CHAPTER 3

CONSIDERATIONS FOR DETERMINING RESEARCH PRIORITIES: LEARNING CYCLES AND IMPACT PATHWAYS

M.C.S. BANTILAN AND J.D.H. KEATINGE

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502324, Andhra Pradesh, India

INTRODUCTION

Agricultural researchers identify and apply new science, novel approaches and innovations that could generate research breakthroughs and improve impacts to support the development of the agricultural sector. During the past few decades, there has been an expansion of the research agenda along the entire research-for-development continuum, with farm- and policy-level implications. The goals and objectives of research have broadened from primarily food production to include sustainable resource management, equity, gender, health, and environmental concerns. These changes have been in response to factors such as the changing regional and global environments, new science and innovations, the redefinition of research targets in the light of new findings, potential market opportunities, institutional learning, and the strengthened capacity of research. Along with the expansion of the research agenda, there is now greater appreciation of the need for quantifying the economic returns to research investment, and other dimensions of impact (social, environmental, and institutional). In accordance with these changes, priority setting in agricultural research has been rapidly changing too with the principal focus shifting from yield and nutrition gains to achieving impact on likely distributive effects and the environmental sustainability of alternative research strategies. New challenges have emerged in research management. If there is to be efficient use of scarce resources, particularly in the public sector, research priority decisions have to be consistent not only with informed scientific opinion or scientific possibilities but also with clients' needs and national and international concerns within the broader policy context. In promoting policies that improve the welfare of the people, especially in developing countries, the ability to set priorities and support correct decisions in agricultural research is critical.

G. Loebenstein and G. Thottappilly (eds.), Agricultural Research Management, 37–64.

Faced with these challenges, the pursuit of a well-balanced portfolio or a focused research agenda has become imperative. It motivates stronger accountability and objective, transparent priority setting. It prompts awareness among agricultural scientists and research managers about the expected benefits and payoffs from research. Increasingly, researchers and managers are compelled to provide solid evidence that they are using resources efficiently and effectively. Thus, the establishment of a transparent, consistent, objective, and participatory priority-setting process has become essential in institutional decision support and research planning.

This chapter presents important dimensions of agricultural research management, featuring the considerations that go into determining priorities. The first section discusses trends that shape the agendas of agricultural research organizations. A conceptual framework for priority setting in agricultural research is presented in the second section, embodying factors influencing impacts, their linkages, and minimum data requirements.

Another section gives an overview of priority-setting methods, ranging from simple statistical congruencies to economic models where both objective and subjective information are considered. Critical considerations in research evaluation and priority setting are addressed with focus on the difficulties encountered in practice.

Subsequent sections use the experiences of international agricultural research centers to illustrate the commonality of priority-setting requirements and processes. The international dimension of the discussion clarifies the role of international public goods and research spillover benefits across regions, as well as the relationship between regional and global priorities. The last section concludes with suggestions on institutionalization based on institutional learning and targeting for an informed approach to research decision-making.

RESEARCH PRIORITIES AS PART OF RESEARCH DECISION SUPPORT SYSTEMS

Agricultural research priority setting is a process involving analysis prior to investment, whereby estimation and ranking of expected future benefits assist research decision-making. Benefits from research investment in agriculture are expected to be realized when research is undertaken and the target users adopt the technology or the research results. The estimated relative benefit levels are compared across alternative options in a research portfolio. There are several levels of aggregation on which research options have to be ranked in order of priority:

- Agroecologies, regions, or countries
- Commodities, crops, or enterprise sector
- Research programs or themes
- Research projects within programs

- Research problems or productivity constraints
- Research needs/gaps

Depending on the level of aggregation required by the research organization, priority setting compares the relative importance of research at each level. It involves a process of explicitly or implicitly exercising a choice over possible research activities with the help of an array of available quantitative and qualitative information. The resulting judgments are expressed as a ranking of options within a research portfolio. Most agricultural research institutions conduct formal or informal priority-setting exercises to help set the research agenda, guide allocation of research resources, and improve the quality and efficiency of research. In national agricultural research systems (NARS), the priorities conform to national-level goals and objectives and are examined across commodities, regions, disciplines, and research problems. At the international level, spillover benefits across countries and regions, and the complementarities of national, regional, and international research objectives are additional concerns. The outcome of the priority-setting exercise is a ranking of commodity groups or agroecoregional zones at aggregate level; or research programs at institute level; or research themes within a program; or productivity constraints within a commodity project.

The benefits of systematic formal priority setting have been reiterated by Janssen (1995), Contant and Bottomley (1988), and Braunschweig (2000) as follows:

- Research objectives are better identified, and differences of opinion are clarified, thereby facilitating consensus building; team building and communication within the institution are improved.
- The chances of successful adoption of a new technology increase because stakeholders are included in the decision-making process.
- Useful information is generated regarding the changes that are necessary in the research environment; better information is used for educating the public about sensitive decisions, and managers are in a better position to defend their decisions, particularly against donors with a conflicting agenda.
- More emphasis is placed on longer-term impacts; informal priority–setting exercises often focus on short-term effects.
- Negative consequences are identified and corrective measures taken early to compensate for potential losses.

ESSENTIAL CONSIDERATIONS IN RESEARCH PRIORITY SETTING

While demands on the agricultural research agenda continue to increase, the last 15 years have seen changes in the funding environment, particularly a growing scarcity of research resources especially in developing countries. Inadequate funding of public agricultural research institutes is the most serious challenge facing NARS. For example, investment in agricultural research in developing countries decelerated to 3.8% annually from 1981 to 1991 compared to a growth rate of 6.4% annually in the previous decade (Alston et al., 1995).

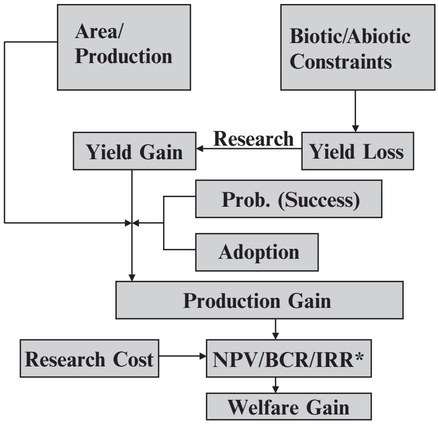
Changing support from traditional funding sources has also affected international agricultural research centers. In fact, while the expenditure of the Consultative Group on International Agricultural Research (CGIAR) has continued to increase in nominal terms since its establishment in 1972, in real terms it has stagnated, especially in the last 15 years. The rate of growth of the CGIAR's research expenditure has continuously declined during the last two decades. Estimates based on CGIAR Annual Reports (1975–2005) indicate that revenue and expenditure had begun to stagnate even before the 1990s, growing at an annual compound growth rate of 8% from 1975 to 1990, compared with a growth rate of 1.35% from 1990 to 2005. The nature of funding has also changed during the last decade. In particular, the proportion of unrestricted funding has continuously declined since the late 1980s while restricted funding has been increasing.

