	21	42	63	84	105	105	105	105	105	105
Undiscounted costs	20	20	20	20	20	10	10	5	5	0	0	0	0	0	0
Undiscounted net benefits	-20	-20	-20	-20	-20	11	32	58	79	105	105	105	105	105	105
Discounted benefits	-20	-19	-18	-17	-16	9	24	41	53	68	64	61	58	56	53

Note: The sum of discounted net benefits is US $397. The internal rate of return is 29.8%.

can be used for improving resource allocation decisions. The method can also be combined with other criteria in a multiple-criteria priority-setting model or simply used to supplement decision makers' informal judgments on research priorities.

A second concern is that agricultural research takes place in a dynamic environment. The simple benefit/cost framework presented above can be modified to account for other important changes impinging on specific commodities (e.g., increased demand due to population growth). No model, however, can effectively capture the complexity of commodity-sector growth over a 15- to 30-year time horizon. Benefit/cost analysis does provide a consistent analytical framework for measuring research impact. Application of the method forces a priority-setting working group to formally state implicit assumptions on the potential of research themes for technology generation and adoption and to explore the impact associated with those assumptions. The process, rather than the numbers that result, is sometimes the most valuable benefit of the exercise.

Information requirements

To apply the benefit/cost method, basic data on the value of commodity production (quantity and price) is required. Assessments of the potential for technology generation (net yield gains) and adoption profiles are also needed. A significant investment must be made in the collection and processing of this information. However, modern spreadsheets, like the one accompanying exercise 5.1, have reduced the computational burdens associated with benefit/cost calculations.

Economic surplus

Description

The economic surplus method is simply a refinement of benefit/cost analysis. Like the benefit/cost method, economic surplus measures the economic (efficiency) benefits associated with research themes. However, in line with the economic theory, economic surplus measures allow for price response to research-induced shifts in the quantity of commodity production and the apportionment of research benefits between producers and consumers, as well as other target groups.

Price response to research-induced quantity shifts

Benefit/cost analysis assumes that producers will supply the same amount of a commodity at every price. This is shown in figure 15, where the supply curve is vertical and is shifted rightward by research. However, economic studies show positive commodity supply responses to price increases. Figure 16 presents a linear supply curve depicting a positive price-quantity relationship. Further, the research-induced shift in the supply curve is assumed to be parallel, which is equivalent to assuming the quantity shift is of similar absolute magnitude at all potential prices. As with benefit/cost analysis, for a

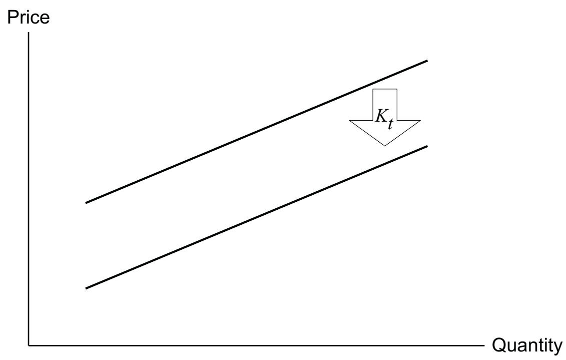


Figure 16. Research-induced supply shift with positive supply response

given price the period-specific research-induced change in quantity equals the product of the expected net yield gain and the period-specific rate of adoption. This quantity shift can then be translated into an absolute per-unit cost reduction (k_t) along the price axis by multiplying the period-specific expected percentage change in quantity (KA_t) times the initial price (P_0) and dividing by the supply elasticity ε:

$$k_t = KA_tP_0/\varepsilon.$$

The supply elasticity is simply a measure of the expected percentage change in quantity supplied associated with a percentage change in price.

Many countries already have empirical estimates of supply response for major commodities. These estimates usually range between 0.3 and 1.0. In the absence of empirical estimates, a supply elasticity of 0.5 is commonly used as an approximation.

Apportioning research benefits between producers and consumers

Research benefits corresponding to a research-induced supply shift are more difficult to measure for economic surplus than for benefit/cost analysis. Basic producer and consumer gains are illustrated in figure 17. The demand curve is downward sloping because less of the commodity is purchased at higher prices. The demand elasticity (percentage change in quantity over percentage change in price) is, therefore, negative. If no empirical estimate is available of the change in the quantity of demand associated with a change in price, a -0.5 demand elasticity is used as an approximation. Figure 17 maps consumer surplus gains from a research-induced supply shift from S to S'. At the original price and quantity, consumers receive area A in benefits (the total area under the demand curve and above the price paid). A commodity supply shift then results in a decrease in equilibrium price from P^o to P^R. Consumers now receive welfare benefits equal to area ABCD. Thus, the net consumer surplus gain is the area BCD.

The impact of the research-induced supply shift on producer surplus is more complex. Originally, producer surplus is represented by the area EB

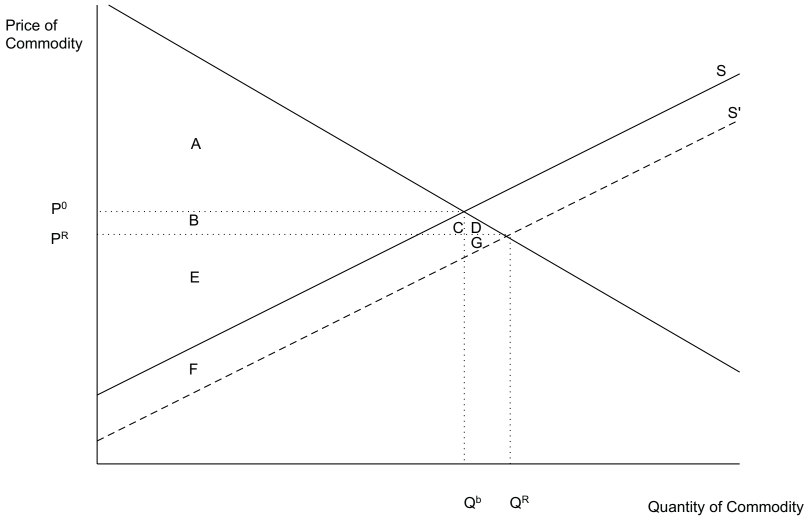


Figure 17. Economic surplus measures in a closed economy

(the area below the commodity price but above the supply curve). After the supply shift, producer surplus equals the area FEG. Thus, the change in producer surplus is determined by two factors: gains from the unit cost reduction in production (area FG) and the decrease in equilibrium price (area B). Producer welfare may either increase or decrease when confronted with a technical innovation, depending on the relative magnitude of the two effects. However, society as a whole, (the aggregation of consumer and producer surplus changes) unambiguously gains area CDFG.

In practice, research-induced changes in producer and consumer surpluses with linear supply and demand curves are easily measured with the following formulas on a spreadsheet:

$$\Delta PS_t = (K_t - Z_t)\, P^0 Q^0 (1 + 0.5 Z_t \eta)$$

and

$$\Delta CS_t = P^0 Q^0 Z_t\, (1 + 0.5 Z_t \eta)$$

where $Z_t = K_t\, \varepsilon/(\varepsilon+\eta)$ is the reduction in price, relative to the initial value, due to the supply shift.

In an open economy, the demand curve is flat and research benefits only accrue to producers. Further, the producer surplus measure reduces to $\Delta PS_t = K_t P^0 Q^0 (1+0.5 K_t \varepsilon)$. The net present value of economic surplus benefits is calculated in the same manner as discussed for steps two and three in the benefit/cost section.

Issues

Economic surplus estimates are less transparent to noneconomists than benefit/cost estimates. There is also a tendency on the part of individuals participating in the research decision-making process to attribute results to the economic model and not to the data and assumptions on technology generation and adoption underlying the model. Application of economic surplus methods, therefore, requires a well developed socioeconomic research capacity. This is not only to apply the method, but also to translate concepts and results for discussion by noneconomists. A number of computer spreadsheet applications are available, like the one in exercise 5.1, that can greatly reduce the costs of implementing economic surplus analysis.

Information requirements

Economic surplus methods require the same basic information as benefit/cost analysis. However, knowledge of producer and consumer responses to price changes (elasticities) are also needed. If significant trade occurs across regions, separate information on regional consumption may also be required, as well as information on the costs of moving commodities between regions.

Further extensions

A major advantage of economic surplus is its ability to incorporate other concurrent changes in the commodity system into the evaluation framework (e.g., population growth, income changes, area expansion, research spillovers from other regions, and changes in external and internal trade policies). A thorough review of economic surplus methods and possible extensions for research priority setting is provided in *Science Under Scarcity* by Alston, Norton, and Pardey (1995).

Scoring

Description

Chapter two discussed the criteria that are commonly used in agricultural research priority setting (efficiency, equity, sustainability, food security, food self-sufficiency, and foreign exchange). Benefit/cost and economic surplus methods focus exclusively on the measurement of a single criterion: efficiency. These methods suggest that equity and food-security criteria are best viewed as a direct trade-off with efficiency. A further premise is that this trade-off can be explored by analyzing the change in benefits associated with the reallocation of research resources to different target groups or areas. Such trade-offs, however, are difficult to quantify, and many research organizations do not wish to invest the time and staff necessary. Scoring models are a shortcut approach for incorporating multiple criteria in the evaluation of research alternatives.

The credibility of a scoring model is largely determined by how rigorous ranking criteria are defined and measured. For example, carefully measured economic efficiency scores (derived from benefit/cost or economic surplus analysis) can be combined with carefully defined and measured equity criteria. Unfortunately, some scoring exercises are undertaken as a substitute for systematic investment in information and analysis. The results may then be useful for building a consensus within a given group of decision makers. But they may possess little external credibility.

The scoring model is implemented in three basic steps. First, decisions are made on the weight to be given to each evaluation criteria. Second, standard measures of the contribution of each research theme to each criteria are elicited. Third, criteria weights and measures are combined to arrive at an overall "score" for each research theme.

Step 1. Criteria weights

Once the criteria most important for evaluating research themes have been decided, each criteria is weighted in terms of its importance in the overall evaluation. The process of agreeing on criteria weights was discussed in chapter two. A simple example is in box 5.4.

Box 5.4. Weighting Criteria

A research organization chooses efficiency, equity, and sustainability as its base criteria for evaluating three research themes in a priority-setting exercise. The organization must decide what weights to give each criterion, such that the total weight allocated across all criteria equals 100 percent.

One possible distribution of criteria weights is as follows:

	Efficiency	**Equity**	**Sustainability**
Weight (%)	60	20	20

Step 2. Measures

After the criteria are weighted, a standardized measure of the contribution of each research theme to each criteria must be elicited. Measures are usually standardized on a scale of one to five, with one representing the lowest (perhaps negative) contribution (box 5.5). Standardized measures of criteria are often based on the subjective assessment of priority-setting working groups or larger stakeholder groups. The credibility of these measures can be greatly increased if criteria are clearly defined in terms of target groups. Measures should then be justified based on judgments of a research theme's ability to positively impact the target groups defined by the criteria.

For example, the contribution of alternative research themes to the food security criterion can be subjectively assessed as a standardized measure on a one to five scale. The quality of the assessment is greatly enhanced if the groups targeted by the criterion are clearly defined along with a measure of the expected contribution of research themes to it. The group targeted by the food security criterion may be farm households in marginal environments

Box 5.5. Standardizing Estimates of Benefits

Efficiency benefits associated with benefit/cost or economic surplus measures can be easily standardized on a one to five scale as demonstrated in table 13. The first row of the table shows the expected discounted net benefits from research themes A through D. Research theme A shows the smallest net potential benefits and is given the lowest standardized measure, 1. Correspondingly, alternative C is at the top of the scale and given the highest standardized measure, 5. Alternatives B and D are then given measures based on the quintile within which they fall on a span from 100 to 600.

Table 13. Standardizing Estimates of Net Research Benefits

	A	**B**	**C**	**D**
Discounted net benefit	100	260	600	420
Standardized measure	1	2	5	4

Quintile are as follows: 100-200 = 1; 200-300 = 2; 300-400 = 3; 400-500 = 4; 500-600 = 5. A, B, C, and D are research themes.

with high transportation costs for importing food from higher potential regions. An appropriate measure of the contribution of research to the welfare of this target group might be a decreased incidence of shortfall in the commodity due to increased local production.

Step 3. Criteria-weighted scores

Finally, criteria weights and measures are combined to create an overall score for each research theme. The score is simply the criteria-weighted average of all measures:

$$\text{Score} = \sum_{i}^{1} W_i M_i$$

where W_i equals the weight of criterion i and M_i equals the measure of criterion i (box 5.6).

Issues

Scoring models are relatively transparent and can be effectively used to foster a dialogue on the weight associated with alternative objectives of agricultural research. A major question to be asked in designing a priority-setting process that includes a scoring model is what investment will be made in formally measuring the contribution of research themes to each specific criterion. At a minimum, target groups for each criterion must be clearly

Box 5.6. Calculating Scores for Research Themes

Table 14 calculates scores for four research themes based on measures of efficiency, equity, and sustainability criteria.

Table 14. Calculated Scores for Research Themes A, B, C, and D Based on Weighted Criteria

	Efficiency	**Equity**	**Sustainability**	**Total**
Weight (%)	60	20	20	100
Theme				**Calculated Score**
A	1	4	2	1.8
B	2	3	2	2.2
C	5	1	2	3.6
D	4	5	2	3.8

identified, along with measures that discriminate the potential benefits provided to those target groups.

Summary

Readers seeking a definitive recommendation on the most appropriate method for agricultural research priority setting may be disappointed, since choice of methods depends on a number of factors. These include availability of data, analytical capacity, demand for rigor, and need for consensus. Further, poor implementation of a relatively rigorous method, like economic surplus, may result in a less credible exercise than a carefully constructed scoring model. Again, method is often far less important to the efficiency of the priority-setting process than the time and resources spent clearly defining the research themes to be ranked. Table 15 summarizes the inputs, process, and outputs for the two major classifications of priority-setting methods: benefit/cost or economic surplus and scoring. A final judgment on what is the most appropriate method should arise through hands-on experience with the methods and a review of the information available.

Reference

Alston, J., G. Norton, and P. Pardey. 1995. Science under Scarcity: Principles and practices for agricultural research evaluation and priority setting. Ithaca, N.Y.: Cornell University Press.

Table 15. Inputs, Process, and Outputs of Priority-Setting Methods

Method	Inputs	Process	Outputs
Benefit/cost and economic surplus	• **Information.** Evaluation of potential for technology generation and adoption; price and production statistics; supply and demand elasticities • **Human Resources.** Socioeconomist	• Rigorous • Analysis of economic benefits may not be transparent to all participants	• Ranking of research themes by economic benefits • Learning about the environment and key parameters for research impact
Scoring	• **Information.** Research objectives, criteria, and criteria measures; other information depending on the analysis associated with criteria measures • **Human Resources.** Depends on the analysis associated with the chosen measures	• Transparent • Potential lack of rigor	• Ranking of research themes by score

Exercise 5.1
Partial Commodity Budgets

In this exercise we calculate net expected yield gains. Begin by copying the file PS-Exer.xls from the diskette enclosed in this book to a subdirectory on the computer where you will work. Then open PS-Exer.xls in Excel.

1. Go to sheet EXERCISE 5.1. Review the formulas for the partial commodity budget under theme 1. Do they correspond to the formulas presented in box 5.1? Are the results similar?
2. Go to the partial commodity budget for theme 2 (line 14) on the same sheet. The minimum, most likely, and maximum elicited gross yield gains (row 16) are initially set to zero. Change the minimum, most likely, and maximum parameter estimates to -150, 150, and 400 kg, respectively. What are the new minimum, most likely, and maximum net yield gain estimates for theme 2?
3. Finally, go to theme 3 on the sheet. Enter the same gross yield gain estimates as for theme 2. The elicited additional input costs per metric ton (line 30) are now set to zero. Change these expected input costs to 2 USD per metric ton for the minimum, most likely, and maximum scenarios. What are the new expected net yield gains for the theme? How do these gains compare with gains in theme 1 where input costs are 1 USD?

Exercise 5.2
Adjusting Net Yield Gains

In this exercise we assume net yield gains have a triangular distribution and adjust them for the probability of exceeding the dissemination threshold using the formula in appendix 5.1. Unadjusted minimum, most likely, and maximum net yield gain estimates for the three themes examined are taken from the results in exercise 5.1.

1. Open the Excel file PS-Exer.xls and go to sheet EXERCISE 5.2. The minimum, most likely, and maximum estimated net yield gains in columns B, C, and D, respectively, are taken from exercise 5.1 results for themes 1 to 3. The dissemination threshold for theme 1 (cell E10) is estimated based on the factors discussed in this chapter. For theme 1, the dissemination threshold is set at 15 percent. Note that the dissemination threshold cannot be set outside the range of minimum to maximum net yield gains. In this case, the threshold cannot be set below zero or above 20 percent.
2. The probability of exceeding the dissemination threshold is calculated (based on the formula in appendix 5.1) at 12.5 percent. Similarly, the calculated net yield gain, conditional on the dissemination threshold being exceeded is calculated as 16.5 percent in cell G10. The adjusted net yield gain, cell H10, is simply the product of these two calculations, in this case, 2.1 percent.

   How does the adjusted net yield gain compare with the unadjusted most likely net yield gain? What does this difference imply about the importance of controlling for research outcomes with no possibility of dissemination?
3. For theme 2, the dissemination threshold is initially set at zero. If risk and additional input costs associated with the technology are low, five percent net yield gains might be sufficient for dissemination. Setting the dissemination threshold at five percent, what is the new adjusted net yield gain?
4. By contrast, theme 3 requires significant investment in additional inputs. Thus, a 15 percent net yield gain is required for dissemination. Enter this threshold estimate in column E. What is the new adjusted net yield gain for the theme? Why is it so low?

Exercise 5.3
Estimating the Technology Adoption Profile

Open the file PS-Exer.xls and go to sheet EXERCISE 5.3.

1. For theme 1, five adoption profile parameters have been entered on row 8. Like the example in box 5.3, the research lag is specified as five years, increasing adoption is specified to occur between five and 10 years. However, no disadoption is expected to occur for technologies associated with the theme, so “na” (not applicable) is entered in columns D and E. Finally, 50 percent of farmers growing the commodity are expected to adopt the technology.

   Below on the left-hand side are the calculated duration of adoption phases and period-specific adoption rates. A graph of the adoption profile is produced below on the right-hand side. Notice that the period-specific adoption rate is zero during the research lag and then increases steadily to 50 percent from year five to year 10. The adoption rate then stays at 50 percent over the remainder of the horizon since no disadoption is specified to occur.
2. For theme 2, starting on row 32, assume the technology will become obsolete five years after full adoption (in year 15) and be completely abandoned three years later (in year 18). Replace the current “na” parameters values in theme 2 with these values. How does the adoption profile differ from the profile in theme 1?
3. Find the adoption profile parameters for theme 3 based on the following information. The technologies associated with research theme 3 already exist and only need to be tailored to specific client needs. Thus, the research lag is two years. However, it still takes eight years from the release of the technology until full adoption is realized by 40 percent of farmers in the target zone. After another eight years (year 18), the technology becomes obsolete and farmers begin to abandon it. The technology is completely abandoned after an additional five years.

Exercise 5.4
Benefit/Cost Analysis

In this exercise the technology generation and adoption parameters developed in exercises 5.2 and 5.3 are used to estimate total research benefits as well as benefits per scientist for the three research themes.