Research evaluation and expected impact pathway – framework for research priority assessment

An understanding of the whole research process is essential to facilitate agricultural research evaluation and priority setting. In principle, research evaluation is undertaken to confirm research effectiveness, efficiency, relevance, and impact. Priority setting is the process of ranking different research alternatives in order to identify a research portfolio in line with the mission of the organization or the agricultural policy of the country. Priority setting includes determining the relative importance of several research objectives.

This section illustrates the process of research evaluation and priority setting by tracing expected impact pathways (Bantilan, 2000; Joshi and Bantilan, 2000). The conceptualization of a framework (Figs. 1, 2, and 3) to guide the research evaluation and priority-setting process starts with the consideration of research investments to fund a set of specific research projects designed to develop new technologies for use by farmers (Fig. 1 on basic parameters for priority setting). This framework identifies the essential factors for priority setting.

If a research project does successfully achieve its objectives, it usually generates outputs in the form of (1) some new knowledge and (2) a change in the technology for use by farmers. To be more specific, the application of science-based technologies resulting from research is expected to bring about increases in yield and product quality of commodities/crops grown presently or subsequently. Research is also expected to improve the efficiency of input use via agronomic practices and crop management. Ultimately, these research-induced gains or changes in the production and consumption environment translate into an upgrading of the welfare of farmers who use the technology as well as of consumers who use the final products.



*Net Present Value (NPV) / Benefit-Cost Ratio (BCR) / Internal Rate of Return IRR)

Figure 1. Basic parameters for measurement of welfare gains.

Before the final benefits of research accrue to society (i.e. producers and consumers), two important conditions must be met. First, the research undertaken must be successful in achieving its targeted objectives. This introduces the notion of the probability of success or relative research capability relating to the risk of an intended technological improvement not eventuating even after a significant period of experimentation or investigation. Thus, this framework enables judgments about the relative strength of research (capacity building) and extension systems (human resources) and rural infrastructure to be factored into the analysis. It also provides space for the consideration of other sources of uncertainty with regard to research success. Second, the increase in production promised by a new technology is ultimately achieved only when the technology is adopted and utilized by farmers. If the technology is not an improvement in some way over the existing technologies, farmers are unlikely to use it. In such an instance, the technology, although developed, is redundant. Yet, even if the technology is an unambiguous improvement, some farmers may still not adopt it. Thus, estimates of the rate of adoption of the results by end users must be carefully made. There may be several reasons for low adoption or slow uptake. One could be the reluctance of farmers to give up their existing, and in their opinion, proven practices. In some cases, adoption of technology may also be influenced by resource endowments. This condition necessitates consideration of the rates of technology adoption and the factors by which it is constrained.

The measurement of expected welfare gains to society is incomplete if it does not take into account the externalities which the technology involves. The externality consideration in this framework may either be negative or positive. Classic examples of negative externalities in agriculture are human-induced soil erosion and the detrimental effects of chemical-based technology. These include the deleterious effects of pesticides on the health of farmers and their families,

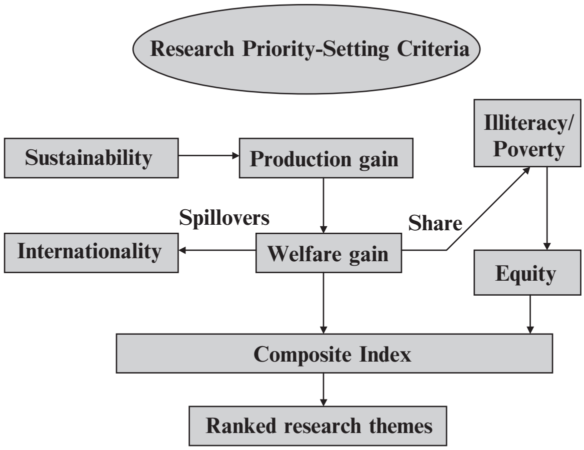


Figure 2. Linkages among four priority-setting criteria.

the transmission of chemical residues along the food chain to consumers, the toxic effects of chemicals on fish, shrimp, frogs, and beneficial insects in farmers' fields, the contamination of ground and surface waters, and the reduction of soil microorganism populations that help sustain soil fertility.

The positive externalities are incorporated within this framework through the concept of spillover effects (Bantilan and Davis, 1991; Bantilan et al., 2004), as shown in Figure 2 which presents the linkages of the overall welfare gain parameters (efficiency, sustainability, spillovers and other factors). Three types of spillover effects are possible. The first type involves across-location spillovers in which a technology developed through research for one product in a specific location can be adapted to improve production efficiency for the same product in another location. This type of spillover effect is relevant because the applicability of the new technology may not be the same for all locations, which may be differentiated by agronomic, climatological, or ecological factors.

The second type of spillover effect refers to across-commodity applicability of a technology. For example, a cultural management technique developed specifically for one commodity may also improve the production efficiency of other commodities

The nature of the first two types of spillover effects reflects the direct applicability of a technology across different locations/production environments and across different commodities. Thus, they are referred to as direct spillover effects.

A third type of spillover effect is referred to as indirect or price spillover effects (Brennan and Bantilan, 2003). Technological change relating to a particular commodity in a specific location brings forth increased supply, which may cause price changes. This is turn may have a price effect on other locations (if the commodities are traded) or on related commodities. This is particularly relevant when the price responsiveness of the product demand is relatively small and/or the rate of product transformation among commodities is significant.

Following the basic parameters and linkages described above, a simple priority-setting procedure is outlined here to show the different phases of the exercise (Fig. 3):

- Clarification of research goals including identification of research domains, objectives/strategy, and critical constraints to agricultural production
- Identification of criteria for the priority-setting exercise (corresponding to research goals)
- Disaggregation of alternative research options at each level
- Elicitation of criteria weights through consultation with experts
- Choice of priority-setting approach: quantitative and qualitative measures
- Collection and processing of available data and resources: research gains, costs, probability of success, adoption levels, etc.
- Evaluation of potential impacts: assessment of expected research benefits based on the data collected and subjective judgments (e.g. environmental effects, impact on the poorer income groups, benefits for women)
- Sensitivity analysis using scenarios for the feasible range of parameter estimates or alternative criteria weights

The variables influencing the evaluation of potential research benefits or impacts may be based on measurable indicators as well as qualitative or subjective assessments. Quantitative or measurable indicators in agricultural research include estimated yield gains, unit cost reduction, research lags (i.e. timeframes for producing results), adoption lags, rates and ceiling level, and other direct and indirect effects on target and nontarget regions or sectors. Qualitative factors cover the probability of research success, effects on the environment or sustainability indicators. These measurements seek correspondence of the research goals and objectives, e.g. reduce poverty, improve food security, and promote sustainable natural resource management through agricultural research.