1. Open the spreadsheet file PS-Exer.xls and go to the sheet EXERCISE 5.4. The sheet contains the formulas necessary to calculate research benefits for the three themes. The model for theme 1 starts on line 3. The models for themes 2 and 3 start on lines 49 and 95, respectively. A five percent discount rate is used in all calculations. This can be changed in the net present value formula (e.g., cell E3 for theme 1).

   Notice that the technology generation and adoption parameters developed for theme 1 have been re-entered on line 10. These parameters are used in columns B to H on lines 16 to 45 to calculate research benefits over a 30-year time horizon. Also notice that since no disadoption of the technology is expected, the maximum adoption rate is used in benefit calculations from year 11 to year 30. Finally, in cell H3 two full-time-equivalent scientists have been devoted to the theme, yielding US $495 in benefits per scientist. What would be the benefits per scientist if three full-time-equivalent scientists were devoted to the theme?
2. Go to theme 2 on line 49. Enter the technology generation and adoption parameter estimates developed for theme 2 in exercises 5.2 and 5.3. What is the expected net present value of theme 2? How do per-scientist benefits for theme 2 compare with those of theme 1 if five full-time-equivalent scientists are required?
3. Again, for theme 3 enter the technology generation and adoption parameters developed in exercises 5.2 and 5.3. However, increase the commodity base (quantity) over which research benefits accrue from 1000 metric tons to 5000 metric tons. What are the full-time-equivalent benefits per scientist if only one scientist is employed on the theme? How do these benefits compare with per-scientist benefits under theme 1 and theme 2? Explain the difference.

Exercise 5.5
Estimating Changes in Economic Surpluses

In this exercise we calculate producer and consumer surplus benefits for our three research themes.

1. Open the file PS-Exer.xls and go to the sheet EXERCISE 5.5. The model for calculation of economic surplus gains under theme 1 begins on line 4 of the sheet. The model for theme 2 begins on line 61 and the model for theme 3 begins on line 118.

   For theme 1, the technology generation and adoption parameters developed in exercises 5.2 and 5.3 are entered in columns D to I on line 15. The only new pieces of information entered on the spreadsheet are the demand and supply elasticities in cells A12 and B12, respectively. These estimates are based on previous empirical work on the demand and supply responsiveness of cereal commodities. Demand elasticities are negative, but are expressed as an absolute value. Total expected benefits from the theme are calculated in cell F6. The consumer and producer shares of total benefits are calculated in cells G6 and H6, respectively. Benefits per full-time-equivalent scientist are calculated on line 9 for the respective columns. How do total benefits compare with those calculated for theme 1 in the benefit/cost model (exercise 5.4)? What share of benefits are received by consumers and what share accrues to producers? Is this benefit ratio related to the ratio of the demand and supply elasticities?
2. For theme 2 enter the relevant technology generation and technology adoption benefit estimates. Again, how do these benefit estimates compare with those generated in the benefit/cost exercise?
3. Assume the commodity addressed by theme 3 is one that is freely traded on the world market (e.g., wheat). Then the quantity demanded in the country will have negligible impact on the price. Equivalently, the country's demand elasticity for the commodity will be extremely large. (A totally flat demand curve with respect to price has an infinite negative demand elasticity). In cell A126 is entered an absolute value of the demand elasticity of 99,999. How are benefits distributed between consumers and producers? How do these results compare with those from the benefit/cost exercise 5.4?

Exercise 5.6
A Three-Criteria Scoring Model

We conclude the exercises in this section by ranking the three themes with a simple scoring model.

1. Open file PS-Exer.xls and go to the sheet EXERCISE 5.6. In the worksheet, each theme is scored based on three criteria: efficiency, equity, and sustainability. Initially, efficiency is given 50 percent of the total weight, equity is given 30 percent of the total weight, and sustainability is given 20 percent of the total weight (line 13). Remember all weights must sum to 100 percent and be the same for each theme under comparison.

   Each criteria must now be given a standardized score of between 0 (lowest) and 5 (highest). For the efficiency criterion we will base this score on the per-researcher benefit estimates developed for each theme in exercise 5.4. Per-researcher benefits for theme 1 have already been entered in cell B8. Enter the appropriate benefit estimates for themes 2 and 3 in cells F8 and G8, respectively.

   Notice how the efficiency criteria scores on line 10 are automatically calculated based on the range of benefit estimates.

   Initial scores for the equity and sustainability criteria have also been entered for each theme. Notice that for the sustainability criterion all themes have received a score of 2. What does this imply about our ability to discriminate between contributions by the three themes to sustainability?

   Finally, on line 15 are the final weighted scores for each theme. How would you rank the themes based on these scores?
2. What if sustainability were now given a score of 5 for theme 1?
3. Returning to the initial scores, how would you rank the themes if the criteria weightings for efficiency, equity, and sustainability were 70, 30, and 0, respectively? (If criteria weights are changed for theme 1, they are automatically updated for themes 2 and 3).

Appendix 5.1. Formulas for Calculating the Probability of Dissemination and Conditional Expected Net Yield Gain

For a triangular probability density, function the cumulative probability of producing an innovation with a net yield gain above k_a is the following:

$$\Pr\left(k \geq k_a\right) = 1 - \frac{\left(k_a - k_l\right)^2}{\left(k_h - k_l\right)\left(k_m - k_l\right)} \quad \textit{if} \quad k_l \leq k_a < k_m \quad \textit{and}$$

$$\Pr\left(k \geq k_a\right) = \frac{\left(k_h - k_a\right)^2}{\left(k_h - k_l\right)\left(k_h - k_m\right)} \quad \textit{if} \quad k_m \leq k_a < k_h.$$

The expected net yield gain, E[k], given that the threshold value for dissemination is reached, can be evaluated from the integrated conditional probability density function as follows:

$$\mathrm{E}\left[k \middle| k \geq k_a\right] = \frac{\left(\frac{2}{\left(k_h - k_1\right)\left(k_m - k_1\right)}\right)\left(\frac{1}{3}k_m^3 - \frac{1}{2}k_m^2 k_1 - \frac{1}{3}k_a^3 + \frac{1}{2}k_a^2 k_1\right) + \left(\frac{2}{\left(k_h - k_1\right)\left(k_h - k_m\right)}\right)\left(\frac{1}{6}k_h^2 - \frac{1}{2}k_m k_h + \frac{1}{3}k_m^3\right)}{\frac{1}{\left(k_h - k_1\right)\left(k_m k_1\right)}\left(k_m^2 - k_a^2\right) + \frac{1}{\left(k_h - k_1\right)\left(k_h - k_m\right)}\left(k_m^2 - k_h^2\right)}$$

for $k_l \leq k_a < k_m$ and

$$\mathrm{E} = \left[k \middle| k \geq k_a\right] = \frac{\left(\frac{1}{3}k_h^3 - k_a^2 k_a + \frac{2}{3}k_a^3\right)}{k_a^2 - k_h^2}$$

for $k_m \leq k_a < k_h$.

Chapter 6
Data Requirements for Agricultural Research Priority Setting

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Introduction

Regardless of the method employed, all priority-setting exercises can be greatly improved by systematic investments in information bases. Agricultural statistics provide a particularly rich source of information for agricultural research planning and priority setting. The production of a commodity is a good indicator of its relative importance. Similarly, prices reflect the relative scarcity of a commodity (or input) in the broader economy. Analysis of data over time can reveal production, area, and yield trends. These are important indicators of change in the agricultural sector and, possibly, of contributions of previous agricultural research investments to growth. Finally, consumption data provides an indication of the relative importance of a commodity to households and industries.

Data on commodity production, price, and consumption are available in most sub-Saharan African countries. However, these potentially important sources of information are often under-exploited for two reasons. First, agricultural research organizations sometimes have limited knowledge of, or access to, agricultural statistical data. Second, research organizations in many countries question the quality of the data available. This chapter examines the potential use of agricultural statistics for research priority setting. It focuses on three important issues for analysts interested in incorporating agricultural statistics into research priority-setting efforts:

1. What are major sources of agricultural statistics in the country and how can the quality of these datasets be assessed?

2. What statistical data is needed, or useful, for agricultural research priority setting?
3. Who should be responsible for the collection and management of statistical data?

Examples from KARI are presented, and the exercise at the end of the chapter gives readers hands-on experience with basic spreadsheet techniques for data management.

Sources of agricultural statistical data

Agricultural research organizations usually do not have a national mandate to collect agricultural production, consumption, and price statistics. That mandate is held by either, or both, the ministry of agriculture and the ministry of planning, as well as the central bureau of statistics if it is located outside the ministry of planning. Ministries of agriculture and planning usually collect district-level production and price data. The central bureau of statistics may also collect production and price data, and conduct an agricultural census every five to 10 years with detailed statistics on farm enterprises. Further, the statistics bureau may conduct a disaggregated census of the population and surveys of household consumption of basic goods. Table 16 shows an example of the agricultural statistics available for Kenya by source and type of information.

A small group of individuals are usually involved in the compilation and analysis of a country's agricultural statistics. Within this group, exchange of data often takes place on a person-to-person basis, rather than as formal exchanges between institutes. A research organization needs to de-

Table 16. Agricultural Statistics in Kenya

Source	Type
Ministry of Agriculture	• District-level production, area, and yield estimates for all commodities • Major retail market prices for important commodities
Ministry of Planning and Central Bureau of Statistics	• District-level production, area, and yield estimates for beans, maize, millet, and sorghum • Retail prices for maize, millet, and sorghum in numerous rural markets • Agricultural census on farm household characteristics • Population census
Department of Resource Surveys and Remote Sensing	• Maize and wheat district-level area and production estimates using aerial photography, radiometric techniques, and ground truthing

velop strong contacts with this network, not only to gain access to statistical data, but also to develop an informed assessment of the quality of datasets available. At least one individual in the organization should be specifically mandated to maintain these contacts. However, only through actual analysis can practitioners develop a deeper understanding of the strengths and weaknesses of specific datasets.

Agricultural statistical data for priority setting

More data is not always better. Quantitative data requirements for research priority setting must be carefully defined, since the cost of processing and analyzing data can be very high. This section identifies the core, as well as optional data required for agricultural research priority setting.

Production statistics

Agricultural production statistics are essential for rigorous priority setting, particularly in commodity research programs. A program that does not know the relative magnitude of production in its research target zones will find it difficult to effectively target its resources. Target-zone production estimates are usually imputed from district-level production estimates (box 6.1). Since these estimates often show high inter-year variation, they should be averaged over the most recent three years for which data is available. District-level production is then allocated to zones based on the relative proportion of total district area in each zone. If more disaggregated production estimates are available (e.g., five km square grids from remote sensing data), more refined methods can be used to impute research zone production.

Area and production data can be used to generate several other useful pieces of information. For example, average yields provide a useful indicator of the yield gap between farm and experiment station production. Growth trends can also be calculated if district-level production and area data is available for the past 10 or more years (box 6.2). Such trends are useful for determining whether observed production increases are due to area expansion (extensification) or yield increases (intensification).

Growth rates should, however, be used with caution as a proxy for past research impact. Rarely would no growth have occurred without research. Other shifts in labor, chemical inputs, land quality, or pests and pathogens may have occurred.

Consumption statistics

Information on commodity consumption is required if analysts wish to identify research benefits accruing to consumers (due to research-induced price decreases), as well as to producers. Yearly consumption is almost never directly monitored. Rather, it is imputed from household consumption surveys and census information on the number of households per district. Once district-level consumption is established, research-zone commodity consump-

Box 6.1. Imputing Research Target Zone Area and Production from District-Level Estimates

Estimates of production in each research target zone can be easily imputed from district-level area and production estimates. In the example below, area and production estimates are given for three districts in columns two and three of table 17, respectively. The percentage of each district lying in research target zones A, B, and C is then given in columns three to five.

Imputed area in target zone A is simply calculated as the sum of the product of each district area estimate and the percentage of the district area in the target zone A (i.e. (100*50 + 150*20 + 250*40)/100). Similarly, target zone production is imputed as the sum of the product of each district production estimate and the percentage of the district area in the target zone.

Table 17. Imputing Research Target Zone Area and Production from District-Level Estimates

			Target zone			
District	**Area estimate**	**Production estimate**	**A**	**B**	**C**	**Total (%)**
1	100	200	50	40	10	100
2	150	400	20	60	20	100
3	250	300	40	50	10	100
Target zone						
Estimated area			180	255	65	
Estimated production			300	470	130	

tion can be imputed with methods similar to those used to estimate production.

Prices

Commodity market price data is usually collected by the ministry of planning or the ministry of agriculture. Price data is always based on a specific location at a specific point in time. When used in priority setting, however, prices must be aggregated over both space and time. Since prices often show large inter- and intra-year variation, they should be deflated over several years and averaged. The consumer price index, which measures price changes over time for a standard basket of household goods, is the most frequently used deflator of observed nominal commodity prices.

Spatial aggregation of prices is more problematic. A central market in the research target zone can be identified and an average price for that market used to represent the price of the commodity in the zone. Alternatively, prices from many markets in the zone can be combined as a weighted average price

Box 6.2. Decomposing Productivity Growth

By definition, production equals area times yield:

$$Q = A^{*}Y \qquad (1)$$

where Q = production, A = area, and Y = yield.

Decomposing this relationship, the change in production equals the change in area times yield plus the change in yield times area:

$$dQ = dAY + dYA \text{ or } Q_t - Q_{t-1} = \left(A_t - A_{t-1}\right)Y_{t-1} + \left(Y_t - Y_{t-1}\right)A_{t-1} \qquad (2)$$

The relationship can also be expressed in terms of rates of growth by dividing both sides by current production:

$$\frac{dQ}{Q} = \frac{dA}{A} + \frac{dY}{Y} \qquad (3)$$

Finally, each components' rate of growth can be equivalently expressed and calculated as first difference of the logarithm:

$$\ln Q_t - \ln Q_{t-1} = \left(\ln A_t - \ln A_{t-1}\right) + \left(\ln Y_t - \ln Y_{t-1}\right) \qquad (4)$$

Average annual growth rates are simply the average of estimated period growth rates.

for the zone. However, even multiple-point price estimates in a zone can mask large price variations from the farm gate to the retail market due to differences in transport costs.

Supply and demand elasticities

Research impact can be measured based on the current production base of a commodity. Technological change causes a commodity to become more profitable relative to other commodities. It may therefore result in additional production increases. On the other hand, quantity increases may drive price downward. Supply elasticities measure the percentage change in production associated with a percentage change in price and allow the analyst to adjust prices based on market behavior. The economic surplus section of chapter five discussed the role of price elasticities in research evaluation. Supply elasticities can be estimated from time-series price and production data after controlling for important factors like rainfall, technology, and infrastructure development. As discussed in chapter five, most estimates of supply elasticity tend to be centered around 0.5, and this estimate is commonly used if no empirical estimate exists for the commodity in the region. Similarly, measures of demand elasticities (the percentage change in demand for a commodity for a given percentage change in price) will be needed if the effect of research on consumers is to be addressed in the analysis.

Responsibilities for compiling statistical data

Once a priority-setting process for agricultural research is put into place, requirements for agricultural statistical data are usually similar across programs. A research organization can avoid duplication of effort in the collection of statistical data by establishing a point person for networking with agencies that collect statistical data. This role usually falls to the socioeconomic division of the research organization. Program-level socioeconomists should work closely with the point person when compiling agricultural statistics for their individual programs. The role of the socioeconomist in priority setting is discussed in chapter seven.

Summary

The type of agricultural statistical data needed for priority setting depends on the criteria and method chosen for the analysis. At the same time, criteria and methods must be compatible with the human resources and data available. In most countries, either the ministry of agriculture or planning, or the central bureau of statistics will collect commodity production and price data. Household welfare surveys may also provide information on commodity consumption. The first investment made in a priority-setting process should be an inventory of the data available. Research organizations do well to appoint a point person responsible for networking with the agencies responsible for collecting and analyzing agricultural statistical data. That person will not only develop the inventory, but will also assess the quality of data.

Exercise 6.1
Availability and Use of Statistical Data

1. Identify the major sources of agricultural statistical data in your country by type (e.g., production and consumption statistics, prices, and supply and demand elasticities), level of aggregation (e.g., district), and source.
2. If you have not already done so, copy the file PS-Exer.xls from the enclosed diskette to a subdirectory on the computer where you will work. Then open the file in Excel. Go to the sheet named EXERCISE 6.1. That spreadsheet is similar to the one in appendix 6.1. It contains maize production statistics for six research zones. We will calculate three aggregate statistics from the data: average production over the last three years of data (1991 to 1993), yearly growth rates from 1983 to 1993, and average annual rate of growth from 1983 to 1993.
   a) **Average production over the last three years of data.** Here, we calculate the average production for the last three years on row 17 of the worksheet. Scroll to cell B17. Here we see that the formula (=AVERAGE(B13:B15)) performs the calculation. Copy the formula to cells C17 through G17 to calculate the average in the other five zones.
   b) **Yearly growth rates from 1983 to 1993.** Review box 6.2 on growth rates and then examine the formula in cell B20 (LN(B6)-LN(B5)), which calculates the annual rate of growth from 1983 to 1984 in zone 1. Similar formulas are used to calculate growth rates in subsequent years. Copy the formulas in column B into columns C to G to calculate the annual growth rates in the other five zones.
   c) **Average annual growth rate from 1983 to 1993**. In cell B31, calculate the average annual growth rate in each zone for the period 1983 to 1993 using the (=AVERAGE) formula. Which zone shows the highest rate of growth in production over the decade?

Appendix 6.1. Maize Production Statistics

	Production (metric tons)					
Year	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
1983	22635	106091	214485	31051	689717	582173
1984	35760	120671	162309	28126	418273	269473
1985	43118	129139	274532	31928	781361	672609
1986	55564	251997	297750	69834	856685	685381
1987	31744	109507	265600	33249	783879	642764
1988	49724	216655	282098	79076	886103	713844
1989	49067	172376	287936	105013	839754	650028
1990	39901	136978	279248	65971	722182	523635
1991	25945	89214	219220	43793	567254	427768
1992	33179	115914	249430	51315	650706	495118
1993	8512	66008	203067	29951	561811	407058
Average 91-93	22545					
Growth rate						
1984	0.46					
1985	0.19					
1986	0.25					
1987	-0.56					
1988	0.45					
1989	-0.01					
1990	-0.21					
1991	-0.43					
1992	0.25					
1993	-1.36					
Average growth rate						

Chapter 7
Information and Human Resource Investments for Research Priority Setting

Adiel Mbabu, Bradford Mills, and John Lynam

Introduction

There are two distinct visions of how agricultural research priority setting should be undertaken. According to the first view, priority setting is a static process undertaken every five to 10 years at the institute level, and at the program level every three to five years. Central to this process, groups of researchers and research stakeholders are convened for periods ranging from one day to several weeks. They produce a list of priorities based on readily available information. External technical assistance is often relied upon to propose and implement appropriate priority-setting methods. In contrast, the second view sees priority setting as a dynamic process and an integral part of the continuous cycle of formulating, implementing, disseminating, and evaluating the research agenda (figure 18). While priorities may be formally set within the time horizons mentioned, the process of priority setting is continuously strengthened, along with the general research cycle, through investments in human and information resources.