Other factors for consideration in enhancing the framework

Government policies

Existing government policies are an important factor, which can influence the welfare gains accruing from research. For example, governments of developed and developing countries alike have policies which subsidize production inputs like fertilizer, seeds, water, and electricity. In other cases, taxes are imposed on some agricultural commodities, especially cash crops like cotton, coffee, and tobacco. To estimate the gross social benefits of research when subsidies or tax policies exist, detailed knowledge of the policies is required. Alston et al. (1986) have shown the implications that various forms of price distortions can have for research evaluation. These policies influence the production and/or consumption of a commodity,

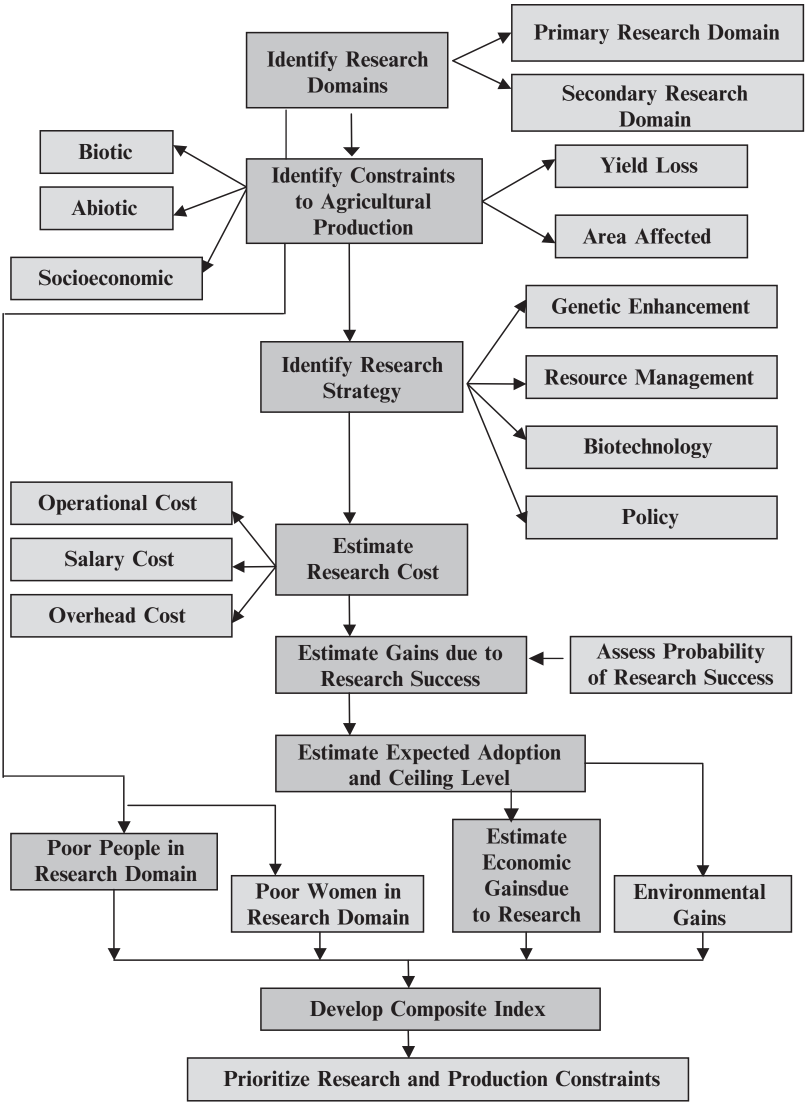


Figure 3. Essential steps in research priority setting.

or the inputs used to produce it. They can influence both the benefits flowing from research and the distribution of those benefits.

Expansion of demand and supply over time

Supply and demand of commodities can shift due to factors other than research. For example, population or income changes may result in a shift in demand for a commodity. Forecasts of demand and supply shifts can be made to avoid underestimation of benefits if expansion of demands or supplies is expected over time.

Equity or distributive effects

Welfare effects from research can significantly vary across research efforts, regions, and commodities. Prioritization of research options is likely to be influenced by the distribution of these effects. It needs to be clarified which of these effects are important. For example, if several sectors are parts of one country and if the total national welfare gain is the objective of the research institution, then a measure of the potential research impact can be had by adding all the gains (or losses) in all sectors. If, however, the objective is to maximize gains to poor farmers only, then the subset of welfare effects in this particular sector is considered to give a measure of how well a particular research option may satisfy this objective. Estimates of these welfare changes, if quantified, can be summarized in a form suitable to assist decision-makers in setting research priorities or making allocation decisions. This information is combined with other information before decision-makers make final judgments about allocations.

Other aspects

Other aspects for consideration in priority setting may include: (a) effect on nutrition; (b) food security; (c) human capital development; (d) institution building and strengthening of national programs; and (e) employment generation effects. It is clear that a spectrum of considerations has to be taken into account for an assessment of research priorities. It is equally clear that a detailed understanding of the components of the research–evaluation continuum is necessary to arrive at a combined quantitative and qualitative assessment of impact. The expected outcome of research or its impact is dependent not only on quantifiable variables but also on others that are difficult to quantify.

Multicriteria nature of priority-setting processes

Given the multicriteria nature of the processes described above, priority-setting methods have evolved to support the complex decisions that must be made by research institutions. The complexity of priority setting is largely due to the multiple criteria involved in research decisions. As discussed above, research objectives and priority-setting criteria may include

- Productivity and efficiency
- Poverty and equity
- Gender concerns
- Environmental sustainability
- Trade-offs

Research managers must ensure the correspondence of research objectives with the set of criteria used for priority setting. In more complex decision-making, a multicriteria decision-making process may be structured to consider trade-offs among research objectives relating to economic, social, environmental, and institutional concerns. This includes trade-offs between productivity and efficiency objectives versus poverty or equity or gender concerns or sustainability creation.

A multicriteria priority-setting framework has important implications. It requires attaching weights to each objective. This is the responsibility of senior research managers and policymakers. Their participation has become increasingly critical in the decision-making process. Appropriate procedures are needed facilitating interaction among decision-makers and for eliciting their preferences.

Mainstreaming poverty considerations in priority setting

Mainstreaming poverty considerations is an important issue in priority setting in the light of recent developments in the global research agendas of international organizations, which have identified poverty eradication as a common goal (UN, 2002; CGIAR, 2005). Mainstreaming poverty recognizes that there are at least five ways by which agricultural research can benefit the poor:

- Increasing poor farmers' productivity
- Greater agricultural employment opportunities for small farmers and landless workers
- Higher wages and growth in adopting regions
- Lowering food prices; and
- Greater access to nutritive crops.