Links between priority setting and other research program formulation and evaluation activities were discussed in chapter one. This chapter focuses on investments in human resource capacity and the information bases needed to support priority setting, as well as to strengthen the broader research cycle. Particular emphasis is placed on developing socioeconomic capacity. This does not imply that priority setting is a uniquely socioeconomic activity. However, socioeconomists do play a crucial role as facilitators and implementers of priority-setting exercises. Further, socioeconomists increasingly

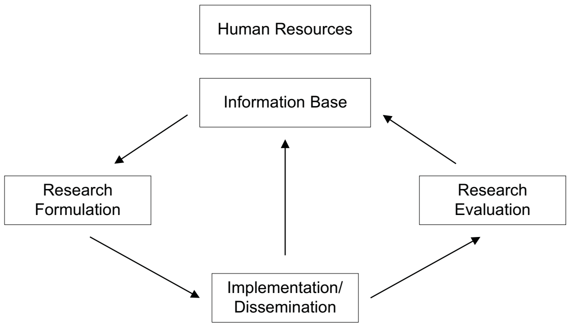

Figure 18. The research cycle

are called upon to provide important inputs into the development of the information bases that underpin priority setting.

This chapter

1. reviews the range of demands for socioeconomic input in agricultural research organizations
2. organizes these demands across the major components of the research cycle
3. presents the strategy of KARI's socioeconomics division for meeting the demand for socioeconomic research with available human resources

The exercise at the end of the chapter assists research leaders in identifying crucial areas for investment in socioeconomic capacity in their research organization. It also helps them review how information generated from these investments can be used in priority setting.

Socioeconomic input in the research cycle

The role of social scientists in agricultural technology generation in Africa has changed dramatically over the past few decades. Until the 1970s, social scientists were responsible primarily for the evaluation of the economic viability and social acceptability of ongoing biophysical research programs. This socioeconomic role was often seen by biophysical scientists as an oversight function, a view that did little to ameliorate tensions between the physical and social sciences. The farming-systems research and extension approach, fostered in the late 1970s, highlighted the role of the social sciences in understanding farmers' perceptions, problems, and technology demands early in the technology-generation cycle. Almost two decades later, the farming systems approach has infused into the research culture of African NARS. Slowly, it has increased awareness of the positive role that social scientists can play in the process of research formulation and implementation.[2]

2. See Byerlee and Franzel (1993) and Collinson (1988) for excellent descriptions of the advances made by social scientists, particularly economists, in several African NARS.

The role of social scientists in identifying potential research interventions for technology users other than farmers, across vertically linked components of commodity subsectors, has also been added to the expanding NARO socioeconomics agenda (Staatz and Bernsten 1992). More recently, internal and external pressures to rationalize the role of the state in agriculture and other rural sectors has brought out the need for socioeconomists to conduct policy research.

The proceeding chapters have also added the role of research priority setting to the agendas of NARO socioeconomists. Socioeconomists are called upon to facilitate the application of priority-setting procedures across programs within a research organization, as well as to lead the application of the methods in individual program exercises. Socioeconomists also play a primary role in the collection of agricultural statistical data and are important members of multidisciplinary teams set up to identify client constraints. All of these demands for socioeconomic input can be related to the basic components of the broader research cycle, including research formulation and implementation, dissemination of results, and evaluation. Contributions to developing human resource capacity and information bases should also be added to this list. A coherent socioeconomic research agenda can be formulated more easily when specific demands are viewed across this cycle. For each component of the research cycle, table 18 presents socioeconomic roles, methods, and information to be generated for use in research priority setting.

Research program formulation

The research program formulation component of the research cycle, can be broken down into five basic steps:

1. definition of research target zones
2. identification of a set of researchable themes (including financial and human resource needs)
3. prioritization of research themes
4. development of projects to implement priority themes
5. allocation of adequate resources to implement projects

The first three steps are generic to research priority setting. The last two relate to the program planning and budgeting activities discussed in chapter one. The information available will determine the rigor and precision with which each step is implemented. Socioeconomists play a fundamental role in research program formulation, in terms of designing and implementing priority setting, as well as by participating in research-program planning and evaluation. Socioeconomists also play an important role, as part of multidisciplinary teams, in the identification of research target zones and technology user needs.

Implementation

As the social sciences are increasingly integrated into agricultural research agendas, most projects include components that assess the economic feasibility and social acceptability of technologies under development. Often, technologies can be modified if social and economic constraints are identified

Table 18. Socioeconomic Roles in the Research Cycle

Information Base		Human Resource Base	Research Formulation	Implementation	Dissemination	Evaluation
Macro	Micro					
Socioeconomic role						
Advise senior management on agricultural development objectives Advise senior management on agriculture and research policy Identify and analyze aggregate agricultural sector statistics	Synthesize technology user needs Synthesize information on current and historical performance of technologies	Provide training and backstopping in socioeconomic methods, including research evaluation and priority setting	Facilitate research priority setting Participate in research program planning and evaluation Participate in the design of priority-setting procedures Identify technology user needs (as part of multidisciplinary teams)	Provide a social science perspective in multidisciplinary research teams Take a lead role in research on socioeconomic constraints to technology use	Identify constraints to dissemination and adoption of technologies	Lead multidisciplinary teams to assess research impact
Methods						
Sector and subsector analysis Quantitative analysis of agricultural statistics Simulation of alternative research policies	Collection of informal survey techniques (RRA, PRA) and formal survey results Meta-analysis on information generated during implementation, dissemination, and evaluation of research projects	Formal workshops, mentoring and on-the-job training	Priority setting, planning, and evaluation tools and techniques	Tools and techniques to monitor the socioeconomic suitability of ongoing research technologies	Tools and techniques to monitor technology dissemination and adoption	Quantitative measurement of ex post research impact

Table 18. Socioeconomic Roles in the Research Cycle (continued)

Information Base		Human Resource Base	Research Formulation	Implementation	Dissemination	Evaluation
Macro	**Micro**					
Information for Priority Setting						
Agricultural development objectives Research organization mandate and priority-setting criteria Benchmark agricultural production, price and other statistics, as well as trends	Client demand for research technologies Research potential to address technology user needs Determinants of technology adoption Determinants of research target zones	Increased capacity to provide information discussed in other columns	Appropriate processes and methods for priority setting in the organization Strategies to link priorities to resource allocations Client demands for research technologies	Client demands for research technologies Yield gains associated with alternative technologies	Yield gains associated with alternative technologies Determinants of technology adoption	Historical impact of agricultural research Determinants of technology adoption

early in the implementation phase. This can greatly reduce the time required for technology generation and increase the probability of adoption. Further, if economic or social constraints prove to be binding, projects can be closed and resources reallocated to more promising areas. A great deal of information on potential yield gains (or other benefits) associated with alternative types of technologies and the determinants of technology adoption is also generated during the implementation phase.

Dissemination of research results

The work of research scientists, and particularly social scientists, does not end with the generation of technologies. Social scientists play an important role in enhancing the process of technology delivery to clients. Social scientists need to examine whether the current modes and institutions for technology delivery are functioning correctly and whether other (sometimes nontraditional) modes for dissemination of technologies may be more effective.

The socioeconomist also continues to play a major role in monitoring the performance of technologies as part of a multidisciplinary team during this phase. Feedback from extension workers and farmers may indicate if technologies need to be redesigned. For their part, farmers may themselves modify technologies in ways that improve on research recommendations. Again, information gathered during the technology dissemination phase can be important for framing future research themes and evaluating their potential.

Evaluation

The assessment of research impact remains a staple domain of socioeconomics. However, biophysical scientists can also benefit from a systematic review of technology performance. Information generated during the ex post evaluation of research activities includes the following:

- the historical scope and level of adoption of research-produced technologies
- the benefits realized from technology adoption
- constraints to increased adoption, particularly researchable constraints

Again, this information is a valuable component of the program information base, especially as a benchmark for the potential impact of future research themes. Research organizations can also use information on the historical impact of agricultural research to sensitize the government and donors on the expected benefits to be gained from continued investment in agricultural research.

Information base

The research cycle never begins as a blank slate. The information base can be seen either as the starting point or the end point of the research cycle. Socioeconomists play an important role in the development of both program- and institute-level information bases. Program information bases are the repository of an array of information generated over time through program research activities and interaction with clients. Programs must make an active commitment to manage this information base. In fact, one of the defining features of an advanced research program is the depth of the information base. Sometimes supplemental investments in information are warranted for more effective research program formulation. The role of socioeconomists in generating information was discussed for each of the previous steps of the research cycle. In terms of priority setting, socioeconomists are often called upon to synthesize diverse informal and formal survey results on technology user needs and information on the historical performance of program technologies into a format that can be readily used for research program formulation.

At the institute level, the information base encompasses three areas: research policy, agricultural policy, and agricultural statistics. Information on research policy guides the organization on agricultural sector development objectives, the expected role of agricultural research, and often, on the specific mandate of the research organization. Chapter two demonstrated how essential this information is for the formulation of research organization objectives and research evaluation criteria. Socioeconomists often play a lead role in compiling research policy information for review by senior managers.

Most research organizations are now taking a more active role in policy formulation for the agricultural sector. In this regard, socioeconomists are being asked to identify policies that will potentially create a more favorable environment for technology generation and adoption, as well as improve the general economic performance of the sector. Subsector and institutional analysis and policy simulation models are important tools for such work. However, planning and finance ministries often have a substantially greater capacity in these areas than do agricultural research organizations. It is extremely important that policy research agendas are developed in conjunction with these other actors. At the program level, socioeconomists will often become involved in policy issues related to commodities and inputs within their program's mandate.

Finally, aggregate statistics on agricultural commodities and inputs provide good indicators of agricultural sector trends. These are an important benchmark in research program formulation. As stated earlier, most agricultural research organizations do not have a primary mandate to collect such aggregate statistical information. Linkages to organizations with this mandate are therefore essential. These linkages, as well as the usage of agricultural statistics in research priority setting, were discussed at length in chapter six.

Human resource base

With regard to human resources, the historical emphasis of agricultural research systems in sub-Saharan Africa has been to build staff capacity in the biological sciences. The social sciences, therefore, has seen a relative under-investment in human resources, compared to the biological disciplines. To make up for this lack, socioeconomists working in research organizations are often called upon to help build socioeconomic capacity by staging formal training, mentoring, and backstopping. The role of facilitators in research priority setting, discussed in chapter one, is an important example of the constructive role that socioeconomists can play in internal capacity building. Other areas include PRA techniques (chapter four), analysis of agricultural statistics (chapter six), and techniques for research priority setting (chapter five). With these many roles, clearly, research organizations are faced with a difficult task in allocating scarce socioeconomic resources across research areas and programs. The following section briefly discusses how KARI has dealt with this challenge.

KARI's strategy for meeting socioeconomic needs with limited human resources

Few agricultural research organizations in sub-Saharan Africa are endowed with sufficient human resources to undertake all socioeconomic activities associated with each phase of the research cycle. KARI has developed a strategy to meet the major demands for socioeconomic input despite such constraints.

KARI structure and the role of socioeconomics

KARI's regional and national research programs are supported by the institute's headquarters. Table 19 presents the mandate, scale, and common units of analysis for socioeconomic activities at each of these levels in KARI's organization.

Regional research programs design and implement problem-based research agendas within geopolitical areas comprised of several districts. Research is conducted within a farming systems framework, and results are applicable to specific recommendation domains within the program mandate area. Social science work focuses on the collection of information on client constraints, as part of multidisciplinary teams, using participatory research techniques. Social scientists also have a role in ensuring that client needs and other relevant information is given the appropriate weight during the actual process of research program formulation. This is done through the development and utilization of a formal priority-setting procedure.

Due to the problem-based nature of the research agenda, social scientists also play a major role, as part of multidisciplinary team, in implementing priority research projects. Farmers' responses to technologies, as well as the adoption and impact of technologies, are documented for incorporation into future research program formulation activities. Given the complex nature of problem-based research, social science efforts in regional research programs focus mainly on household or individual interactions with agricultural technologies. Research impact is measured at the level of the farming system.

National research programs, on the other hand, are mandated to do applied research on specific commodities or production factors. Research is usually conducted along disciplinary lines and focused on broad target zones determined by agroecological criteria. Like other scientists, socioeconomists in national programs tend to undertake more disciplinary-oriented research at

Table 19. Mandate, Scale, and Unit of Analysis of Socioeconomics within the KARI Structure

Component	Program Mandate	Spatial Domain	Unit of Analysis	Emphasis in Technology Generation Cycle
Regional research programs	Problem-based farming systems approach	Farming system	Household/community	1. Microenvironment information collection 2. Program formulation based on client technology needs 3. Implementation of problem-based research 4. Monitoring use of research results
National research programs	Commodity- or factor-based applied research	Agroecological target zone	Commodity markets/ household/society	1. Commodity- or factor-specific information collection 2. Program formulation based on aggregate impact 3. Implementation of program research 4. Ex post assessment of program impact
Headquarters	Leadership, coordination, policy links	Kenya agricultural sector	Markets/agricultural sector institutions; role of state	1. Macro-environment information collection 2. Sensitization of research constituency to ex ante and ex post research impact

a more aggregate level of analysis than their counterparts in regional research programs. The impacts of specific technologies on households may still be examined, but the roles of markets and institutions are more often the focus of socioeconomic analysis. In terms of the research cycle, socioeconomists still play a lead role in incorporating information on client constraints related to the mandate commodity or production factor into the program information base. The information generated by regional research programs is often a useful platform for building such an information base. National program socioeconomists must also make greater investments than their regional counterparts in the synthesis of macroenvironment information relevant to the specific commodity or production-factor mandate of their program. This is most effectively done through linkages with headquarters-based socioeconomists developing the agricultural statistics component of the institute's information base. As in regional research programs, the socioeconomist is called upon to play a lead role in priority-setting exercises.

The role of the socioeconomics division at KARI headquarters is to provide guidance and support to the regional and national research programs, particularly in terms of appropriate quantitative and qualitative methods. In some cases, like the provision of facilitators for program-level priority setting, the division may arrange for specialized program-level socioeconomists to backstop other program-level socioeconomic activities. The headquarters staff is also mandated to develop a macroenvironment information base, and to supply research leaders with information on the potential role of technology generation in Kenyan agricultural sector development. Finally, the division is responsible for conducting analyses of the potential impact of alternative agricultural policies.

Prioritizing the socioeconomics research agenda

Given the broad agenda and the need to address the demands of three distinct groups within the institute, the socioeconomics division regularly makes difficult decisions on how to employ its limited human resources. As table 20 indicates, only 22 socioeconomists have the basic qualifications for a research officer in KARI (master's degree or above). With 14 officers in master's-degree or postdoctorate training, this number could rise to 36 under the very optimistic assumption of no attrition. Even so, the socioeconomics division is not able to provide full support to 17 national and 11 regional centers.

Table 20. Current Staff Capacity in the Socioeconomics Division in KARI

	On-Station					In-Training			
	PhD	**MSc/MA**	**BSc/BA**	**Diploma**	**Expatriate**	**PhD**	**MSc**	**BSc**	**Total**
Headquarters	0	2	4	4	4	2	1	0	17
National research programs	2	12	6	3	1	4	4	1	33
Regional research programs	0	6	4	2	1	2	1	0	17
Total	2	20	14	9	6	8	6	1	67

This problem is further compounded by disciplinary shortfalls. The program needs agricultural economists, rural sociologists, anthropologists, and geographers to effectively fulfill all its obligations. However, of the 22 already trained to the master's level or above, 21 hold degrees in agricultural economics and one has a master's degree in sociology. None is trained in geography. Thus, there is a need to build both general socioeconomic capacity, and a diversified disciplinary mix.

To allocate its scarce socioeconomic human resources, KARI management has developed a strategy establishing clusters of socioeconomic capacity in priority research programs, leaving other programs without socioeconomic input in the short run.

Regional research programs

Kenya's regional research programs divide the country geographically, ensuring that the whole nation is covered by the regional research network. Complete coverage is important for ensuring a minimum level of equity in the distribution of agricultural research services. Further, the regional programs form an important basis for all research program formulation activities by identifying the grassroots constraints of clients. Therefore, even though socioeconomic capacity is in short supply, every regional research program that establishes a multidisciplinary farming-systems research team must be allocated a full-time socioeconomist for the team.

National research programs

Given KARI's strong commitment of socioeconomic resources to the regional programs, complete coverage of national research programs is impossible. Further, given the range and complexity of the socioeconomic issues addressed in the major commodity and production-factor programs, more than one socioeconomist may be required to adequately address the mandate of a national research program. An appropriate compromise is to initially allocate two socioeconomists to each of the top five priority national programs. These economists should focus on establishing price and production databases for the commodities and production factors within their mandates. At the same time, they should develop budgets for technology evaluation and conduct subsector analyses to identify key constraints to the adoption of improved technologies.

Headquarters

Five socioeconomists are needed to develop the headquarters-based socioeconomics division. In addition to the assistant director, two socioeconomists do policy and agricultural statistical analysis. The two others lead efforts in thematic areas, either based on a crops/livestock or national/regional program demarcation.

Short- and long-term capacity building

Even under this strategy, shortfalls in socioeconomic capacity continue. Three short-term interventions can ameliorate the projected shortfall in numbers and disciplinary mixes. First, cross-center cooperation of socioeconomists should be increased. Although each socioeconomist is responsible for the research programs of their respective host centers, they can also assist other centers and programs upon request. Such requests should be funneled through the assistant director of the division in order to maximize program coverage, while minimizing the potential for over-commitment of individuals. Second, all socioeconomists can be exposed to the basic perspectives of the major disciplines (economics, sociology, anthropology, and geography). The utilization of very specialized disciplinary skills is often limited in applied research, and a series of in-service courses can highlight the tools from other disciplines that can be drawn upon within the social sciences. Third, as discussed, cooperation with socioeconomists in other institutions with overlapping research agendas is crucial for the effective utilization of existing socioeconomic capacity. Important KARI partners—national and international—include the Kenyan Ministry of Planning and Development, the Ministry of Agriculture, Livestock Development and Marketing, international agricultural research centers, universities, and selected NGOs. These groups should also be actively involved in planning major socioeconomic activities. In the long term, however, human resource constraints can only be ameliorated through continued commitment to investment in formal advanced degree training.

References

Bernsten, R.H. and J.M. Staatz. 1992. The role of sub-sector analysis in setting research priorities. MSU Agricultural Economics Staff Paper 92-104. East Lansing: Michigan State University.

Byerlee, D. and S. Franzel. 1993. Institutionalizing the role of economists in national research institutes. CIMMYT Economics Working paper No. 93-01. Centro Internacional de Mejoramiento de Maíz y Trigo: Mexico, D.F.

Collinson, M. 1988. The development of African farming systems: Some personal views. *Agricultural Administration and Extension* 29, 1:7-22.

Exercise 7.1
Human Resource and Information Investments for Priority Setting

Discuss the following in a small group:

1. How many socioeconomists are currently employed in your research organization? At what levels are they working (e.g., at headquarters, in regional or national programs)? At which phases of the research cycle are their efforts concentrated?
2. Has your organization systematically developed information bases for use in research program formulation? What specific investments may be needed to strengthen information bases in the organization? At what level should these investments be made?
3. If a limited number of trained socioeconomists is an important constraint to improved research program formulation, what specific investments should be made to ease this constraint?

Chapter 8
Technology, Location, and Trade: Kenyan Vegetables[3]

Mercy Kamau and Bradford Mills

Abstract

Agricultural research impacts in sub-Saharan Africa are often location specific and arise through a lengthy process of technology generation and adoption. In this chapter, a framework for technology assessment is presented which clearly demarcates the spatial and temporal dimensions of potential research benefits, but is also compatible with broader research planning efforts and available human resources. Application in KARI's brassica and snap bean research themes demonstrates that location-specific commodity production base, the potential for technology generation, and the potential for technology adoption are important determinants of research impact. Commodity market structure and rapid population growth also influence the magnitude and distribution of research benefits.