This discussion refers to some points made by Ryan (2004) regarding additional considerations that need to be clarified in relation to poverty-targeted agricultural research priority setting. The first point is that it is not necessarily given that research investments targeted at the locations of the poor will achieve maximum impact on the resident poor. Many factors mediate this relationship and make it difficult to argue that priorities at the macro level should be primarily based upon the location of the poor. These factors include price effects, migration, and research spillovers in other regions. For example, where poor households in marginal areas are net food purchasers and the market infrastructure is adequate, technological change in more-favored areas can be an effective way of benefiting the poor in the marginal areas. Lower commodity prices result, and migration offers opportunities for low-income workers to participate in the benefits of higher wages and employment. However, as Fan and Hazell (2000) have shown, the marginal returns to research are higher in less-favored environments and also the effect of this on poverty alleviation is greater. Then it is not clear whether it is appropriate to neglect the less-favored areas and allow "trickle down" forces from more favored areas to equilibrate the benefits.

The second point for consideration is that the wage and employment effects of targeted research can be counterintuitive. In particular, if labor- intensive commodities have nonresponsive demands, then research on them could lead to mechanization or to their substitution in production by less labor-intensive commodities.

A third point raised is that growth linkages between agricultural and nearby rural industry can generate significant multiplier effects benefiting the poor most when agricultural income is a high proportion of total income. This has differential implications for targeted agricultural research in Asia and Africa. In Asia, there is increasing village-level evidence showing that a high percentage of rural workers are engaged primarily in nonagricultural employment. This is reflected in the inverse relationship between nonagricultural income and farm size, with smallholders, near-landless and landless workers deriving between one-third and two-thirds of their income from off-farm sources. Hence, they stand to benefit more from growth in the nonfarm sector than do the more affluent larger farmers. To the extent that nonfarm income is even more important for the poor in marginal areas, the issue arises whether agricultural R&D should give way to other interventions. In Africa the situation seems the opposite, with the rural poor depending more on agriculture than the nonpoor (Reardon, 1997).

By analyzing a typology of agricultural regions based upon agroecological zones and socioeconomic factors that condition the size and distribution of benefits from technological change, Haddad and Hazell (2001) identified five broad areas of focus for a pro-poor research agenda:

- Increasing productivity in less-favored lands, especially in heavily populated areas but also in high-potential lands constrained by poor infrastructure and market access
- Increasing production of staple food in areas where food price effects are still important and/or in areas that have a comparative advantage in growing these crops
- Helping smallholder farms to diversity into higher-value products, especially in areas where market prospects are good
- Increasing employment and income-earning opportunities for landless and near-landless workers in labor-surplus regions
- Nutritional enhancement of diets by investing in agricultural technology that reduces the price of micronutrient-rich foods; increase in physical access in remote rural areas, or increase in the nutrient content of food staple crops via traditional or transgenic technologies

Choosing an appropriate method

Research-evaluation and priority-setting methods have evolved from simple techniques used in consideration of single research objectives to systematic and formal mechanisms for assessing priorities corresponding to multiple objectives. A lot of effort now goes into evaluating agricultural research, due in part to the increasing complexity of problems, and in part to the tight research budgets and the resulting pressure for greater accountability. A large and diverse array of criteria has been employed by national and international organizations supporting agricultural research. These include: efficiency, equity or income distribution, food insecurity, per capita income, export enhancement, import replacement, among others.

This section presents an overview of the approaches used in priority setting. It features the various procedures used to identify and select the criteria for prioritizing research options and to identify measurable indicators as well as elicit subjective judgments. It includes novel techniques of quantifying the benefits from alternative research investments in order to facilitate informed decision-making on the utilization of agricultural research resources. This section also discusses several factors which influence the choice of priority-setting methods. The advantages and disadvantages of the different methods are mentioned as well as their suitability in different situations. In many cases, analysts combine these methods. Ultimately, they complement the intuitive judgments of research managers and administrators and the scientific intuition of scientists and researchers.

Different types of approaches have been developed for establishing research priorities (Contant and Bottomley, 1988; Davis et al., 1987; Alston et al., 1995): traditional tools (rules of thumb: precedence and congruence; checklist and scoring); cost-benefit analysis and economic surplus, mathematical programming and simulation models, among others.

Traditional tools

Rules of thumb

This approach is simple and quick, and needs minimal data. It is usually used as a preliminary approach ahead of a more formal priority-setting exercise. The two most commonly used methods in this approach are precedence and congruence. These methods emphasize the status quo and rely heavily on historical data. The precedence method uses the level of funding in the previous year as the basis for allocation of resources to project themes and projects. Allocations are marginally increased or decreased depending on the overall funding situation. Any excess resources available are distributed proportionately across research themes. This method can provide long-term continuity in funding of research themes and projects. However, one disadvantage of this model is that it continues allocating resources to areas that have reached the limits of their productivity even if the changing research environment may warrant a shift in funding. The precedence method is not forward-looking; it does not take into account emerging problems or any promising new areas of research or research investments that are likely to give the greatest impact.

Congruence models rank alternative research areas, commodities, or regions on the basis of a single criterion. The value of production is frequently used; and other measures include value of consumption, impact on total population and impact on poor people. The appropriate measure may be determined from the objectives and criteria of the research program. A review of studies, which used the congruence index in assessing research intensities and the relative importance of commodities, is provided in Scobie (1984).

Checklist

The checklist consists of a list of relevant criteria against which the research alternatives are checked. Like the two traditional tools described above, a checklist is often used as a benchmark or starting point in establishing the relative importance of research options. In practice, it may be viewed as an initial ranking of commodities (or research themes, projects), providing research managers some basis for discussion and further analysis. In many cases, these methods are combined with more rigorous methods.

Scoring

Scoring or weighted criteria are used to rank alternative research options according to multiple criteria that reflect multiple research objectives, as follows:

- The research alternatives are scored according to each criterion by using a discrete scale.
- The research objectives are defined, and weights are assigned to each criterion by the decision-makers.
- The scores are then multiplied by each criterion weight and then added up to determine the order of priorities.

Scoring models are widely used for priority setting because they are relatively transparent. When a meaningful conceptual framework is applied in scoring models, they can foster a dialogue considering research criteria and the weights associated with alternative research objectives. Useful scoring models should, at a minimum, incorporate basic economic principles into the priority-setting exercise. For example, economic efficiency measures such as net present value can be combined with equity criteria to rank research alternatives. A scoring model that is based on an economic approach incorporates the need to identify meaningful objectives, distinguish between weights and measures, recognize that research is a blunt instrument, and attempt to approximate economic efficiency measures (Alston et al., 1995).

Cost-benefit analysis and economic surplus

Cost-benefit analysis

The cost-benefit method for priority setting is a formal economic model that uses efficiency as the main criterion for ranking alternative research themes. There are three main steps in applying this model. First, the potential for generation and adoption of technologies is estimated for alternative research themes. A prime requirement is to establish, for the target cropping systems, the actual gains to be expected from the improved technology over and above the existing productivity levels achieved by the existing technologies in use by farmers. In addition, the relative value of the improved technology may be estimated from the viewpoint of environmental protection and cropping system sustainability. These data provide a baseline against which to estimate the gains that can be expected from further improving the existing technology as a result of research or by direct application of known technologies.

Second, a stream of annual benefits and costs associated with each research theme is identified for the planning horizon. With discounting for factors such as probability of success, time lags, and ceiling rate of adoption, reasonable estimates can be made for the costs and benefits of a suggested research and/or development effort. Third, annual benefits and costs are discounted to calculate the project's worth. The latter is usually presented as a NPV or IRR. Technologies are ranked according to the values of NPV or IRR.

Cost-benefit methods indicate research priorities on the basis of efficiency criteria. This provides an insight into whether or not investment in research is making efficient use of scarce resources. This model can also be used to assess trade-offs in efficiency among research alternatives.

The narrow focus on efficiency is a disadvantage of this model as is its difficulty in capturing changes in the agricultural research environment. However, in priority-setting approaches based on multiple criteria, estimates from cost-benefit models can be integrated with other criteria. Besides a consistent ranking of research alternatives on the basis of efficiency, the process involved in applying cost-benefit models can force decision-makers to explicitly state the assumptions underlying technology generation and adoption for various research alternatives as well as explore the different impact scenarios on the basis of different assumptions. The basic data required for benefit-cost models are quantity and prices, assessment of the potential for technology generation measured by net yield gain, and the profile of adoption. Significant investments need to be made in collecting and analyzing this data although several computer programs have eased computation of benefit-cost estimates.

An alternative type of cost-benefit measure uses the domestic resource cost ratio (DRC). DRC estimates a given country's comparative advantage in producing a certain good. It calculates the cost-benefit ratio using the concept of opportunity cost, which indicates the social profitability of producing a certain commodity. However, this approach has major shortcomings as a single measure to allocate resources, ie, decisions based solely on a favorable DRC ratio tend to be biased against research investment in commodities that at present do not have a comparative advantage, e.g. future potential niche markets. However, the DRC approach is a relatively easy method of calculating the social costs and benefits of producing different commodities, and can provide complementary information for setting research priorities.

Economic surplus

The economic surplus principle is based on the idea that improved technologies are expected to enhance productivity or reduce the producers' unit cost of production, which translates into a shift representing an increase in the producers' supply when they adopt the new technologies. The calculation of the supply shift involves the use of available or estimated on-farm input and output data (e.g. yield levels and input costs). Annual gains based on the empirical market benefits from adoption of the technologies are computed over the horizon at which the benefit is expected to accrue at anticipated adoption levels. This estimation only covers benefits accruing due to measurable market effects.

The economic surplus model is an enhancement of the cost-benefit approach to priority setting. It also ranks research alternatives on the basis of economic efficiency. Economic surplus models consider price responses to productivity increases induced by investment in research and technical change. These models also distribute the benefits from research investment between producers and consumers in the form of producer surplus and consumer surplus, each of which can be stratified by income or other socioeconomic criteria.

Approaches employing the concept of economic surplus to examine research priorities have been used in both national and international research assessments. National research programs usually assess priorities from the perspective of maximizing benefits that would accrue to the whole nation or to specific groups within it. These decisions may not be influenced by the additional benefits that may accrue to other countries or regions outside their mandate. An extension of the economic surplus method for assessing these international research spillover benefits is discussed below.

Multiregional international trade model

A multiregional international trade model using the concept of economic surplus has been developed to enable intercountry or interregional effects to be explicitly incorporated into an *ex ante* analysis of aggregate commodity and regional priorities in agricultural research (Davis et al., 1987). It employed techniques of economic surplus couched in an international trade model to derive *ex ante* measures of the relative benefits of alternative commodity and regional research portfolios and the distribution of these benefits among consumers, producers, importers and exporters. A novel approach of defining appropriate research domains has been identified to assess the spillover effect research undertaken in one region may have in other regions with similar agroclimatic and socioeconomic environments. Further refinements in empirical applications have used Geographic Information Systems (GIS) to enhance spatial characterization and mapping of research domains. (Deb et al., 2004). The model also factors into the analysis the probability of success and the likely ceiling level of adoption by farmers. An empirical analysis using this model has been conducted for a broad range of commodities at an international level and includes all major producing and consuming regions of the world. (Davis et al., 1987; Lubulwa et al., 2000).

Other methods in practice

Two additional approaches in setting priorities have been developed, i.e. mathematical programming and simulation models. Unlike the two previous classes of research priority setting tools, which only produce a ranking of the research alternatives, these methods aim at selecting an "optimal" research portfolio and establishing functional relationships between research investments and impacts. The basic approach in mathematical programming is to formulate an objective function that is maximized subject to certain constraints such as funding requirements, human resources, or institutional capacity. The objective function can include multiple objectives and a weighting system to reflect differences in the importance of the objectives. The results illustrate the tradeoffs among objectives and implications of changing constraints.

Simulation models are based on the principles of production economics whereby the functional relationship between the input (i.e. research investment) and the agricultural output is estimated. A production function may be used to represent the econometric relationship between agricultural productivity on the one hand, and research (and extension) expenditures and additional determining factors on the other. Then, the effects on productivity of various research expenditures, e.g. introducing different technologica1 innovations, are simulated. Simulation models are very flexible, and can be used to analyze the wider impact of research investments. However, estimating econometric relationships is based on time-series data, which are not always readily available.

By and large, despite substantial efforts to improve the tools used in priority setting, only a few of the less sophisticated methods have been implemented by research organizations. Norton et al. (1992) explain it as a failure of economists "to communicate adequately to priority-setting practitioners the progress that has been realized on developing research performance measures and priority-setting methods." In contrast, Shumway (1983) argues that "the perceived benefits to most organizations of the more sophisticated procedures are apparently outweighed by their cost." Moreover, the extreme uncertainty surrounding knowledge production further limits the potential of sophisticated methods (Shumway, 1981). As a result, research managers often turn to simplified methods, knowing that data errors far outweigh errors caused by imprecise procedures.

Factors influencing the choice of an appropriate method

Following the three requirements suggested by Braunschweig (2000) in choosing an appropriate method, i.e. transparency, participation, and standardized measurement, the strengths and shortcomings of the different approaches are summarized below.

Use of rule-of-thumb approaches continues to decline with the availability of alternative procedures that can account for new research programs and the innovative nature of new science or new research areas with high potential. Alternative approaches, including cost-benefit and economic surplus analysis, mathematical programming, and simulation models, all require the research evaluation analysts to play the key role in the priority-setting process. It is in the scoring model that extensive participation at each stage, i.e. eliciting information, defining the criteria, assessing the alternatives, and establishing priorities, is required.