Introduction

Vegetables represent an increasingly significant component of the Kenyan agricultural sector as a source of food for the rural population (both staple and supplements) and a foreign exchange earner (FAO 1993). Within the vegetable subsector, *Brassica olercea* (subspecies *B. capitata* and *B. ocephala*) are the most important commodity group in terms of production with a national average of about 530,000 tonnes per year. Snap beans (*Phaseolus Vulgaries L.*), by contrast, constitute a relatively small portion of the subsector. However, rapid growth has lead to a tripling of snap bean production from 1982 to the current average of 18,000 tonnes per year. Further, snap beans' high

3. This chapter is based on "Technology, Location, and Trade" *Agricultural Systems* Vol. 59: 3, reprinted with permission of Elsevier Applied Science Publishers Ltd., London.

value to weight ratio makes them an important component of Kenyan vegetable exports. The KARI horticulture program currently allocates 5.6 full-time-equivalent researchers to snap bean research and 4.4 researchers to brassicas research. These human resources must be allocated to locations and research themes with the largest potential impacts.

Formal evaluation of potential research benefits can greatly strengthen the process by which research priorities are both set and translated into resource allocation decisions. Recent studies suggest that increases in the degree of participation, as well as the spatial and sectorial scope of ex ante evaluation can improve agricultural research program relevance (Collion and Kissi 1994, Wood and Pardey, 1998, Bernsten and Staatz 1992). In terms of implementation, the need to integrate research evaluation within the broader institutional processes of research planning and resource allocation have been recognized (Stewart 1995, Kamau et al. 1997). Similarly, a number of advances have been made in economic methods for ex ante evaluation. Measures of the change in consumer and producer economic surplus from research on a single commodity in a single region have been developed for open and closed economies (Peterson 1967, Akino and Hayami 1975). Single-region applications have included important exogenous demand shifts from population and income (Scobie and Posada 1973, Norton et al. 1987). Economic surplus methods for research evaluation have also been extended to account for trade between a country and the rest of the world, as well as multiple regions with fixed price wedges reflecting transport costs (Edwards and Freebairn 1984, Alston et al. 1995, Mills 1997).

Unfortunately, advances in economic evaluation methods have remained largely separate from concerns of institutional capacity, participation, and utilization. This paper attempts to fill that gap by presenting an evaluation of the potential impact of brassica and snap bean research in Kenya based on a procedure developed by ISNAR and KARI. The procedure is specifically designed to measure the spatial scope and potential spillovers of benefits from specific program research themes in order to assist programs in the choice of both location and themes for research investment. The procedure also supports institute needs for broad participation in priority setting and resource allocation decisions. At the same time, it is compatible with current human resource capacity to undertake the analysis.

Applications to brassicas and snap beans provide a good contrast in terms of area of production, the potential for technology generation and adoption, market structure, and exogenous sources of growth in supply and demand. The next section of the paper develops a spatial and thematic framework for brassica and snap bean research options based on farm-level constraints. Section three characterizes the structure of brassica and snap bean commodity markets and highlights important exogenous influences on both sectors. A multiple-market equilibrium displacement model of research impact is also presented. Simulation results for the two commodity groups are presented in section four. The paper concludes with a brief discussion of how ex ante technology assessments are being used by KARI for the broader process of research planning and priority setting.

Research options

A priority-setting working group composed of key horticultural program and extension service experts identified options for brassicas and snap bean research in three steps during a five-day workshop. First, research target zones with similar expected changes in crop yields from new technology were demarcated. Second, major research themes were established based on the extensive listing of client constraints within each zone. Finally, the potential for generation and adoption of new technologies was estimated for each theme. These steps were then reviewed and modified by a wider body of program stakeholders during a one-day meeting. All other commodity programs at KARI have completed a similar procedure with the assistance of the socioeconomics division.

Research target zones

There is tremendous diversity in agricultural production systems in Kenya. Agroclimatic conditions are a major factor in this diversity and can be used to demarcate areas where the expected impact of specific agricultural technologies will be fairly similar in terms of yield. A number of generic classification schemes exist for Kenya, the Farm Management Handbook agroclimatic classification is the most widely known (Jaetzold and Schmidt 1993). However, rapid advances in GIS software and databases allow for the production of program or even problem-specific schemes from basic environmental criteria.

Even with a GIS, experts must make important choices about variables and criteria ranges. The horticultural program priority-setting working group identified elevation, minimum and maximum average monthly temperature, and rainfall as key environmental determinants of vegetable production.[4] After several mapping iterations, the working group established five research target zones based on criteria ranges for these variables: coastal lowlands, semiarid, mid-altitude, high mid-altitude, and high altitude (table 21). Brassicas and snap bean area and production estimates were then calculated for each production zone from district-level area and production estimates (table 22). Most brassica and snap bean production occurs in the high mid-altitude and mid-altitude zones. However, 14 percent of brassica production occurs in the high altitude zone and 12 percent of snap bean production occurs in the semiarid zone. Further assessment activities were focused on each commodity's three major production areas. Thus, two potential research zones were immediately eliminated for each commodity through spatial targeting.

4. The choice of variables was partially constrained by the availability of georeferenced data. Arguably, variables and criteria ranges differ for specific vegetables. However, given the number of vegetables addressed by the program, crop-specific schemes would quickly make within-program comparisons intractable.

Table 21. Vegetable Program Target Zones

Zone	Elevation (m)	Rainfall (mm)	Temperature °C
High Altitude	2400-3000	1000-2000 (annual)	Min 3°C June-July
High Mid-Altitude	1800-2400	March-June (350-800) October-December (350-700)	Min 7°C March-April Min 8°C October-November
Mid-Altitude	1150-1800	April-June (350-700)	
Semiarid (Supplementary irrigation)	600-1150	October-December (325-600)	Max. 32°C annual average
Coastal Lowlands	0-800	April-June (400-800) October-December (350-800)	Max 30°C annual average

Research themes

The priority-setting working group also established research themes within zones by grouping major constraints derived from knowledge of farmer circumstances obtained in previous formal surveys and rural appraisals. Several KARI programs have also incorporated PRA techniques into the process of identifying of research themes to further strengthen their knowledge bases. Incorporation of PRAs by most programs has been constrained, however, by costs and knowledge of the methods.[5] Five research themes, common across

Table 22. Area and Production by Research Target Zone

	High	High-mid	Mid-alt.	Semiarid	Coastal	Rest of Kenya
Estimated Area	*ha*	*ha*	*ha*	*ha*	*ha*	*ha*
Brassicas	5,215	16,403	15,407	935	421	0
Snap beans	261	1,869	3,439	597	0	0
Est. Production	*ton*	*ton*	*ton*	*ton*	*ton*	*ton*
Brassicas	75,800	251,500	191,400	11,900	2,300	0
Snap beans	860	5,800	9,500	2,200	0	0
Est. Consumption	*ton*	*ton*	*ton*	*ton*	*ton*	*ton*
Brassicas	32,410	122,989	211,739	17,087	32,064	116,703
Real Hort. Prices	*Ksh/ton*	*Ksh/ton*	*Ksh/ton*	*Ksh/ton*	*Ksh/ton*	*Ksh/ton*
Brassicas	3,571	5,359	5,753	7,550	11,245	18,886
Snap beans		20,000	20,000	20,000		
Population Growth	*%*	*%*	*%*	*%*	*%*	*%*
1979-1989	3,98	3.67	3.16	3.31	3.06	3.32

Sources: Ministry of Agriculture district-level production statistics; Central Bureau of Statistics census and household consumption statistics. Population growth, CBS 1982 and 1994.
Note: Brassica zone prices were estimated based on 1991 to 1994 wholesale horticultural prices for cabbage and kales collected by the Ministry of Agriculture's marketing board in 13 regional horticultural markets and Nairobi and Mombassa. Mean snap bean prices are based on 1994 F.O.B. price less 10 percent transportation costs. Major snap bean production zones are roughly equidistant from Nairobi airport. All prices are expressed in real 1994 Kenyan shillings.

5. KARI has launched a major training effort in this area. Further research is needed to develop participatory research programming techniques appropriate for program resource bases, both human and fiscal.

zones, were established: "varietal development" activities focused on improving yields through introduction, evaluation, and breeding of high yielding, stress and disease tolerant cultivars; "crop management" activities focused on improving cultural practices such as soil fertility management, plant population, and water use efficiency; "crop protection" activities focused on improving the management of major diseases and insect pests; "postharvest" activities focused on minimizing losses and adding value through improved harvesting techniques, as well as postharvest handling, packaging, transportation, and storage; and "technology dissemination" activities focused on increasing both the client groups' accessibility to new technologies and researchers' knowledge of technology user needs. It may be argued that technology dissemination is a component of each of the other four themes, and therefore, should not be included separately. However, in the Kenyan case a number of technologies already exist that research and extension agents feel could significantly increase farmer productivity. These technologies are not being adopted because either they have not been effectively incorporated into the farmer knowledge base on technological options or because farmers' criteria for evaluating technologies is not adequately understood. As part of the research planning process, the horticultural priority-setting working group and subsequent stakeholder group wished to explicitly highlight the importance of developing program capacity to improve the two-way flow of researcher and farmer knowledge by establishing technology dissemination as an independent research theme.

Potential for generation and adoption of technology

Research impact occurs through the generation and adoption of technologies. Since this is a long and uncertain process, ex ante evaluation must be based on expert judgment about the potential of future technologies. Biases, which are inherent in such subjective estimates were controlled for in four ways. First, the same structured elicitation process was used for all themes and zones to create a common basis for comparison. Second, parameter estimates were benchmarked with data prepared by the program socioeconomist on historical production trends and the performance of previously released technologies. Third, the elicitation took place in a group setting to control the strategic behavior of individuals with interests in a specific research theme or location. For each theme and location a period of free discussion was allowed before the working group was asked to reach a consensus. When elicitation was completed for all themes and zones, the relative distribution of parameter estimates were reviewed again by the group. Although farmers and other technology end users were not directly involved at this stage, as with the identification of research themes, knowledge of their conditions and constraints was an important prerequisite for meaningful estimates. Finally, scientists presented the estimates to a larger group of program stakeholders who included farmers and other program technology users. Stakeholder groups then broke into discussion groups to review and modify specific parameter estimates.

Our experience with a number of programs suggests that this process effectively controls bias in parameter estimates within a program. Still, significant bias may exist in cross-program comparisons. Specifically, programs with a strong knowledge base on client constraints and the historical performance of technologies appear to provide more conservative estimates on the potential for technology generation and adoption. An additional step may be needed to rationalize parameter estimates when using ex ante benefits estimates to inform cross-program resource allocation decisions. We briefly present the conceptual framework for estimating technology generation and adoption parameters. The estimates of the priority-setting working group and stakeholder group are presented in appendix 8.1.

Technology generation, by the nature of the research process, is uncertain and best represented as a distribution of possible outcomes in terms of commodity yield increases (or losses avoided). The priority-setting working group reviewed the potential for generation of technologies addressing the constraints identified in each theme and established the minimum, most likely, and maximum potential net yield increases for each zone using simple partial commodity budgets of gross yield gains and additional inputs associated with each technology option. A more rigorous definition of what is commonly referred to as 'the probability of research success' was also incorporated into the elicitation process. Farmers, particularly resource-poor farmers, will only adopt technologies if net yield gains are significantly greater than zero. The specific threshold level for adoption will depend on factors such as farmers' perceptions of technology risk, additional labor or capital investments associated with the technology, and scale of production (Feder et al. 1985). For each theme the working group established the threshold net yield gain necessary for technologies to be disseminated to farmers and other technology users based on consideration of these factors. Two parameters were then calculated, assuming a triangular distribution of yield gains for simplicity: 1) the probability of developing technologies that exceed the dissemination threshold and 2) the expected net yield gain conditional on the dissemination threshold being exceeded. Further explanation of the triangular distribution and the two parameters is found in appendix 8.2.

As an example, the priority-setting working group and the stakeholder group felt there was a large potential to increase the net yields of snap beans through varietal development activities. Expected minimum, most likely, and maximum net yield gains of 25, 50, and 75 percent, respectively, were estimated for the semiarid zone. Since the minimum expected yield gain exceeds the 7.5 percent dissemination threshold, the probability of dissemination is one and the conditional expected yield gain is 50 percent.

Adoption profiles measure the rate and extent of the adoption of a technology and directly influence estimates of research impact. Typically an adoption profile consists of four phases: 1) the research lag, ending with release of a new technology, 2) an increasing adoption phase where a growing number of farmers learn about the technology and opt to use it, 3) an adoption plateau where the majority of farmers have been exposed to the technology and have decided whether or not to adopt, and 4) declining adoption if the technology becomes obsolete and is abandoned by farmers. The adoption profiles are assumed to have a trapezoidal form in ensuing calculations.

All adoption profile parameter estimates are conditional upon the technologies exceeding the dissemination threshold specified for the theme. Research lag estimates were based on the standard number of years required for programs to develop new technologies for specific themes and locations. Similarly, time to full adoption and maximum adoption rate were benchmarked on the historical performance of the types of technologies associated with each research theme. These numbers were then adjusted for each zone based on an extension service representative's knowledge of previous technology adoption in the area, as well as factors like farmer linkages to extension services and markets, commodity contribution to farmer production objectives, and the change new technologies entail for current production systems.

For example, horticultural program varietal development efforts focus on screening and adaptation and the research lag is very short. In all zones, snap bean varietal development is expected to yield results for dissemination after three years. Since snap bean growers frequently obtain new varieties from research and extension, maximum adoption levels are expected to increase rapidly to 70 percent of producers three years after release. Further, the program is continuously screening new varieties and those varieties generated during the current research cycle are expected to be replaced five years after maximum adoption and then be completely abandoned a further five years down the road.

Market structure and modeling research impact

Market structure determines the distribution of research benefits between producers and consumers and, to a lesser extent, the overall magnitude of research benefits. Brassicas and snap beans have markedly different market structures. Brassicas are essentially traded in a closed economy, where Kenya's internal supply is assumed equal to demand in a given year. Table 22 provides Brassica consumption estimates by zone, based on census data and household consumption surveys. When compared to production estimates by zone, the results suggest that the high mid-altitude and high altitude zones generate major surpluses for consumption in other regions of Kenya.

Snap beans, by contrast, are produced exclusively for the export market, where Kenya is a major supplier of the fine and extra fine beans (Nyoro 1993). Snap bean exports are targeted to the European winter market and evidence exists that Kenya can significantly influence market price during this season (Argwings-Kodhek 1993). Kenya currently represents around 12 percent of international snap bean trade (Peterson and Henry 1992). This market share represents a conservative estimate of Kenya's influence on world market prices given the seasonality of supply.

Kenyan traders in agricultural produce face high transport and other transaction costs due to poor roads and other market inefficiencies. This is particularly true for brassicas, which have a high bulk to weight ratio. The intra-country trade in Kenyan brassicas is reflected by the distribution of prices across zones. The two surplus zones, high and high mid-altitude, show the lowest prices, while the coastal zone and the rest of Kenya (including Nairobi) show the highest average real price for the 1991 to 1994 period (table 22). Snap beans have a relatively high value to weight ratio, which facilitates trade. The beans, however, require a well developed marketing system to minimize spoilage as they are transported to consumers in Europe. Major snap bean production zones are roughly equidistant from Nairobi airport and transport budgets suggest costs between the zones and the airport are not significantly different (Argwings-Kodhek 1993). Mean snap bean prices for all zones are based on 1994 FOB prices, less 10 percent for transport.

Producer and consumer responses to changes in the effective prices of the two commodities are captured through supply and demand elasticities. The specification of price elasticities may have a significant impact on the distribution of research benefits between producers and consumers, but will usually have a relatively small impact on the total distribution of benefits. Rao (1989) reviews the empirical literature on supply response in developing countries and finds long-run elasticity estimates to lie in the 0.3 to 1.2 range. In Kenya, a supply elasticity of 0.68 has been estimated for the major staple maize (Kiori and Gitu 1992). Based on this range, a relatively conservative long-run supply elasticity of 0.5 is used in the model. On the demand side, for Kenya, Bezuneh et al. (1988) estimate a -0.76 price elasticity for ‘other foods’, presumably a significant share of which are vegetables. Similarly, we use a relatively conservative demand elasticity of -0.5 for brassicas. On the other hand, snap beans are for all practical purposes not consumed in Kenya and internal demand is assumed to be unresponsive to price. The elasticity of external demand for snap beans is specified as -0.5, in line with developed country estimates.

Population growth will have an important influence on future demand for brassicas. Population growth rates for each zone were calculated from the 1979 and 1989 district census estimates. Table 22 shows growth rates range from 3.87 percent per annum in the high altitude zone to 3.06 per annum in the coastal zone. When projecting future demand, these growth rates are discounted by 25 percent to reflect expected decreases in population growth. Since there is no internal market for Snap Beans, Kenyan population growth is assumed to not affect demand. Finally, it should be noted that all parameter estimates specified for the model are potentially subject to considerable variation over the 30-year horizon of the simulation, but represent the best current estimates of future trends.

Research impact

The change in economic surpluses (consumer surplus and producer surplus) is the most commonly used measure of the economic benefits generated from agricultural research. Changes in consumer and producer surplus are calculated for specific research themes within zones over a 30-year time period with a multi-period, multiple-market equilibrium displacement model. The model builds on previous multi-region single commodity frameworks for research evaluation (e.g., Alston et al. 1995 and Mills 1997) and accounts for period-specific research-induced supply shifts, increased demand for commodities due to population growth, inter-zonal price wedges, and the impact of research-induced price spillovers to other zones. As in most previous efforts, exogenous shifts are manifest through parallel shifts in linear supply and demand curves. These assumptions are explored at length in the literature, but it should be noted that a parallel shift in supply implies the absolute magnitude of the unit-cost reduction from research is invariant to subsequent shifts in commodity price (Rose 1980, Norton and Davis 1981, Voon and Edwards 1991).

Research-induced supply shifts

Successful research induces a zone-specific absolute unit-cost reduction that is equivalent to a shift in the effective price needed to produce a given number of units of the commodity. The unit-cost reduction K_{it} is simply calculated for every period as the product of the probability of net yield gains exceeding the dissemination threshold, $\Pr(k_i > k_i^a)$, the expected net yield gain conditional upon the dissemination threshold being exceeded, $E[k_i | k_i > k_i^a]$, the expected adoption rate for the period, A_{it}, and the initial unit price of the commodity P_{i0} divided by the supply elasticity for the zone, ε_i:

$$K_{it} = \Pr(k_i > k_i^a) E[k_i \mid k_i > k_i^a] A_{it} P_{i0} / \varepsilon_i. \tag{1}$$

The supply elasticity is included in equation (1) to translate physical yield changes into field-level changes accounting for farmer behavior.

The initial zone-specific linear supply curve is specified as

$$Qs_{i0} = \alpha_{i0} + B_i P_{i0} \tag{2}$$

where Qs_{i0} is the initial quantity supplied in zone i, α_{i0} is the initial quantity axis intercept in zone i, and B_i is the fixed supply slope parameter in zone i. The supply intercept and fixed slope parameter are easily calculated from the initial quantity supply, price, and elasticity estimates for the zone. The unit-cost reduction for a specific point in time t translates into a research-induced change in the quantity supplied though the intercept term as follows:

$$Q^R s_{it} = \alpha^R_{it} + B_i P_{it} \tag{3}$$

where $\alpha^R_{it} = \alpha_{i0} + K_{it} B_i$ is the intercept of the with-research supply curve in zone i for period t.