The cost-benefit analysis and scoring models are fairly transparent because, in both, the process of generating priorities is easily understood. Cost-benefit analysis focuses on the economic impact of research. The other dimensions of research benefits are only included to the extent that they can be quantified in monetary values. Simulation models can also take into account a wider range of research effects. However, they do not provide a ranking of research projects based on multiple objectives.

Applied economic surplus analysis of welfare gains is being increasingly applied with the availability of data on yield gains, reduction of unit cost, or increase in income based on primary and secondary sources. The measurable economic indicators are complemented with qualitative data on expected environmental effects (e.g. farmers' perceptions of long-term environmental changes). This is also enhanced with a detailed account of both quantitative and qualitative information provided by scientists and experts, including farmers.

Both mathematical programming and scoring can incorporate many different impacts, including qualitative ones. The scoring model provides a systematic procedure by dividing the process into two steps: (1) scoring the contributions of the alternative research options with respect to each criterion; and (2) weighting the criteria. In the programming model, the decision-maker has to attach utility values directly to one unit of each criterion, a rather difficult task given the different measurement units of the criteria employed.

These methods continue to be used according to the requirements of research organizations, along with various trade-offs considered above. In the process, new approaches continue to be developed by research evaluation practitioners to overcome the shortcomings and methodological deficiencies experienced in practice.

Empirical applications in setting research priorities involve a combination of approaches. In practice, these approaches serve as complementary tools to guide research planning and resource allocation. For instance, the outcome of a cost-benefit analysis could be used as the input for a scoring model. Also, the programming approach could be used to allocate resources to priorities generated by the scoring model. The expected benefits that are amenable to quantification (e.g. expected yield gains or anticipated adoption rates) are quantified while descriptive documentation is used for those that are difficult to quantify. In the latter case, experts (including both researchers and research beneficiaries) are important sources of detailed descriptions, which may serve as the basis for qualitatively understanding the impact pathway and anticipated ultimate research impacts.

Inclusion of qualitative impacts in priority setting

Since research evaluation and priority setting involve the process of making choices in the context of scarcity, most of the studies mentioned above have placed emphasis on the economic principles of efficiency and on costs and benefits that can be expressed in monetary values. This has raised concerns because externalities, distributional effects, and longer-term impacts tend to be neglected with such an emphasis.

For inclusion of qualitative impacts in priority setting, a systematic process documentation of the impact pathways is useful in identifying the sources of the qualitative effects of technology adoption. It helps in clarifying the nature of impacts by considering whether or not the expected changes due to technology adoption can be valued using conventional markets, and therefore identifying variables that have market impacts and those that relate to nonmarket effects (Bantilan et al., 2005). A listing of the potential positive and negative effects aids in the analysis of the market and nonmarket impacts of alternative technology options. This is particularly useful for assessing qualitative effects and relative preferences among alternatives. It records the market impacts reflecting yield gains or reduced yield losses and changes in unit cost. The measurement of environmental effects in monetary terms within the context of economic surplus draws from changes in the social marginal cost of production (i.e. product supply) and the demand for the marketed product. The inventory of nonmarket effects may be substantial, e.g. significant positive effects may result in longer-term yield stability, or increased resource availability in the future. This potential change may adjust the farm-level benefit calculations for implicit price effects, which may be positive or negative, reflecting the environmental benefit or damage and a corresponding change in cost. A detailed account of the analysis of possible market and nonmarket impacts is presented in Bantilan et al. (2005). This study explains how conventional calculations that exclude environmental effects can skew measures of the full potential benefits from an improved technology. It illustrates the critical importance and use of qualitative information in understanding the environmental and long-term effects that may be expected from adoption of natural resource management technologies.

Using the results of impact assessment in priority setting: learning cycles and feedback process

Ex post impact assessment of research boosts the confidence of scientists, research managers, and stakeholders and makes a case for enhanced support for research. Information obtained during the process of impact evaluation can also help in research prioritization. For example, data from primary field studies provide a good basis for reasonable estimates of parameters, which are used in the priority-setting exercise. The essential impact assessment information includes: (1) levels and speed of adoption, and reasons for nonadoption of technology; (2) farmers' perceptions of desirable traits or features of technology options; (3) on-farm gains due to alleviation of biotic and abiotic constraints; and (4) infrastructural, institutional, and policy constraints in facilitating technology exchange.

Two categories of impact data may be developed. The first is a set of primary data on adoption and related variables generated from formal and informal on-farm surveys. The second is a set of secondary data based on documentation (published and nonpublished reports). On-farm reconnaissance and formal surveys may be primarily aimed at continuously assessing the extent of adoption of improved technology from the secondary database. This confirms the extent of utilization of improved technologies by farmers in the target regions. Research lag is a major parameter determining the present value of research, and the cost of miscalculating it in terms of erroneous priority ranking can be significant. Verification of research and adoption lags used can be accomplished by cross-checking data from various sources.

Farmers' opinions on important constraints as well as their perceptions of desirable cultivation and management technology options may also be generated from primary surveys. These farmers' perspectives provide the following information: (1) they identify the constraints and research opportunities; (2) they provide an empirical basis for the expected ceiling levels of adoption, i.e. technologies introduced in an environment characterized by significant bottlenecks to adoption cannot be expected to have high adoption ceilings unless these constraints are addressed; and (3) they identify the research options that directly address the users' needs and are most likely to be adopted.

Estimates of yield losses due to important constraints and on-farm gains due to improved technology are also vital pieces of information for deciding research priorities. Impact studies can be used to validate estimates of expected yields. Furthermore, the estimates generated from these surveys (i.e. yield gains or unit cost reductions) also provide a way of predicting the potential supply shift, a necessary parameter for estimating potential impacts in cost/benefit analyses.

Another important outcome from impact studies is the assessment of researchers' perceptions or constraints, which can be technological, institutional, infrastructural, and policy. Two aspects are relevant for seed policy and priority setting: (a) standard variety release procedures of breeders' selecting materials that can make it through the formal release system; and (b) criteria for varietal release do not necessarily match farmers' needs and preferences.

In the process of documenting *ex post* impact using both primary and secondary data, it is possible to derive insights that can help better inform *ex ante* priority assessment and provide grounds for additional investment in the resultant research portfolio (Bantilan and Ryan, 1996). However, *ex post* experience is not the panacea when revalidating earlier *ex ante* assessments. At best, *ex post* experience can inform the *ex ante* process, hopefully in a way that helps minimize the moral hazards associated with scientists' estimates of their expected outputs and milestones.

Measurement problems

The unique empirical challenge of understanding the expected impact pathway is aggravated by problems of measurement. The approaches described above (like congruence, precedence, and scoring) appeal to single or multiple indicators of expected benefits, usually based on readily available, published data or subjective estimates of the level of relative benefits. Benefit/cost ratios combine the actual cost of research and development and technology transfer with the expected stream of benefits based on the levels of technology uptake or adoption.