Since there is almost no unused arable land in Kenya, production increases due to area expansion are limited to price-induced effects in the model. While potential area expansion might be more explicitly captured in a multi-commodity framework, we refrain from this approach for two reasons. First, we have no empirical evidence on the magnitude of cross-commodity supply elasticites. Second, in terms of implementation, multi-commodity models for within-program research evaluation tend to deflect attention from the direct impact of research investments on the specific commodity on hand.

Demand curve shifts due to population growth

Exogenous shifts in the brassica demand curve, due to population growth, are included in the model. Let the linear demand curve for zone *i* in period *t* be expressed as

$$Qd_{it} = \gamma_{it} + \delta_i P_{it} \tag{4}$$

where Qd_{it} is the quantity demanded in zone *i* at time *t*, γ_{it} is the demand intercept in zone *i* at time *t*, and δ_i is the fixed demand slope parameter for zone *i*.

Again, the zone-specific demand intercept and slope parameters are calculated from the initial demand, price, and elasticity. Population growth will result in an increase in the intercept term of the demand function in period *t+1* of

$$\gamma_{it}+1 = \gamma_{it} + \pi_i Qd_{it} \tag{5}$$

where π_i is the population growth rate for zone *i*. No income effects are included in the model for either commodity. Average growth in the per capita gross national product of Kenya between 1985 and 1994 was zero and no clear trend exists on the future direction or magnitude of income growth (World Bank 1996). If rapid income growth were to occur, assuming both commodities are normal goods, internal demand would also increase and result in moderately larger consumer surplus benefits from research.

Constant inter-zonal price wedges

Finally, prices in zone *i* for period *t*, P_{it}, are specified in terms of a base price P_{nt}, net of a price wedge, T_i, which reflects the transaction costs of shipping surplus the commodity to (or from) the base zone. T_i is also assumed to be constant in real terms over time:

$$P_{it} = P_{nt} - T_i. \tag{6}$$

Market clearing conditions

International export (or import) markets can be modeled in the same way as domestic markets. For each period, equilibrium quantities and prices are determined in the with- and without-research scenarios through the respective market clearing conditions:

$$\sum_i Qs_{it} = \sum_i Qd_{it} \quad and \quad \sum_i Q^R s_{it} = \sum_i Q^R d_{it}. \tag{7}$$

If equilibrium quantities differ in the two scenarios, zonal prices will also differ in the without (P_{it},) and with (P^R_{it},) research scenarios.

Producer and consumer surplus measures

Research-induced changes in producer and consumer surplus (ΔPS and ΔCS) are easily calculated from equilibrium quantities and prices for the with- and without-research scenarios. The change in producer surplus in zone *i* at time *t* is calculated as

$$\Delta Ps_{it} = (K_{it} + P^R_{it} - P_{it})[Qs_{it} + 0.5(Q^Rs_{it} - Qs_{it})]. \quad (8a)$$

The corresponding change in consumer surplus is

$$\Delta Cs_{it} = (P_{it} - P^R_{it})[Qd_{it} + 0.5(Q^Rd_{it} - Qd_{it})]. \quad (8b)$$

The present values for the stream of producer and consumer surplus changes (VPS and VCS, respectively) over the 30-year research planning horizon for each zone are

$$VPS_i = \sum_{t=0}^{30} \Delta PS_{it} / (1+r)^t \text{ and } VCS_i = \sum_{t=0}^{30} \Delta CS_{it} / (1+r)^t \quad (9)$$

where r is the real discount rate for the use of public-sector financial resources. In this study the real discount rate is assumed to be five percent based on the interest rate of Government of Kenya agricultural sector loans. Surplus changes can be added across zones to assess the total impact (within and across zones) of spatially targeted research.

Results and discussion

Potential benefits from brassicas and snap beans are as shown in table 23 for each theme and zone. For snap beans, the theme generating largest benefits is technology dissemination, followed by postharvest and then varietal development. The magnitude of benefits from technology dissemination, relative to other themes, is due to estimated research-induced net yield gains of 40 percent. Net yield gains from varietal development activities are also expected to be high. However, the adoption and disadoption of improved snap bean varieties is expected to be rapid. Hence total estimated benefits are much lower than those shown for technology dissemination. Benefits from crop management are the lowest of all themes due to low expected yield gains and adoption rates. Distribution of benefits across zones is generally consistent with the size of the production base.

Brassica benefit estimates presented in table 23 are generally much larger than those for snap beans due to the size of the production base. Technology dissemination again emerges as the theme with the highest potential research benefits due to large expected net yield gains. The crop protection theme shows the second largest benefits. The varietal development theme is third, as the short period between adoption and disadoption again reduces potential benefits. The size of the production base plays a major role in determining the relative distribution of benefits by zone within themes.

Table 23. Potential Economic Surplus Generated from Research, in Millions of Kenyan Shillings

	Brassicas				Snap Beans			
Theme	**Mid-Altitude**	**High Mid-Altitude**	**High Altitude**	**Total**	**Semi-Arid**	**Mid-Altitude**	**High Mid-Altitude**	**Total**
Varietal Development								
Consumer Surplus	2,131	1,922	368	4,518				
Producer Surplus	2,364	1,760	127	3,933	195	475	291	953
Total Surplus	4,496	3,683	495	8,452				
Crop Management								
Consumer Surplus	596	900		1,500				
Producer Surplus	571	762		1,320	20	27	16	63
Total Surplus	1,167	1,661		2,819				
Crop Protection								
Consumer Surplus	2,574	3,637		6,280				
Producer Surplus	2,625	3,257		5,653	237	372	80	686
Total Surplus	5,199	6,893		11,933				
Technology Dissemination								
Consumer Surplus	3,192	4,823	755	8,929				
Producer Surplus	3,317	4,417	288	7,499	253	1,088	666	1,992
Total Surplus	6,509	9,240	1,044	16,428				
Postharvest								
Consumer Surplus	1,259	1,529	220	3,028				
Producer Surplus	1,233	1,312	77	2,560	207	551	337	1,090
Total Surplus	2,493	2,841	297	5,588				

The market structure of the two commodity groups also affects the distribution of benefits between consumers and producers. Kenyans do not consume a significant share of snap beans and, hence, receive no consumer gains from research-induced price decreases. Brassicas, by contrast, are traded in a closed economy and aggregate benefits are roughly equally distributed between producers and consumers. Producers benefit through lower costs of production due to research in their zone. However, producers are hurt by research in other zones that placed downward pressure on prices. Consumers benefit unambiguously from a fall in prices due to research in either their own zone or other producing zones.

Market structure also influences price changes over time. The terminal market conditions, after simulating the cumulative effects from snap bean and brassica research for 30 years, are presented in Table 24.[6] As a result of snap bean research, the price is expected to fall by 8.2 percent while the quantity produced would increase by 58.4 percent. The research-induced supply shift increases the market share of Kenyan snap beans from 12 percent to 18 percent. Kenyan producers benefit most from research (6200 million Ksh)

Table 24. Aggregate Research Impact on Terminal Market Conditions

	Without Research	**With Research**
Brassicas		
Percentage Change in Kenyan Price (High Mid-Altitude Zone)	101	21
Percentage Change in Kenya Quantity	52	84
Aggregate Research Benefits (Million Ksh)		
to Kenyan producers	0	33,954
to Kenyan consumers	0	36,480
Total	0	70,434
Snap Beans		
Percentage Change in Kenyan Price	0	-8
Percentage Change in Kenyan Quantity	0	58
Percentage Change in Kenyan Traded Share	12	18
Aggregate Research Benefits (Million Ksh)		
to Kenyan producers	0	6,199
to Kenyan consumers	0	2,829
to rest of world producers	0	-2,403

6. Aggregate snap bean and brassica research impacts were estimated by adding expected net yield gains across themes within each zone and averaging adoption profile parameters across themes within zones.

while the rest of the world producers end up by losing (2400 million Ksh). The most interesting result is that consumers in the rest of the world receive surplus benefits equal to 2800 million Ksh from lower world market prices.[7] Since most of these consumers reside in Europe, the scenario suggests European donors could more than justify support to Kenyan snap bean research through benefits to their own countries. In the case of Brassicas, prices without research increase by 101 percent due to the increased demand induced by population growth. The quantity produced increases by 53 percent in response to this price change. With research, the price increase is dampened to 21 percent and quantity supplied increases 85 percent. The aggregate research benefits to the society as a whole are very large (70,000 million Ksh) and equally distributed between the producers and consumers.

Utilization of results of commodity-program priority setting

The majority of KARI commodity programs have now completed ex ante research evaluation activities and used the results to set program priorities with their stakeholders. The programs generally feel that this structured approach has helped them to learn a great deal about the environment within which they generate technologies, as well as how to strategically position their programs to address future challenges. Involvement of stakeholders in the process has widened the perception that KARI is concerned about responding to client needs and has enhanced the relevance of projects developed by program scientists. Just as importantly, the process has helped to clarify the need for further program information investments in areas ranging from PRAs to georeferenced data for biophysical modeling of yield response.

Since priority setting is an iterative process, intelligent investment in information, appropriate to the resource constraints faced by programs, can be made to support future rounds. Ex ante evaluation methods can also be strengthened in future rounds. Attention is currently being devoted to elicitation of commodity budgets and technology generation and adoption parameters within a farming systems framework. Further research may be needed on the inter-temporal aspects of unit-cost reductions, particularly in natural resource management programs.

A number of issues also remain on how to effectively utilize formal ex ante evaluation techniques in the broader process of research planning. First, expertise in ex ante assessment techniques is limited. KARI has trained facilitators within the socioeconomics division and has developed computer spreadsheet applications and training materials with ISNAR to assist programs in ex ante assessment and priority setting. However, as with socioeconomic capacity in all public-sector research institutes in sub-Saharan Africa, conditions of service have made retention of skilled individuals difficult.

7. Rest of the world benefits implicitly assume other snap bean producing countries are not investing in research. Even with investments by other countries, Kenya investments will put downward pressure on world prices, prevent losses of world market share, and yield rest of the world benefits of a similar magnitude.

Second, ex ante impact assessment requires a heavy initial investment by programs in information bases, which some programs have been reluctant to make. Fortunately, once this initial investment is made, the information base can be easily updated for future priority-setting rounds. Third, ex ante evaluations are only one source of information for priority setting and resource allocation. The broader role of stakeholder groups in priority setting and resource allocation varies widely across programs and more structured guidelines are needed. Similarly, while research themes are clearly derived from client constraints, priority themes need to be translated into program activities as part of an integrated process of program planning, monitoring, and evaluation. While the KARI structure calls for stakeholder groups to annually review program projects for coherence with stated priorities, the efficacy of the review process also varies widely. In many programs the stakeholder review process is currently dominated by researchers. The horticultural program is fortunate to have a relatively vocal group of large-scale horticultural producers who can clearly articulate their technology needs. But the participation of "silent" stakeholders, particularly resource-poor farmers, needs to be carefully managed to ensure they are also heard. Ex ante assumptions on the potential for technology generation and adoption also need to be explicitly incorporated into future ex post monitoring and evaluation efforts. Stakeholder groups will then have a much better basis for annual project review. Finally, priorities will also need to be set across commodity groups with very different stakeholders. The mandate to target specific client groups at the expense of others needs to be explored more explicitly. KARI has made great progress in improving its process for research program planning. These issues represent challenges for further improvement.

Acknowledgments

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References

Akino, M. and Y. Hayami. 1975. Efficiency and equity in public research: Rice breeding in Japan's economic development. *American Journal of Agricultural Economics* 57: 1-10.

Alston, J.M., G.W. Norton, and P.G. Pardey. 1995. Science under scarcity: Principles and practices for agricultural research evaluation and priority setting. Ithaca, N.Y.: Cornell University Press.

Argwings-Kodhek, G. 1993. Exporting Kenya's horticultural production. In *Proceedings of the conference on agricultural exports and market* *development.* Policy Analysis Matrix. Nairobi: Kenya Commercial Bank, Institute of Banking and Finance.

Bernsten, R. and J. Staatz. 1992. The role of subsector analysis in setting research priorities. MSUAgricultural Economics Staff Paper 92-104. East Lansing: Michigan State University.

Bezunch, M., B. Deaton, and G. Norton. 1988. Food aid impacts in rural Kenya. *American Journal of Agricultural Economics* 70: 181-191.

CBS. 1982. Rural household budget survey - basic report. Nairobi: Central Bureau of Statistics.

CBS. 1994. Kenya population census - 1989. Nairobi: Central Bureau of Statistics.

Collion, M. and A. Kissi. 1994. Guide d'élaboration de programmes et d'établissement de priorités. ISNAR Research Management Guidelines No. 2. The Hague: International Service for National Agricultural Research.

Edwards, G.W. and J.W. Freebairn. 1984. The gains from research into tradable commodities. *American Journal of Agricultural Economics* 66: 41-49.

FAO. 1993. Horticulture and traditional food crop project, volume II, report no. 86/93 ADB-Ken 34. Investment Centre, FAO/ADB Co-operative program.

Feder, G., R.E. Just, and D. Zilberman. 1985. Adoption of agricultural innovations in developing countries: A survey. *Economic Development and Cultural Change* 33: 255-98.

Jaetzold, R. and H. Schmidt. 1983. Farm management handbook of Kenya. Nairobi: Ministry of Agriculture.

Kamau, M., D. Kilambya, and B. Mills. 1997. Commodity program priority setting: The Kenya Agricultural Research Institute experience. Briefing Paper No. 34. The Hague: International Service for National Agricultural Research.

Kiori, G. and K. Gitu. 1992. Supply response in Kenyan agriculture: A disaggregated approach. Ministry of Planning and National Development Technical Paper 92-1 1. Nairobi: Ministry of Planning and National Development.

Mills, B.F. 1997. Ex-Ante agricultural research evaluation with site specific technology generation: The case of sorghum in Kenya. *Agricultural Economics* 6: 125-38.

Ministry of Agriculture Livestock Development and Marketing. District annual reports 1990 - 1994. Nairobi: Ministry of Agriculture Livestock Development and Marketing.

Norton, G. W. and J.S. Davis. 1981. Evaluating returns to agricultural research: A review. *American Journal of Agricultural Economics* 63: 683-99.

Norton, G.W., V.G. Ganoza, and C. Pomareda. 1987. Potential benefits of agricultural research and extension in Peru. *American Journal of Agricultural Economics* 69: 247-57.

Nyoro, J. K. 1993. Production of horticultural export crops in Kenya. In *Proceedings of the Conference on Agricultural Exports and Market*

Development. Policy Analysis Matrix. Nairobi: Kenya Commercial Bank, Institute of Banking and Finance.

Peterson, W. 1967. Return to poultry research in the United States. *Journal of Farm Economics* 49: 656-70.

Peterson, W. and G. Henry. 1992. International snap bean trade: Present status and future prospects. In *Snap beans in the developing world,* edited by G. Henry and W. Janssen. Cali: Centro International de Agricultura Tropical.

Rao, J. 1989. Agricultural supply response: A survey. *Agricultural Economics* 3: 1-22.

Rose, R.N. 1980. Supply shifts and research benefits: A comment. *American Journal of Agricultural Economics* 62: 834-44.

Scobie, G.M. and R.T. Posada. 1973. The impact of technical change on income distribution: The case of rice in Colombia. *American Journal of Agricultural Economics* 60: 85-92.

Stewart, J. 1995. Models of priority setting for public research. *Research Policy* 24: 115- 126.

Voon, J.P. and G.W. Edwards. 1991. The calculation of research benefits with linear and nonlinear specifications of demand and supply functions. *American Journal of Agricultural Economics* 73: 415-20.

Wood, S. and P. Pardey. 1998. Agroecological aspects of evaluating agricultural R&D. *Agricultural Systems* 57 (1): 13-41.

World Bank. 1996. World Development Report 1996. Oxford: Oxford University Press.

Appendix 8.1. Expected Net Yield Gains and Adoption Parameters

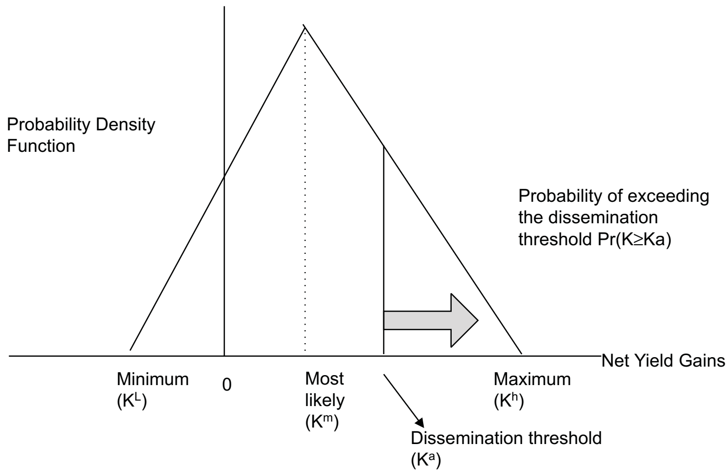
	Brassicas								
	Percent Net Yield Gains								
	Min.	Most Likely	Max.	Dissemination Threshold	Research and Development Lag (Years)	Maximum Adoption (Years)	Maximum Adoption Rate (%)	Start of Disadoption (Years)	Complete Disadoption (Years)
Varietal Development									
High Mid-Altitude	20	30	60	15	3	7	60	11	15
High Altitude	10	25	50	10	3	7	50	11	15
Mid-Altitude	20	60	80	15	3	7	60	11	15
Crop Management									
High Mid-Altitude	0	10	20	7.5	3	7	50	na	na
High Altitude	0	0	0	0					
Mid-Altitude	0	5	20	6.7	3	7	60	na	na
Crop Protection									
High Mid-Altitude	5	20	50	10	3	7	70	na	na
High Altitude	5	20	50	15	3	7	70	na	na
Mid-Altitude	5	20	40	15	3	7	70	na	na
Technology Development									
High Mid-Altitude	15	30	60	15	3	7	60	na	na
High Altitude	15	25	50	15	3	7	60	na	na
Mid-Altitude	10	30	60	15	3	7	50	na	na
Postharvest									
High Mid-Altitude	5	18	25	14.4	3	7	65	na	na
High Altitude	5	10	15	10	3	7	40	na	na
Mid-Altitude	5	18	25	14.4	3	7	60	na	na

Appendix 8.1. Expected Net Yield Gains and Adoption Parameters (continued)

	Snap Beans								
	Percent Net Yield Gains								
	Min.	Most Likely	Max.	Dissemination Threshold	Research and Development Lag (Years)	Maximum Adoption (Years)	Maximum Adoption Rate (%)	Start of Disadoption (Years)	Complete Disadoption (Years)
Varietal Development									
High Mid-Altitude	10	30	50	7,5	3	6	70	11	16
High Altitude	20	30	50	7.5	3	6	70	11	16
Mid-Altitude	25	50	75	7.5	3	6	70	11	16
Crop Management									
High Mid-Altitude	5	10	20	15	4	8	25	na	na
High Altitude	5	10	20	15	4	8	25	na	na
Mid-Altitude	5	15	25	15	4	8	25	na	na
Crop Protection									
High Mid-Altitude	5	10	25	15	4	14	70	na	na
High Altitude	5	15	30	8	4	14	70	na	na
Mid-Altitude	20	35	70	15	4	14	70	na	na
Technology Development									
High Mid-Altitude	15	35	70	15	3	7	60	na	na
High Altitude	15	35	70	15	3	7	60	na	na
Mid-Altitude	15	35	70	15	3	7	60	na	na
Postharvest									
High Mid-Altitude	15	18	20	15	3	6	70	na	na
High Altitude	15	18	20	15	3	6	70	na	na
Mid-Altitude	15	33	35	15	3	6	70	na	na

Appendix 8.2. Modeling the Probability Distribution of Research Outcomes

Let k represent the net yield gain of an innovation. The minimum potential net yield gain is k^l; the most probable net yield gain is k^m; and the maximum net yield gain is k^h. The minimum net yield gain necessary for an innovation to be released for dissemination is k^a. For every k there is a corresponding probability f(k), where f(k) is assumed to arise from a triangular probability density function. The probability of achieving k^a is $Pr(k>k^a)$. The expected net yield gain, conditional upon k^a being achieved, is $E[k|k>k^a]$.



Chapter 9
Beyond Economic Benefits: Sorghum in Kenya[8]

Bradford Mills and Lawrence M'Ragwa

Introduction

The complex relationship between technologies and other components of the agricultural economy limits effective forecasting of the economic benefits to be gained from alternative agricultural research investments. This is particularly true in sub-Saharan Africa, where agricultural production systems are characterized by tremendous diversity and rapid change. The horticultural program priority-setting exercise discussed in the previous chapter demonstrates that population growth and market structure can be important determinants of potential agricultural research benefits. However, concerns are commonly raised when using economic-surplus-based measures that two key factors are not adequately captured in the analysis. The first factor is the future nonresearch-induced growth (or decline) in production of specific commodities. The second factor is the social benefits to be gained by targeting research directly to poor households.

Research can be a major contributor to agricultural commodity growth. However, it is rarely the only source of growth. In many countries in sub-Saharan Africa, a major portion of commodity area expansion is directly linked to population growth. This is particularly true in marginal environments where population growth causes expansion of farming activities onto previously uncultivated areas.[9] In areas already under continuous cultivation, increasing labor to land ratios tend to lead to intensification of production and accompanying yield increases. Other factors, like infrastructure development, may also influence production. Increased production, in turn, creates a larger commodity base upon which research benefits accrue. Current area and production trends can provide benchmark indicators of expected future

8. This chapter draws on material from Mills (1997).
9. Research can influence the rate of area expansion by increasing the suitability of commodities for marginal environments.

commodity growth trends and can be easily factored into research benefit analysis. The influence of other potential sources of growth on commodity production can also be explored through the structured development of growth scenarios.

Equity concerns are more difficult to address. Both national and international research organizations face pressure to ensure that the rural poor share in gains from agricultural research. Many countries now have national welfare surveys that can be used to identify where the poor reside and which commodities they produce and consume. Once the poor and their characteristics are identified, economic surplus analysis can help research planners to understand the relative share of benefits they receive from alternative research investments. On the other hand, economic theory provides little guidance on appropriate weights for redistributing benefits between different social groups in order to address equity concerns.

This chapter uses results of a program-level priority-setting exercise undertaken in the KARI sorghum program to explicitly address nonresearch-induced growth and equity concerns. Successive sections

1. establish the thematic and spatial framework for the analysis
2. analyze sorghum markets in Kenya
3. present area expansion and equity concerns
4. identify the number of poor households in each research zone using household welfare survey results and estimate their share of sorghum research benefits

The chapter concludes with a brief discussion of the political process of allocating resources to target the poor.

Research themes, zones, and the potential for technology generation and adoption

The sorghum program priority-setting process was guided by a priority-setting working group composed of key program scientists and extension workers from different disciplines and regions throughout Kenya.[10] The working group identified four major research themes within the sorghum program. Three of these are reviewed in this chapter: varietal development; crop management; and processing, utilization, and storage.[11] In addition to these themes, the national mandate of the program was divided into broad research zones. These demarcate areas within which the application of new technologies arising from the research themes are deemed to have a relatively homogeneous biophysical (e.g., yield) effect.

10. The working group consisted of agronomists, entomologists, pathologists, plant breeders, processing specialists, socioeconomists, and extension officers.
11. The fourth major research theme is technology dissemination, which focuses on disseminating existing research results through improved linkages with farmers and extension. The translation of research results into economic benefits under the theme is, arguably, different and benefit estimates are not discussed in this paper.

Four research zones were identified by the working group: the humid coastal, semiarid lowland, moist mid-altitude, and cold dry highlands. Zones were demarcated by interactively mapping alternative sets of agroclimatic criteria from a GIS.[12] The three agroclimatic determinants (elevation, rainfall, and temperature) and the final criteria used to define relevant sorghum research zones are given in table 25. A map of zone locations within Kenya is in appendix 9.1.

Table 25. Sorghum Target Zones

	Elevation (meters)	Rainfall[a] (mm)	Temperature (degrees Celsius)
Humid coastal	0-250	225-500 March-June, 50 March-April, and 40 June	not applicable
Semiarid lowlands	250-1150	250-525 March-July or October-December	>11° average min. for July
Moist mid-altitude	1150-1750	500-1250 March-July	not applicable
Cold dry highlands	1750-2300	40 March-April	> 5° average min. for July

[a] For the semiarid lowlands, rainfall may occur either between March and July or October and December.

Sorghum production estimates for each zone were then calculated based on district-level production averages (1990 to 1993) from the Central Bureau of Statistics (CBS) and first rain and second rain estimates (table 26).[13] When production statistics are allocated to zones, the moist mid-altitude zone ranks first, accounting for 63 percent of the area sown to sorghum and 78 percent of total sorghum production. The semiarid lowlands zone ranks a distant second, while the cold dry highlands and humid coastal zones have very low imputed production estimates.

Ex ante technology generation and adoption parameters were estimated by the KARI sorghum program priority-setting working group and reviewed in a larger meeting of program stakeholders known as the “program research advisory committee” or PRAC.

The working group assumptions on the potential for technology generation and adoption are in tables 27 and 28, respectively, for each research theme and zone. The rationale behind the assumptions can be read in the program’s priority-setting document (KARI 1995). Benchmark information on historical yield and production growth trends in the target zones, along with available information on adoption of previously released technologies, were used as reference points for parameter elicitation.

12. Further description of the final criteria used in the sorghum program target zones is found in KARI (1995).
13. District area and production statistics were allocated to research zones based on the proportion of the district classified to each zone.

Table 26. Benchmark Sorghum Supply and Demand by Research Target Zone

	Production (1000 MT)	Consumption (1000 MT)	Net Surplus (1000 MT)
Humid coastal	0.02	3.51	-3.49
Semiarid lowlands	13.85	12.08	1.77
Moist mid-altitude	61.20	31.53	29.67
Cold dry highlands	3.53	16.88	-13.35
Non-urban rest of Kenya[a]	0.00	8.58	-8.58
Nairobi	0.00	6.03	-6.03
Total	78.60	78.60	0.00

Note: MT = metric tons.
Sources: Central Bureau of Statistics, 1991 to 1993 Annual Production Statistics; Central Bureau of Statistics Census and Household Consumption Statistics (CBS 1982, 1994).
[a]These districts are in non-sorghum-growing regions, primarily the arid northern province.

Characteristics of sorghum markets in Kenya

Current net sorghum production—consumption balances, prices, and expected exogenous demand shifts due to population growth—were also estimated for each research zone using existing agricultural sector data. Sorghum markets in Kenya are generally characterized as closed to international trade.[14] Hence, the aggregate demand for sorghum within Kenya is assumed to equal aggregate supply. The distribution of sorghum consumption across districts is then calculated based on household sorghum/millet consumption estimates from the 1979 Kenya Rural Household Budget Survey and 1989 district-level household population figures (CBS 1982 and 1994).[15] Finally, the consumption of sorghum is allocated to target zones proportional to the zone area in each district. The resulting figures are compared with the research zone production estimates to impute the current net sorghum surplus by zone, table 26.

The results show the moist mid-altitude zone is the major surplus producer of sorghum in Kenya, while the semiarid lowlands zone is roughly self-sufficient in an average year. The major net deficit zone is the cold dry highlands which, along with the humid coastal zone, Nairobi, and the non-urban rest of Kenya must rely on surpluses from the moist mid-altitude zone to meet consumption needs.

14. FAO trade statistics indicate that between 1989 and 1992, Kenya imported only 15,000 metric tons of sorghum (all in 1992) and exported 16,000 metric tons. However, these figures do not include illicit cross-border trade, particularly with Uganda on the country's western border.
15. No household-level millet or sorghum consumption figures existed for the urban centers of Nairobi and Mombassa, or the districts in the northeastern province. National household averages are used in these areas.

Table 27. Estimated Expected Yield Gains from Research, by Target Zone

Theme/zone	Net yield gains (5)			Adoption threshold	Probability of dissemination	Conditional expected net yield increase (%)
	Minimum	Most likely	Maximum			
Vertical Development						
Humid coastal	6.75	40.50	54.00	15.00	0.96	34.71
Semiarid lowlands	5.25	37.50	49.50	15.00	0.93	32.11
Moist mid-altitude	0.00	14.30	42.00	15.00	0.63	22.91
Cold dry highlands	0.00	10.00	22.00	15.00	0.19	17.50
Crop Management						
Humid coastal	22.50	45.00	75.00	25.00	0.99	47.62
Semiarid lowlands	15.00	37.50	45.00	30.00	0.67	36.25
Moist mid-altitude	17.50	37.50	125.00	50.00	0.60	71.97
Cold dry highlands	25.00	50.00	83.30	30.00	0.98	53.19
Processing, Utilization, and Storage						
Humid coastal	10.00	17.50	25.00	20.00	0.22	21.46
Semiarid lowlands	3.50	7.50	20.00	15.00	0.12	16.46
Moist mid-altitude	10.00	20.00	50.00	12.50	0.98	27.09
Cold dry highlands	0.00	10.00	20.00	15.00	0.130	16.46

The spatial distribution of sorghum prices was empirically estimated from 1992 and 1993 CBS and Ministry of Agriculture monthly retail price data for 23 markets across Kenya. The markets were spatially referenced and Thiessen polygons were constructed in order to allocate all area within Kenya to the nearest market (Eastman 1992). Area-weighted monthly prices were then calculated for each research zone. In table 29, the observed distribution of zone prices is expressed relative to January through April 1995 retail prices in the capital city of Nairobi. The estimated price wedges are

Table 28. Estimated Adoption Profile for Sorghum Technology, by Target Zone

Theme/zone	Research and Development Lag (Years)	Maximum Adoption (Years)	Maximum Adoption Rate (%)	Start of Disadoption (Years)	Complete Disadoption (Years)
Vertical Development					
Humid coastal	7	22	5	29	44
Semiarid lowlands	6	16	20	22	32
Moist mid-altitude	6	16	20	22	32
Cold dry highlands	8	23	50	nd	nd
Crop Management					
Humid coastal	4	19	20	nd	nd
Semiarid lowlands	4	14	25	nd	nd
Moist mid-altitude	4	14	5	nd	nd
Cold dry highlands	4	14	40	nd	nd
Processing, Utilization, and Storage					
Humid coastal	3	8	40	nd	nd
Semiarid lowlands	2	7	40	nd	nd
Moist mid-altitude	2	5	70	nd	nd
Cold dry highlands	3	8	12.5	nd	nd

Table 29. Sorghum Prices Per Ton and Population Growth by Target Zone

	Price		Population growth	
Target Zone	Kenya Shilling Per Ton	Wedge to Nairobi	1979-1989 Growth Rate (%)	Projected Growth Rate (-25%)
Humid coastal	10,730	1,795[a,b,c,d]	4.12	3.09
Semiarid lowlands	7,671	-1,264[b,c,e]	3.44	2.58
Moist mid-altitude	6,470	-2,465[a,d,e]	3.13	2.35
Cold dry highlands	6,401	-2,534[a,d,c]	3.64	2.73
Nairobi	8,935	0[b,c]	4.70	3.53
Non-urban rest of Kenya	na	na	1.24	0.93

Sources: Central Bureau of Statistics and Ministry of Agriculture retail market prices surveys, Central Bureaus of Statistics 1979 and 1989 censuses.
Notes: Estimates in this table are expressed relative to January - April 1995 Nairobi retail prices in Kenyan shillings (one United States dollar equals approximately 55 Kenyan shillings).
[a] Wedge significantly different (5% level) from the semiarid lowland zone in paired t-Test.
[b] Wedge significantly different (5% level) from the moist mid-altitude zone in paired t-Test.
[c] Wedge significantly different (5% level) from the cold dry highland zone in paired t-Test.
[d] Wedge significantly different (5% level) from the Nairobi zone in paired t-Test.
[e] Wedge significantly different (5% level) from the humid coastal zone in paired t-Test.
na = not available, Nairobi prices used in the analysis.

assumed to reflect the costs of moving sorghum between zones. These wedges are held constant in simulations of research-induced supply shifts in specific zones.

While research can be expected to influence the supply of sorghum in Kenya, the most important factor influencing sorghum demand is population growth. Zone-specific population growth rates are calculated using 1979 and 1989 district census estimates, again assuming that population is proportionally distributed by zone area in each district (CBS 1994). Between 1979 and 1989 the Nairobi area had the highest rate of population growth, 4.7 percent per annum, while the non-urban rest of Kenya (primarily the northern province districts) showed the lowest rate of growth, at 1.2 percent per annum (table 29). The sorghum-producing zones all showed very high rates of population growth, ranging from 3.1 percent per annum in the moist mid-altitude zone to 4.1 percent per annum in the humid coastal zone. These growth rates were discounted by 25 percent when modeling the impact of population growth on the demand for sorghum over the next 30 years in order to reflect projected decreased rates of population growth. In simulating supply-side shifts, the initial assumption was made of no exogenous sources of growth other than the research-induced shifts of supply. This assumption is reasonable given that the overall area under sorghum production remained fairly constant over the past 20 years. Nonetheless, it is examined in greater depth later in this chapter.

Finally, the nature of shifts in the supply and demand curves will have an important impact on the magnitude of the benefits to be gained by research and the distribution of these benefits between producers and consumers. In the absence of contrary information, supply and demand curves are assumed to be linear and to shift in parallel. The actual slopes of the curves are determined by the supply and demand elasticities for sorghum. No supply elasticities had been estimated specifically for sorghum in Kenya. However, Rao (1987) reviews the empirical literature on supply response in developing countries and finds that long-run supply responses generally lie in the 0.3 to 1.2 range. In empirical studies of supply response, Bapna, Binswanger, and Quizon (1984) estimate supply elasticities ranging from 0.38 to 0.77 for the semiarid sorghum zones in India. Chidder and Hrabovszky (1983) estimate a supply elasticity of 0.16 for sorghum in the Sudan. In Kenya, a supply elasticity of 0.68 was estimated for maize (Kiori and Gitu 1992), a production substitute for sorghum in certain zones. Based on this range of estimates, the current study used a long-run supply elasticity of 0.5. While the choice of supply elasticity will affect the absolute value of estimated research benefits, it will rarely affect the relative ranking of research themes and zones. Similarly, an own-price demand elasticity of -0.5 is used, in line with the estimate of Bezuneh, Deaton, and Norton (1988) for sorghum and millet consumption in Kenya.

Research benefits in spatially linked production zones

Like the horticulture exercise in chapter eight, the change in economic surpluses (consumer surplus and producer surplus) is used to measure the economic benefits generated from specific research themes within zones over a 30-year time period. The model also accounts for period-specific research-induced supply shifts, increased demand for commodities due to population growth, inter-zonal price wedges, and research-induced price spillovers to other target zones.

Simulated changes in producer and consumer surplus due to research-induced supply shifts are presented in table 30 based on a five percent real discount rate. Changes in total surplus vary markedly across research themes and target zones. Based on program assumptions about the potential for generation and adoption of technologies and its current allocation of human resources, the sorghum program expects to generate total benefits of 294 million Kenyan shillings (Ksh) through varietal development research, Ksh 445 million through crop management research, and Ksh 2,392 million through processing, utilization, and storage research.

Sorghum production shows a greater variance across zones than do expected yield gains, adoption rates, or prices. Therefore, within each theme, the ranking of benefit estimates corresponds to the distribution of production. However, the potential for generation and adoption of technologies plays an important role in determining the ranking of research theme benefits within each zone. In the moist mid-altitude zone, the processing, utilization, and storage research theme shows far greater potential benefits than the varietal development or crop management research themes. This is due to the significantly higher expected rate of adoption of technologies generated under the former theme. Similarly, for the semiarid lowlands zone, benefits are concen-

Table 30. Potential Economic Surplus Generated by Sorghum Research

	Humid Coastal	Semiarid Lowlands	Moist Mid-Altitude	Cold Dry Highlands	All Zones
Varietal Development		*(millions of Kenyan shillings)*			
Producer Surplus	0.03	55.91	88.54	2.46	145.89
Consumer Surplus	0.02	46.20	98.84	2.77	148.17
Total Surplus	0.05	102.10	187.39	5.23	294.06
		Crop Management			
Producer Surplus	0.24	78.04	90.55	56.67	222.74
Consumer Surplus	0.12	64.04	101.13	56.26	222.70
Total Surplus	0.37	142.33	191.67	112.92	445.43
		Processing, Utilization, and Storage			
Producer Surplus	0.07	12.97	1134.43	0.78	1146.17
Consumer Surplus	0.04	10.92	1233.43	0.89	1246.29
Total Surplus	0.10	23.89	2368.21	1.67	2392.46
		Per Full-Time-Equivalent Researcher			
		Varietal Development			
Total Surplus	0.17	102.10	187.39	5.23	89.11
		Crop Management			
Total Surplus	0.53	118.61	95.84	112.92	90.90
		Processing, Utilization, and Storage			
Total Surplus	0.50	23.89	4736.42	0.84	646.61

trated in the varietal development and crop management research themes. In the cold dry highlands, crop management shows higher benefits than the other themes. Finally, in the humid coastal zone, benefit estimates are extremely low for all themes due to the small production base.

In all cases, producer gains represent a slightly greater proportion of total surplus changes than consumer gains. Further, consumer surplus benefits are widely distributed across Kenya due to price decreases through linked markets. Producer surplus gains, by contrast, are concentrated within the targeted research zone, where the additional surplus generated from lower unit production costs outweighs the loss incurred from a lower price. Research has a negative effect on producer surplus in zones not specifically targeted by research because the lower equilibrium price is not offset by unit cost reductions in the zone.

Table 30 also presents potential research benefits based on the number of full-time-equivalent researchers involved in each research theme. This estimate is based on the current allocation of human resources in the sorghum program across themes and zones. Zone-specific themes with large ratios of benefits to number of full-time-equivalent researchers may be priority areas for further human resource investments. Research production functions, however, are rarely linear and the reallocation of human and financial resources needs to be determined through a consensus-building process with the program research advisory committee.[16]

Finally, an examination of equilibrium price and quantity trends over time highlights the challenge that population growth poses for agricultural technology development in Kenya. Without research, and explicitly assuming no other source of growth in production, population-induced demand growth in a closed economy is projected to cause the equilibrium sorghum price to increase by 69.7 percent over the 30-year planning horizon. The accompanying increase in equilibrium quantity, induced by the price rise, is 46.8 percent. If the expected research impacts are achieved in all themes and zones, the equilibrium price of sorghum will still increase by 50.9 percent, while the equilibrium quantity will increase by 58.6 percent over the same 30-year horizon.[17] The accompanying net present value of research benefits over the 30-year period are estimated at slightly more than three billion Kenyan shillings.