The economic surplus principle is based on the idea that improved technologies are expected to reduce producers' unit cost of production which translates into a supply shift when they adopt the new technology. Thus, different measures yield different rankings, so the choice of criteria and corresponding measures is critical. The impact of different research alternatives on different criteria is measured on different scales. Some of these scales are inherently qualitative, which makes it virtually impossible to compare a unit of one criterion against a unit of another in a meaningful way. As Braunschweig (2000) suggests, a standardized measurement procedure allows the scores for different criteria to be aggregated in order to obtain an overall assessment of each research alternative.

Measurement problems also have a great bearing on the evaluation of more strategic research because it does not directly change productivity or production costs, yet this is a research area that has not been sufficiently tackled by traditional priority-setting approaches. For example, new knowledge generated by the research process, even if it may not be directly applicable in the productive sector, may still have substantial value in terms of strengthening scientific capacity.

Data availability and reliability

Relevant primary and secondary data are essential in ensuring objective priority-setting processes but data availability at the disaggregated level (or even at the national level) is usually constrained, especially in many developing countries. The problem of data reliability is pronounced because of the forward-looking nature of priority setting whereby expectations on key variables are required. This raises the issue of developing suitable elicitation techniques and identifying experts who can provide reliable subjective judgments on the likely costs, benefits, and other variables of research activities.

Minimum data requirements and database development

To identify the essential data requirements for research priority setting, this section uses the whole research–development–impact continuum discussed above. This continuum spans all stages from initial research efforts to expected impacts on farmers' welfare gains.

In agricultural research, the initial stages involve basic research, such as development of breeding populations and germplasm characterization. Subsequently, scientists engage in both applied research (e.g. development of seed-based technology with testing leading to an identifiable product) and adaptive research (the stages of testing leading to release of technology by the national agricultural research system). The final stages represent the development of optimal seed multiplication strategies and adoption of the technology, i.e. the final stages to achieve impact. This sketch helps in identifying the types of information and the minimum data set required for priority setting.

To illustrate further the identification of minimum data requirements, we use the specific example of chickpea biological nitrogen fixation (BNF) research, starting with the identification of the research objectives, i.e. improving the nitrogen (N_2) fixing ability of chickpea. This involves the following activities (Bantilan and Johansen, 1995):

Stage 1 involves the development of the concept of genetic alteration of the plant for better nodulation, through selection within existing cultivars. This stage leads to the basic concepts and methodology for the development of the improved technology.

Stage 2 involves the actual conduct of the prescribed selection procedure to identify lines with superior N_2 fixing capability and their validation in on-station experiments.

Stage 3 involves on-farm validation of the value of the selections. Note that stages 1, 2, and 3 represent the basic, applied, and adaptive research components in the development of this technology.

Stage 4 is the demonstration, extension, and adoption of the technology among farmers. The process underlying the adoption of the technology characterizes adoption-related variables like adoption lag, rate of adoption, and ceiling level of adoption, as described below.

Introduction of a new technology is not usually met with immediate adoption. The gestation period between the generation of a technology and its adoption varies by sector, commodity, and type of technology. There are farmers who adopt only after the effects have been convincingly demonstrated. Farmers may hesitate to adopt a technology due to the difficulty in its use, nonavailability of the inputs required, market uncertainty, price fluctuations or preference for very low crop management technology. Thus, the level of adoption may be initially low, rising at an increasing rate after sufficient diffusion is attained, and finally reaching a ceiling level of adoption.

Based on the above sketch and the priority-setting framework described earlier, the basic data requirements and the steps required to develop the supporting database can be identified:

1. Identify the elements of the research portfolio to be prioritized. This may disaggregate by crops, research themes, programs, projects, or constraints.
2. In the case of commodities, assemble data by country or region on the area, production, and consumption of these commodities.
3. Define agroclimatically homogeneous regions.
4. Collect data on key factors involved in the various stages of the research process. For example, to estimate the expected impact for the BNF research illustrated above, previous average research experience shows that it takes around 5 years to undertake basic and strategic research, 4 or 5 more years to produce an improved variety, and another 5 or 6 years to reach the ceiling level of adoption (ICRISAT, 1992).
5. For computing estimates of the potential benefits of research, build on the research objectives and corresponding measurable criteria, which may require the following data:
   - yield gain
   - unit cost reduction

- production
- consumption
- adoption estimates

6. Estimate the probability of success of each research option.
7. Assemble data on prices and price elasticities of demand and supply for each commodity. Include data on discount rates, exchange rates, transport costs, and potential spillover effects for traded commodities.
8. Assemble data on research costs for measuring costs relative to research benefits.

Structured database

Systematic calculation of the measures of the various priority-setting criteria requires a structured database. The database developed from the research evaluation and priority-setting process contains comprehensive information on variables including research objectives, target research domains, estimated yield losses, expected yield gains, probability of success, adoption rates and ceiling levels, research and adoption lags, expected output, and manpower and capital requirements. This database serves as a benchmark or reference for research evaluation of future projects. This database should be continuously updated through impact monitoring.

Institutionalization

Research evaluation and priority setting within an organization involves a sustained effort to establish a built-in mechanism for setting priorities as part of the decision-making and research management processes. In this case, the management evolves a continuous cycle of priority setting with a defined and regular interval to provide an avenue of feedback and timely redirection of research. Establishing such a mechanism will require the following essential steps: (1) adaptation of a uniform methodological framework to assure comparability and consistency of identified priorities; (2) regular database update; (3) establishment of a monitoring process for performance, adoption, and impact; and (4) training to develop the capacity of scientists associated with priority setting. Training is essential not only to undertake priority setting consistently and objectively, but also to achieve transparency and active participation within the organization. Finally, in order to institutionalize and facilitate organizational priority-setting processes, *ex ante* impact analysis should be written into research proposals such that movement along the research evaluation and impact pathway continuum can be monitored, so that any necessary mid-course adjustments can be made and *ex post* impact assessments done. A decentralized process using nested institutional and project logframes may help to identify milestones for institutional and individual project evaluations.

Research priority setting: international dimensions

The international dimensions of research priority setting may be exemplified by the exercises conducted by the CGIAR. Its priority-setting initiative was driven by a determination to build an objective and transparent basis through its Medium Term Plans (MTPs). The 15 centers belonging to the CGIAR faced the challenge of a changing external environment where funds for research were declining, and pursuit of a focused research agenda became imperative. This change motivated stronger accountability and a search for an objective research priority-setting and resource-allocation process among the CGIAR centers operating around the world.