Area expansion and equity concerns

Participants in priority-setting exercises are sometimes concerned that research and research-induced price effects are not the only factor influencing commodity growth.[18] Priority-setting working groups and stakeholder groups may wish to explore alternative assumptions about future commodity growth and the implications of those assumptions for agricultural research benefit estimates. Quantitative statistics on recent area and production growth trends in research target zones provide a crucial benchmark. Similarly, research programs may have an explicit mandate to differentially target research results to rural areas with high concentrations of poorer households.[19] Again, household survey data can provide important benchmark information on the distribution of household welfare across research regions. This section uses published data, available in most countries, to empirically explore these growth and equity concerns.

Area expansion

An examination of national production statistics suggests that during the 1970s Kenya saw a general substitution away from sorghum production and

16. Alternatively, nonlinearities in the research production function can be modeled by eliciting expected changes in technology generation and adoption parameters for a given change in program resources.
17. Technology generation and adoption parameters were aggregated across themes in each zone by adding expected net yield parameters and averaging adoption profile parameters.
18. This concern is supported by a recent estimate that only one-third of observed commodity growth in sub-Saharan Africa is associated with agricultural research efforts (Block 1995).
19. This assumes that agricultural research is an effective policy instrument for redistributing resources to poorer households.

consumption to maize and wheat (FAO 1996). The 1980s then showed relatively stable ratios within the sorghum, maize, and wheat commodity group. These aggregate growth trends, however, mask regional disparities. As table 29 showed, population growth is greatest outside the major sorghum-producing area (the moist mid-altitude zone). Using 1984 to 1993 district-level data, we test whether this population growth was accompanied by growth in the area under sorghum production in the semiarid lowlands, cold dry highland, and moist mid-altitude zones (table 31).[20] The observed trends suggest the semiarid lowlands and cold dry highlands both had negative rates of area expansion over the 1984 to 1993 period. By contrast, the average annual rate of area expansion for sorghum in the moist mid-altitude zone was 4.3 percent per year. Despite these area trends, there was rapid growth in production, particularly in the semiarid lowlands zone (averaging 12.4 percent per annum over the period). This suggests that production gains in the semiarid lowlands zone have come primarily through yield increases.[21]

If we assume that nonresearch-induced supply growth is due primarily to area expansion, inclusion of exogenous supply growth in the research benefits model further widens the future gap in the production bases of the zones. Thus, the available agricultural statistics do not support the claim that the semiarid lowlands zone should receive differential targeting of sorghum program research resources based on recent area growth trends. The results of this specific application should not, however, be interpreted as implying that nonresearch-induced growth cannot have an important influence on future research benefits. Rather, the results highlight the need to develop accurate profiles of current commodity-sector trends as a basis for future predictions. Other factors, such as research and extension efforts to promote new sorghum technologies and emerging markets among breweries and millers, might suggest more favorable future growth trends in the semiarid lowlands zone. But the semiarid lowlands production base will have to expand at the rate of 50 percent annually for total research benefits in the semiarid lowlands to equal benefits in the mid-altitude zone over the 30-year period under evaluation.

Equity

Equity concerns usually focus on ensuring that households at the lower end of the distribution of percapita household expenditures (henceforth referred to as poor households) benefit from the generation and adoption of agricultural technologies. Justifications for differential targeting of poor households are found in chapter two. At the aggregate level, programs may target additional research resources to areas where the majority of poor households are located or where the relative ratio of poor to non-poor households is high. At a more disaggregate level, within specific zones poor and non-poor house-

20. The method for calculating average annual growth rates is presented in chapter five. It should be noted that the accuracy of the data used in the analysis is open to debate and none of the average annual growth rates presented are statistically different from zero.
21. The KARI sorghum program has released several varieties that have contributed to the observed yield increase.

Table 31. Growth Trends and Household Welfare in Sorghum Research Target Zones, 1984-1993

	Humid Coastal	Semiarid Lowlands	Moist Mid-Altitude	Cold Dry Highlands
Annual rate of expansion	—	-1.0	-4.3	-3.1
Annual rate of production	—	12.4	5.4	2.1
Households in bottom two expenditure quintiles				
Number	28,580	209,270	631,960	335,770
Percent of households in zone	34	48	43	35

Note: Area and production time series are not available for most districts in the humid coastal zone.
Sources: Central Bureau of Statistics Sorghum Area and Production Estimates, 1984-93; Central Bureau of Statistics National Welfare Monitoring Survey, 1996.

holds have different control of and access to resources. Resource differences often translate into different production systems and technology demands. If the poor can be identified within zones, programs may then focus on research themes, and associated constraints, that address their specific needs and resources. This application focuses on aggregate targeting by location. However, the distribution of sorghum production and consumption by the size of household land holding and the implications for the distribution of research benefits to poor and non-poor households is also briefly examined.

Information on the distribution of household welfare is available from the 1994 Kenya National Welfare Monitoring Survey. Specifically, published tables exist on the number of households in each district falling within each quintile of the national distribution of household expenditures.[22] However, household welfare is better reflected by household expenditures per capita. Household quintile distribution information was, therefore, adjusted for differences in average household size per district. The estimated number of households falling in the bottom two quintiles (bottom 40 percent) of the national distribution of per capita household expenditures is presented in table 31. The majority of these relatively poor households reside in the moist mid-altitude zone. This is primarily due to the large number of households in the zone. However, the moist mid-altitude zone also shows a slightly higher incidence of households in the bottom two quintiles than the national average (43 percent versus 40 percent).

22. Expenditure quintiles divide households into five expenditure groups of equal size based on all districts. District or research zone expenditure distributions can then be compared to those of the whole country. For example, districts with a greater share of low-expenditure households would be expected to show more than 40 percent of households in the bottom two quintiles.

The cold dry highland zone shows the second largest total number of poor households. However, only 35 percent of households reside in the bottom two expenditure quintiles. By contrast, the relatively sparsely populated semiarid lowlands zone contains only 209,270 households in the bottom two quintiles of the national per capita household expenditure distribution. These low-expenditure households, however, represent 48 percent of households in the semiarid lowlands zone. An argument can be made for differentially targeting the semiarid lowlands zone because of this high incidence of poverty. But it must be explicitly recognized that the absolute number of poor targeted through such a strategy may be smaller than by research in the moist mid-altitude or cold dry highland zones.

Even if research is targeted to zones where the absolute number or incidence of poorer households is quite high, the question remains of what share the poorer households receive of research benefits, as either producers or consumers of sorghum. Unfortunately, the Kenya welfare survey does not provide information on the production and consumption of sorghum by household expenditure. Information on sorghum production and consumption is, however, provided by size of household land holding. The rest of the analysis assumes that sorghum production and consumption characteristics of the 42.2 percent of households with a land holding of less than one hectare are representative of households in the bottom two expenditure quintiles.[23] Based on this assumption, households with less than one hectare of land are estimated to produce 6.5 percent of all sorghum and consume 19.5 percent of all sorghum.[24] The distribution of research benefits to poor and non-poor households in both the semiarid lowlands and moist mid-altitude zones are presented in table 32 for two scenarios. In the first scenario, research is conducted only in the semiarid zone. However, the benefits to consumers and losses to producers that occur in the moist mid-altitude zone from price spillovers are also measured. In the second scenario, research occurs only in the moist mid-altitude zone, but gains to consumers and losses to producers through price spillovers in the semiarid lowlands zone are again measured.

Several interesting points can be drawn from the results. First, research benefits in both zones are heavily biased towards non-poor households, since they are the major producers and consumers of sorghum. Second, in aggregate, poorer households benefit from research primarily as consumers of lower priced sorghum. Finally, total research benefits (producer plus consumer) for poor households in the semiarid lowlands are slightly greater when research is concentrated in the moist mid-altitude zone than when research is concentrated in the semiarid lowlands zone. This latter result is due to the strong impact that research-induced price decreases have on net consumers of sorghum. Thus, the poor in the semiarid lowland zone potentially

23. This assumption does create a potential bias against poorer households in the extensive production systems found in the semiarid lowlands zone.
24. These figures compare unfavorably in terms of equity, with maize, where poor household production and consumption are 35.7 percent and 36.7 percent of the total share, respectively. Hence, within the broader scope of research on commodities, sorghum may not be the most effective mechanism for targeting the poor.

Table 32. Distribution of Research Benefits by Zone and Welfare Class (millions of Kenyan shillings)

		Semiarid Lowlands		Moist Mid-Altitude		Total	
		Producers	**Consumers**	**Producers**	**Consumers**	**Producers**	**Consumers**
Scenario 1:							
Research in semiarid lowlands	poor	24	5	-9	-9	15	19
	non-poor	343	22	-127	-127	216	76
Scenario 2:							
Research in moist mid-altitude	poor	-14	42	100	102	86	145
	non-poor	-204	174	1,441	422	1,238	597

benefit more from increased sorghum research in the moist mid-altitude zone than from research in their own semiarid zone.

While the results are, again, very specific to the current case, and dependent on assumptions about the share of poorer households in sorghum production and consumption, they do highlight the important role that price spillovers can play in analyses of the distribution of research benefits. Two additional pieces of information are needed to undertake a more in-depth analysis of the impact of sorghum research on poorer households: 1) the distribution of sorghum production and consumption by per capita household expenditure quintiles and 2) the potential for generation and adoption of sorghum technologies specific to the needs of the poor in each zone. The first piece of information could be recovered from the national welfare survey data. The second piece would have to be elicited from the sorghum program priority-setting working group based on their knowledge of the technology needs of poor households in each zone.

The political process of resource allocation

The economic analysis presented above can assist practitioners in establishing the set of potential benefits accruing to poor and non-poor households from different allocations of research resources across or within research zones or program themes. The economic analysis is, however, of limited guidance in deciding what weight should be given to benefits going to poor households relative to non-poor households when allocating research resources. In the present case, we can state that poorer households appear to benefit more from blunt targeting of research efforts to the moist mid-altitude zone than from research targeted towards production in the semiarid lowlands zone. However, the analysis cannot determine an appropriate ratio for foregoing potential benefits for non-poor households to target technology development to poor households.

Results in table 32 suggest that only about one eighth of the benefits from sorghum research go to the poor. This ratio could certainly be improved through more concentrated targeting of research on the needs of poor households. But what are the trade-offs? We can frame such trade-offs in terms of actual production gains from research. For example, would it be acceptable to shift research resources to target the poor until one ton of addition sorghum was gained by poor households and two tons taken away from non-poor households? What if one ton of additional sorghum for the poor was traded for five tons for the non-poor; or if one ton for the poor were traded for ten tons for the non-poor? Clearly, if equity criteria are to be employed, agricultural research policy must specify what are acceptable trade-offs.

A related issue is the effectiveness of agricultural research as a mechanism for targeting the poor. Ideally, redistribution of benefits from non-poor to poor households should take place at minimal cost to society. Perhaps sorghum program resources can be more effectively used to target poverty if they are transferred to the maize program, or alternatively, transferred to a basic health care project. When equity trade-offs are presented in this broader framework, most proponents of equity concerns express considerably lower rates of trade-offs for the redistribution of benefits. This is because there are often significantly cheaper options for transferring resources from non-poor to poor households. Research planners must often view equity issues within the broader portfolio of rural development activities.

References

Alston, J., G. Norton, and P. Pardey. 1995. Science under scarcity: Principles and practices for agricultural research evaluation and priority setting. Ithaca, N.Y.: Cornell University Press.

Bapna, S., H. Binswanger, and J. Quizon. 1984. Systems of output supply and factor demand equations for semiarid tropical India. *India Journal of Agricultural Economics* 39: 179-202.

Bezunch, M., B. Deaton, and G. Norton. 1988. Food aid impacts in rural Kenya. *American Journal of Agricultural Economics* February: 181-191.

Block, S.A. 1995. The recovery of agricultural productivity in sub-Saharan Africa. *Food Policy* 20 (October 1995): 385-406.

Buchanan, J. and G. Tullock. 1962. The calculus of consent. Ann Arbor: University of Michigan Press.

CBS. 1982. Rural household budget survey--basic report. Unpublished document. Nairobi: Government Printer.

CBS. 1994. Kenya population census 1989. Nairobi: Government Printer.

CBS. 1996. Welfare monitoring survey II: 1994 basic report. Nairobi: Government Printer.

Chidder A. and J.P. Hrabovszky. 1983. Agricultural price and investment policy in the Sudan: A linear programming approach. Rome: Food and Agriculture Organization of the United Nations.

Corbett, J. 1994. Agroclimatic classification of maize production zones in Kenya: A multi-variate cluster analysis approach. KARI/CIMMYT Maize Database Project Paper. Nairobi: Kenya Agricultural Research Institute.

Eastman, J.R. 1992. IDRISI Version 4: Technical reference manual. Worcester: Graduate School of Geography, Clark University.

FAO. 1996. FAOSTAT Database. Rome: Food and Agriculture Organization of the United Nations.

KARI. 1995. Sorghum research priorities in the Kenya Agricultural Research Institute. Nairobi: Kenya Agricultural Research Institute.

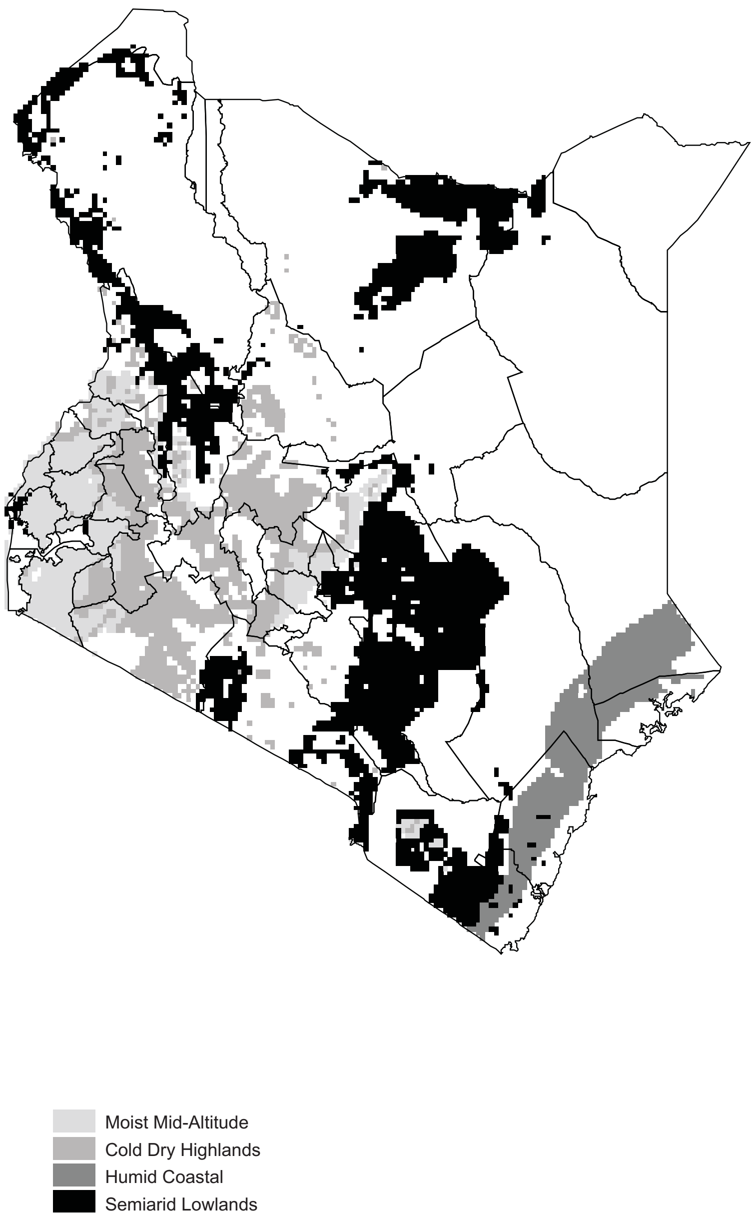
Kiori, G. and K. Gitu. 1991. Supply response in Kenya agriculture: A disaggregated approach. Ministry of Planning and National Development Technical Paper 92-11. Nairobi: Ministry of Planning and National Development.

Mills, B., P. Mwangi, V. Munyi, and L. Wambuguh. 1994. An analysis of production and price trends for maize, millet, sorghum, and wheat. NARL Socio-Economics Working Paper No. 3. Nairobi: Kenya Agricultural Research Institute.

Mills, B. 1997. Ex-ante agricultural research evaluation with site-specific technology generation: The case of sorghum in Kenya. *Agricultural Economics* 16 (2): 125-138.

Rao, J. 1989. Agricultural supply response: A survey. *Agricultural Economics* 3: 1-22.

Appendix 9.1. Sorghum Research Target Zones



Chapter 10
Priority Setting in a Production-Factor Research Program

Daniel Kilambya, Steven Nandwa, and Steven Were Omamo

The generation and adoption of research interventions based on production factors is complex. That's because the impacts of such interventions occur through the interplay of intricate biophysical effects in diverse farming systems. A major challenge in modeling production-factor-based technology generation lies in translating research-induced changes in biophysical phenomena like soil fertility, toxicity, and water-holding capacity into associated changes in crop and livestock yields. On the adoption side, assessing the degree to and speed at which such technologies might be developed, released, and adopted by farmers is often more difficult and prone to uncertainty than that for commodity-based interventions. Moreover, since the biophysical effects are often felt beyond individual farms and over the course of several production cycles, the determinants of adoption of technological packages within which factor-based technologies are embedded may be difficult to ascertain. These features of factor-based research impacts render their quantification, which is a key step in any priority-setting exercise, difficult but crucial.

This chapter presents the main outcomes of priority setting in KARI's soil fertility and plant nutrition research program. The program is one of KARI's largest, with a mandate area covering all agroecosystems in Kenya. even with its relatively large human resource capacity, the program cannot address the full range of soil fertility problems facing its diverse client base. Priority research areas, thus, must be identified and research resources concentrated accordingly.

This chapter has three objectives:

1. to describe the overall process followed, the specific methods developed, and the associated data requirements for setting priorities in the soil fertility and plant nutrition research program
2. to present the results of efforts to identify principal production systems, define research themes, assess the potential for technology generation and adoption, and estimate the benefits of research conducted across research themes and zones
3. to discuss the implications of the results of the priority-setting exercise for medium-term resource allocation and draw conclusions about the strengths and weaknesses of the procedure

Method and data

The priority-setting working group for the plant nutrition and soil fertility research program based its strategy on a five-step process that had been developed for setting priorities in KARI's commodity-based research programs. The steps were as follows:

1. compiling a detailed information base on the mandate area
2. identifying research target zones and research themes
3. specifying potentials for technology generation and adoption
4. identifying and quantifying benefits accruing from research themes and ranking research alternatives
5. establishing priorities with program stakeholders

The information base required to complete these steps was extensive. It included spatially disaggregated agroclimatic and demographic data; time series data on regional and aggregate yields, output levels, and prices of the major commodities produced in the mandate area; background information on farmer constraints, technology adoption behavior, and socioeconomic differentiation; and data on key variables describing the soil resource base, for example, soil nutrient balances, toxicity, and depth.

Underlying the effort to quantify potentials for technology generation and adoption (step 3) was an assumption that successful research would induce a shift in the aggregate supply of a commodity by reducing production costs, increasing yields, or both. By implication, factor-based research that reduced costs or increased yields throughout a farming system would result in supply shifts for a number of commodities. Quantification of potentials for technology generation and adoption, therefore, involved estimation of potential impacts on yields of not just one but several commodities simultaneously.

Early in the priority-setting exercise, the priority-setting working group recognized that the processes that drive resource degradation or preservation seldom are confined to agriculture. Focusing solely on yield impacts would, therefore, not fully capture the potential effects of factor-based research. However, joint consideration of yield and non-yield impacts of research interventions proved to be difficult and confusing; it considerably increased the complexity of the exercise but added little insight into issues affecting resource allocation in the soil fertility and plant nutrition program. In the absence of the kinds of data with which estimates of the non-yield impacts of research could be made, the strategy chosen by the program was to focus on yield-related effects and consider non-yield impacts only if the former were judged insufficient to guide the research effort.

Estimates of yield-based research impacts were embedded in a farming systems framework in several cumulative steps. First, the principal farming (or production) systems in the program's target zones were described, as were each system's importance in each zone (i.e., its share of farmed area). Second, yield-based benefits of the program's research activities were quantified. This was done by specifying, for each theme and zone, the degree to and period over which the yield of each commodity in each farming system would either increase due to research interventions or remain unchanged. Third, these estimated "raw" net yield gains were adjusted according to the share of each affected commodity within each affected production system and the importance of these production systems in the specified research target zones. These "adjusted" net yield gains were then used to model outward shifts in the zonal and national supply curves of the relevant commodities. This process took as given specific adoption profiles for technologies developed under each theme and aggregate commodity output and price levels. The procedure resulted in multi-commodity estimates of welfare (economic surplus) gains from research in each zone and for each research theme.

Results

The priority-setting exercise took place over several months. During this time, a number of workshops were held during which the priority-setting working group deliberated and decided on issues such as the research target zones for which interventions would be developed, the production systems within these zones, the research themes likely to impact these systems, the potential for technology generation and adoption under each theme, and the potential economic benefits by zone and theme.

Research target zones[25]

Kenya exhibits considerable geographic diversity in agricultural production potential. Soil texture and composition are two factors likely to be of particular concern to the soil fertility and plant nutrition research program. These are not only key determinants of agricultural productivity, but they also show significant spatial variability. The program is thus alert for potential impacts of soil and water management practices on the texture and composition of soil, and ultimately, on yields of key commodities. This preoccupation implies a need for detailed site-specific research. But if the technologies developed by the program are to be widely adopted and create a sufficient return on the investment of public resources, they must address problems facing the broader farming community. This requirement implies a focus on

25. A detailed discussion of the zonation procedure used by the soil fertility and plant nutrition research program is in chapter three: "Spatial Targeting of Program Research."

broad-based constraints. The program, therefore, cannot effectively address its national mandate via a narrow focus on site-specific technologies.

The priority-setting working group resolved this tension by attempting to identify a subset of potential technology interventions relevant across a range of local production systems. Identifying research zones within which new technologies would likely have a somewhat homogeneous biophysical impact on production was a crucial prerequisite to this spatial evaluation of potential research impact. Five zones were defined based on altitude, rainfall, and population density as follows: zone 1, the low-altitude and relatively high-rainfall coastal zone; zone 2, arid and semiarid lands with low population density; zone 3, the arid and semiarid lands zone with high population density; zone 4, the mid-altitude, medium-rainfall zone with high population density; and zone 5, the high-altitude, high-rainfall zone with both high and low population densities. These five zones underpinned all priority-setting deliberations in the program. Not only did they provide essential structure to the entire process, they also helped bound discussions on the configuration of production systems in the country.

Production systems

Secondary data sources and in-depth discussions based on scientists' specialized knowledge of Kenyan agriculture led the priority-setting working group to identify 33 major production systems comprising 35 different commodities in the five zones. In general, the higher the production potential of a zone, the larger the number of commodities produced, and the greater the number and complexity of extant production systems.

For example, in zone 1 (coastal), nine production systems were identified (table 33). Coconut- and mango-based systems concentrated at the lowest elevations dominate the zone, followed by more subsistence-oriented systems in which maize, beans, and cassava are prominent. Systems in which citrus fruits, cotton, and livestock dominate are less prevalent but still important. Pure-stand cash-cropping systems occupy a small area relative to others but are important sources of farming income.

Similar exercises were completed for the other four zones. In summary, production systems in the arid and semiarid lands zones 2 and 3 are fewer in number and less varied than are those in zone 1. Maize, beans, and livestock appear in most systems, dominating all but a few. Whereas cow peas and pigeon peas are important in zone 2, the slightly higher agroecological potential in zone 3 permits production of coffee and horticultural products. The correlation between agroecological potential and the number and complexity of production systems is further evident in zone 4. Seventeen different commodities occupy significant areas in the zone and appear in nine production systems. Given the importance of small-scale producers in the region, maize and beans for home consumption appear in almost all production systems. However, systems in which cash crops like coffee, tea, and sugarcane are prominent account for almost half of cropped area in the zone. Horticultural products, potatoes, and sugar also are significant. Zone 5 also has a large number of major commodities and production systems—11 and seven, respectively. While large-scale mixed farms producing maize, wheat, barley,

Table 33. Principal Production Systems in Zone 1, Coastal

Production system	Share of production system in target zone (%)	Commodities (and % shares) in production systems
1	35	Coconut (40), mango (30), citrus (10), cashews (10), cassava (5), groundnut (4), bixa (1)
2	20	Maize/beans (40), cassava (30), livestock (10), mango (15), cowpeas (5)
3	15	Citrus (40), maize/beans (30), livestock (10), sesame (10), cowpeas (10)
4	8	Cotton (25), maize (25), beans (15), cassava (15), groundnut (10), cowpeas (5), livestock (5)
5	6	Rice (100)
6	5	Sisal (100)
7	7	Livestock (90), millet (10)
8	2	Bixa (100)
9	2	Citrus (100)

tea, and milk predominate, the more diversified, subsistence-oriented production systems of smallholders are significant and growing in importance.

These numerous commodities and production systems, coupled with the sometimes complex composition of specific systems, presented both opportunities and hurdles for the priority-setting exercise. At the same time, the detailed picture of the agricultural composition of the zones that emerged from the analysis meant that deliberations on potential research impact were firmly rooted in factual information on local production systems. But the analytical and computational challenges were greatly increased. While the estimates of research impact could be zone-, system-, and commodity-specific, arriving at these measures meant that lengthy and complicated discussions had to be held on research themes and their potentials for technology generation, dissemination, and adoption.

Research themes

Based on data sources ranging from formal household surveys, RRAs, PRAs, and soil surveys, the priority-setting working group completed detailed zone-specific constraint identification and analysis. From this exercise emerged a number of clear-cut research activities. Related research activities were then grouped into four research themes that addressed issues and problems raised by the major soil types appearing in the five target zones.

The first theme, “problem soils,” addresses soil quality difficulties—acidity and alkalinity, salinity, sodicity, hard-setting, crusting, leaching, aluminum and manganese toxicity, and phosphorus fixation. These work alone or in combination to constrain agricultural productivity growth. Problem soils are location-specific but not location-unique. They, thus, are ubiquitous countrywide, in some cases accounting for large portions of extant soils. The second theme, “inorganic fertilizer management,” seeks to raise agricultural productivity in target zones by increasing the efficiency of fertilizer use on farmers’ fields. Difficulties in improving inorganic fertilizer management are linked to soil features and, therefore, also tend to be specific to zones. One of the soil fertility and plant nutrition program’s longest-held positions is that improved management of soil organic matter is important not only in its own right, but also in a mutually reinforcing role with enhanced efficiency of nutrient use. This is the rationale behind the third theme, “soil organic matter management.” Under this theme, improved management of the quantity and quality of soil organic matter is recognized as an important issue in all target zones. The final theme, “technology transfer,” identifies and addresses enduring constraints to technology adoption. Difficulties in technology transfer often hinge on socioeconomic constraints faced by farmers, which are likely to vary across zones. Thus, while the technology transfer theme clearly straddles the other three, it is viewed as sufficiently important to warrant separate treatment.

Potential for technology generation and adoption

Estimates of the potential benefits of the four research themes—both aggregate and by target zone—required assessments of yield gains for all commodities in all production systems. For each theme and zone, expected minimum, most likely, and maximum net yield gains for all impacted commodities and production systems were obtained by combining estimates of expected minimum, most likely, and maximum yield gains with assessments of the costs incurred in attaining these gains. Also required were estimates of zone-specific threshold net yield gains for technology dissemination—that is, farmers’ minimum acceptable yield gains for adoption of new technologies. In most cases, the priority-setting working group determined that success in a given research theme would not affect all production systems in a zone. Further, within a production system impacted by a research theme, yields of only some commodities will increase, and even these increases will differ across commodities.

To illustrate these points, consider again the case of zone 1 (coastal). The priority-setting working group judged that the problem soils theme would affect just four of the nine production systems in the zone (table 34). Even then, yields of only grain and livestock products (mainly milk) would be affected. While the estimated “raw” net yield gains for maize and milk were identical across production systems, differences in the shares, first, of the four systems in the zone and, second, of each commodity in each system resulted in divergent “adjusted” net yield gains. Having been thus scaled-down by the shares of the systems in the zones and the shares of the

Table 34. Estimated Net Yield Gains for the Problem Soils Research Theme in Zone 1, Coastal

Prod. system	Commodity	Share in system	Raw net yield gains (%) Min.	Most likely	Max.	Adjusted net yield gains (%) Min.	Most likely	Max
2	Maize	0.27	49	98	196	2.65	5.29	10.58
	Livestock	0.10	4	15	38	0.08	0.30	0.76
3	Livestock	0.10	4	15	38	0.06	0.23	0.57
4	Maize	0.25	49	98	196	0.98	1.96	3.92
	Livestock	0.05	4	15	38	0.02	0.06	0.15
9	Millet	0.10	29	58	97	0.20	0.41	0.68
	Livestock	0.90	4	15	38	0.25	0.95	2.39

commodities in the systems, the adjusted gains were considerably smaller than were the raw estimates.

Similar calculations were done for the other three themes. In summary, the inorganic fertilizer management theme would impact a smaller number of production systems in the zone than would the problem soils theme, but it would affect a wider range of commodities: citrus fruits and cotton would register the largest percentage net yield gains after adjustment. Under the soil organic matter management theme, yields of mangoes, citrus fruits, maize, and cowpeas would register greatest increases in the major systems. While the technology transfer theme would impact a similar number of production systems as would the other three themes, it would raise net yields for a larger number of commodities, namely maize, beans, cassava, cowpeas, mangoes, livestock products (milk), citrus fruits, groundnuts, and millet. However, the magnitudes of the net yield gains under this theme would be comparable to those in the other themes.

There also were important differences in estimated net yield gains across zones. Broadly, potential gains in the arid and semiarid lands zones (2 and 3) were judged to be smaller than those in the higher potential zones (4 and 5), but greater than those in the coastal zone 1. In zones 4 and 5, the priority-setting working group determined that the five themes would potentially impact a wider range of commodities than they would in all the other zones. In most cases, the largest estimated potential net yield gains were for maize and beans but commodities like tea, coffee, and livestock products showed significant gains in specific zones and production systems.

Technologies developed under the four themes are expected to exhibit distinct adoption profiles and adoption rates (table 35). Research lags range from one year (technology transfer) to eight years (problem soils), while the number of years before maximum adoption have a low of nine years (inorganic fertilizer management) and a high of 15 years (problem soils). Yet cumulative durations to the onset of disadoption of technologies and to complete disadoption are quite similar. These profiles, along with estimates of maximum adoption rates, point to much greater potential for technology adoption under the inorganic fertilizer management, soil organic matter management, and technology transfer themes than under the problem soils theme.

Table 35. Adoption Profiles for the Soil Fertility and Plant Nutrition Program's Research Themes

Research theme	Research lag (years)	Years to adoption (cumulative)	Maximum adoption rate (%)	Begin disadoption (cumulative years)	Complete disadoption (cumulative years)
Problem soils	8	15	35	30	50
Inorganic fertilizer management	3	9	54	15	30
Soil organic matter management	4	10	52	20	50
Technology transfer	1	11	15	15	50

Market structure is an important determinant of the magnitude and distribution of research benefits and thus must be modeled carefully. Ideally, market conditions for all commodities impacted by the research themes would have been specified in each target zone. However, given the large number of commodities to be impacted, such a regional disaggregation of commodity markets was not practical. Because data on regional market structure were not available across the range of commodities under analysis, fully open "national" markets with no transaction costs between regions were assumed for all commodities. That is, only one "national" price for each commodity would apply throughout the country. Where district-level price data were available, these national prices were computed as weighted averages of district prices, with weights given by the shares of national production occurring in a given district. Other important simplifying assumptions were a price elasticity of supply of 0.5 for all commodities and a real discount rate of five percent per year over a 30-year planning horizon.

Also, to simplify computations, net yield gains for specific themes were aggregated across production systems and zones. The result was a set of national expected net yield gains for the four themes. That is, all commodities would be impacted similarly by a given theme in all zones (table 36).[26] On average, technologies generated under the inorganic fertilizer management and technology transfer themes were determined to have higher probabilities of exceeding dissemination thresholds. They were also seen to have somewhat higher conditional net yield gains than the other two themes. These differences had important implications for the magnitude and distribution of research benefits.

26. This aggregation procedure is analogous to the congruence method in that it does not allow for across-zone variations in research impact via differences in estimated net yield gains, instead attributing all such variation to differences in quantities of impacted commodities produced in the five zones. An alternative that makes better use of the available information is to specify zone-specific potentials for technology generation and adoption, which could then be used to compute zone-specific supply shifts.

Table 36. Potential for Technology Generation for Each Research Theme Across All Zones

Theme	Estimated net yield gain (%)			Estimated dissemination threshold	Probability of exceeding threshold	Conditional net yield gain (%)
	Min.	Most likely	Max.			
Problem soils	3.11	6.88	11.91	10.00	0.08	10.56
Inorganic fertilizer management	3.90	8.34	14.03	10.00	0.11	10.59
Soil organic matter management	4.34	7.76	13.18	10.00	0.28	11.18
Technology transfer	3.85	7.67	12.00	8.00	0.21	10.93

Research benefits

Because of the multi-system and multi-commodity impacts of the research themes, relatively large potential economic benefits to research were estimated: more than Ksh 63 billion over 30 years (table 37).[27] However, the overall magnitude of these benefits is less important than the distribution of the gains across research themes and target zones. The estimates indicate that potential benefits of research under the four themes differ significantly. More than 87 percent of all potential gains from the program's activities fall under

Table 37. Distribution of Research Benefits in Billions of Kenyan Shillings, by Zone and Theme

Zones	Research themes				Zonal total
	Problem soils	Inorganic fertilizer management	Soil organic matter management	Technology transfer	
1	0.10	0.72	0.57	0.99	**1.49** (2.4%)
2	1.11	8.03	6.43	0.97	**16.53** (26.2%)
3	0.44	3.14	2.51	0.38	**6.45** (10.2%)
4	1.36	9.84	7.88	1.18	**20.26** (32.2%)
5	1.22	8.86	7.09	1.07	**18.28** (29.0%)
Theme totals	**4.22** (6.7%)	**30.59** (48.6%)	**24.50** (38%)	**3.69** (5.9%)	**63.00**

27. Comparable estimates for KARI's cassava, wheat, and maize research programs are 12 billion, 17 billion, and 89 billion shillings, respectively.

the inorganic fertilizer management and soil organic matter management themes. Returns to the problem soils and technology transfer themes each account for roughly six percent of total gains.

The distribution of research benefits across target zones also varies. Most gains fall in zones 2, 4, and 5. High-potential zones 4 and 5 register large benefits (32 percent and 29 percent of the total, respectively) because of the large number of commodities in the zones whose yields can potentially be impacted by research on improved soil fertility management. Zone 2, an arid and semiarid lands zone with fewer crops and production systems, accrues large gains (26 percent of the total) because of its great expanse. The smallest gains fall in zones 1 and 3, the former due to the relatively low estimated commodity net yield gains from soils research in the zone and the latter due to its small area. Thus, more than 60 percent of all benefits fall in high-potential, high-population-density zones 4 and 5. Significantly, however, more than 37 percent of the benefits accrue to the arid and semiarid lands zones (2 and 3).

Implications for medium-term planning and resource allocation

The overall goal of the priority-setting exercise described in this chapter was to provide guidelines for future resource allocation in the soil fertility and plant nutrition research program. To arrive at this assessment, the distribution of resources, in particular, human resources, implied by the estimates of research benefits across zones and themes were compared with the existing pattern of resource allocation.

The results indicate that while the largest benefits are most likely to fall in the mid-altitude, high-rainfall zone 4, benefits per researcher (full-time equivalent) are highest in arid and semiarid lands zone 2 and in the high-altitude, high-rainfall zone 4 (table 38). A redirection of resources toward both of these areas and away from the coastal zone 1 may be warranted.

Benefits per researcher under the inorganic fertilizer management and soil organic matter management themes are twice those under the problem soils and technology transfer themes (table 38). This finding justifies the current distribution of scientists across research themes in which the number of scientists working under the latter two themes is roughly half the number working in either of the former. Indeed, the results suggest that a slight reallocation of human resources toward the soil organic matter management theme and away from the problem soils and technology transfer themes may further increase the potential impact of research program activities.

The most obvious implication of these results is that a continued emphasis on research aimed at more efficient use of inorganic fertilizers is warranted, as is that on improved soil organic matter management. The relatively low returns to research on problematic soils and technology transfer suggests that any research undertaken under these themes must be focused and selective. But because production constraints related to problematic soils and technology transfer are widespread, the program might seek to address them by building on its already strong collaborative links with KARI's adaptive re-

Table 38. Resource Allocation Gaps across Target Zones

	Benefits per Researcher (Ksh billion per FTE)	Current Distribution of Human Resources (%)	Distribution Implied by Estimates of Research Benefits (%)	Resource Allocation Gap (%)
Zone				
1	0.25	19	2.36	+16.39
2	3.31	16	26.24	-10.61
3	1.16	13	10.23	+2.27
4	2.03	31	32.16	-0.91
5	2.61	22	29.01	-7.13
Theme				
Problem soils	1.06	13	6.70	+6.3
Inorganic fertilizer management	2.04	47	48.56	-1.5
Soil organic matter management	2.45	31	38.89	-7.89
Technology transfer	1.23	9	5.85	+3.15

Note: FTE = full-time equivalent researchers.

gional research programs, with other institutions within the Kenyan NARS, and with the international agricultural research centers in the region. Significantly, many of these potential collaborators are located either in zones 4 and 5 or have long-term research interests in these areas. Since the results of this exercise imply that about two-thirds of the program's efforts should be devoted to these zones, prospects for the success of this type of collaboration are high. In addition, KARI's new emphasis on low-rainfall areas has come at a time when other partners are moving in a similar direction. These developments further strengthen the case for strategic collaboration in research on soil fertility management.

Conclusions

Scientists' subjective estimates of a wide range of parameters underpin the results of the priority-setting exercise described in this chapter. Strong assumptions underlie the method employed to quantify and aggregate research benefits. Several avenues, thus, exist by which errors can enter the process. Tentative support for the approach is provided by results that not only conform to basic expectations but also add insight into the issues under consideration: the distribution of potential research benefits across the research themes and research target zones affirms the comparative advantage of the soil fertility and plant nutrition program in research on inorganic fertilizer management and organic matter management; and inter-regional shifts of research resources toward areas with high or increasing population pressure on the soil resource base are suggested. The question of how best to capture and incorporate non-yield impacts of production-factor-based research remains unanswered. However, the experience described here of priority setting using a yield-based approach suggests that this limitation need not prevent factor-based research programs from prioritizing their research activities based on economic measures of research impact.

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