During the late 1980s to the early 1990s, the CGIAR Technical Advisory Council's (CGIAR/TAC) guidelines identified four basic factors for identifying agricultural research priorities. These included (CGIAR, 1988):

- Comparative advantage (e.g., the advantage that CGIAR has in undertaking projects where long-term, continuous effort is required)
- Internationality (i.e. the existence of externalities and spillover effects)
- Partnership (i.e. encouragement of intercenter and center-NARS activities)
- Efficiency and equity

The last factor especially related to total potential benefits and high expected payoffs, with consideration to the distributive consequences of successful research. This means identifying the area (ecological and geographical regions) and people affected, the benefits of research in relation to costs, feasibility of implementation and successful completion, and potential effects on the livelihoods of the poorer or marginalized sections.

The CGIAR evolved a structured priority-setting strategy aimed at reflecting its multiple research objectives. The determination of the priority research portfolio was built on an analytical priority-setting methodology based on a set of measures established for each of four criteria: economic efficiency or total welfare gain, equity, or distribution of the total welfare gain, sustainability, and internationality. Several CGIAR centers applied a similar set of criteria but evolved their own systems, depending on their requirements and capabilities. For example, a more significant effort for the 1994–1998 priority-setting exercise at ICRISAT, one of the CGIAR institutes mandated to target semi-arid tropics (SAT) research, involved application of a participatory approach. In this case, the problem was one of prioritizing among numerous competing research possibilities to make optimum use of scarce research funds against the background of a strategic plan. ICRISAT used an *ex ante* multiobjective framework, considering indicators for economic efficiency, equity, internationality, and sustainability, for assessing research priorities. A supply-side methodological orientation was used to complement the (CGIAR/TAC) demand-side analysis. The distinct advantage of the quantitative framework that was established is that at a time of intense competition for scarce funds, it makes explicit the benefits that would flow from additional investments to an institute as well as the opportunity costs corresponding to reductions. The priority-setting methodology used for ICRISAT was found to provide clear criteria for establishing choices among competing research activities. It is more analytically rigorous, draws on scientists' empirical and intuitive knowledge base, and is transparent and interactive. Research themes were identified as impact-oriented, projecting clear milestones against which progress can be measured and evaluated. The assumptions about prospective yield increases, research lags, probabilities of success, and adoption lags and ceilings are tested against actual delivery of a new research-induced technology. This forms an integral part of the research evaluation process and facilitates revising priorities in the light of such experiences. This methodology was also later applied in other CGIAR centers (Kelley et al., 1995; Bantilan and Ryan, 1996; ILRI, 1999; IRRI, 1997).

In a follow-up MTP cycle 1998–2000, CGIAR centers pursued extensive discussions with partners where broad targets were identified that captured the areas of research and the nature of the benefits they intended to deliver through these partnerships during this particular MTP period. For example, four targets were articulated by ICRISAT:

Prosperity. Poverty is a fundamental cause of hunger, disease, environmental degradation, and a host of other afflictions. Since the majority of the poor in the SAT are engaged in farming or other agriculturally related enterprises, the road to prosperity lies toward the development of more productive and efficient agricultural systems.

Diversity. Poor farmers with small landholdings cannot afford the risk of being overly dependent on just a few crops or cropping systems. Diversity creates options; it spreads risk; it evens out peaks and valleys in labor use and income; it enables the creation of added value by expanding the application of farmers' management skills to new enterprises. More diverse, complex cropping systems are usually more robust and stable, and sustainable over time.

Environment. Environmental resources are the fundamental inputs of agriculture. The conscious or unconscious abuse of these resources can throw entire societies into poverty. This target has particular relevance to the SAT where poverty is a driving force behind short-term exploitation of the environment to satisfy pressing food needs.

Inclusiveness. Research products must be understood and valued by those who use them if they are to have impact. It is difficult to achieve this unless these stakeholders are involved in the identification of relevant research priorities, and in the research process itself.

The target of inclusiveness appealed to participatory methods to support the priority-setting process and decision support tools that facilitate the participation of stakeholders and allow them to express their preferences.

Subsequent 3-year MTP cycles followed, and the criteria used to rank priorities were more or less maintained across the CGIAR centers. The strategies and priority guidelines offered by the CGIAR TAC (later called Science Council) were influential in this evolution. The criteria broadened to consist of: equity, efficiency, internationality, sustainability, new science opportunity, relevance to NARS priorities, and future trends which could change basic assumptions. Notably, major efforts continue to be launched to consult NARS partners and other stakeholders in the setting of priorities. The approaches to strategic planning and priority setting in the CGIAR continued to advance in the past few years, where the basis of priority setting has not only become more inclusive and participatory, but also increasingly appeals to process plans for strategic planning, impact pathways, situation and outlook analysis, periodic commodity and sector reviews, and more systematic understanding and foresight of the external environment and megatrends.

CONCLUSIONS

Priority-setting exercises have evolved in response to the need felt by scientists and research managers for simple and transparent procedures for making resource allocations to research projects. Research managers have come increasingly to realize that in order for research resources to be used efficiently and effectively, there should be a clear basis for setting research priorities. Complex considerations have to be weighed by the priority-setting process, and guidelines that are consistent with the broad agenda of research investment should be pursued for a problem-based, impact-driven agricultural research for development.

This chapter covered several important considerations that have to be weighed by the priority-setting process. It featured recent trends in the global agricultural research-funding scenario. These trends provide compelling reasons for a serious initiative among research evaluation practitioners to provide more systematic guidelines for research planning and priority setting. A simple research evaluation and impact pathway framework was discussed to identify the key parameters and minimum datasets needed for prioritization. Factors including government policies, expansion in demand and supply and other key issues not covered by the simple framework were discussed to feature some potential areas for enhancement. This chapter also discussed the multiple-criteria nature of agricultural research priority-setting processes, making a special mention of mainstreaming poverty.

The issue of choosing an appropriate method from among the several methods in practice was addressed with an overview of the various approaches and a discussion of their advantages and disadvantages and their suitability in different situations. It was shown that in many cases, analysts combine two or more methods and tend to complement the intuitive judgments of research managers and administrators with the scientific intuition of scientists and researchers. While measurable economic benefits lend strong support to the priority ranking of a research portfolio, additional considerations involving (a) the inclusion of qualitative impacts; and (b) utilization of *ex post* impact assessment in priority setting, were also elucidated.

As the analysis presented in this chapter demonstrates, the recent methodologies developed illuminate not only the relative economic benefits accruable from alternative strategies but also the trade-offs which might be implied in the distribution of benefits. A good balance between theoretical rigor and practical feasibility in the priority-setting applications is needed. According to the availability of more disaggregated data, these approaches allow the determination of the distribution of benefits among the poor or nonpoor sections of the country. These considerations are of interest to policymakers who are required to make judgments on the allocation of scarce resources.

The final sections of this chapter expounded on the issues of institutionalization and the international dimensions of research priority setting in agriculture. It reiterated the message that in order to institutionalize and facilitate organizational priority-setting processes, *ex ante* impact analysis should be written into research proposals such that movement along the research-development-impact pathway can be monitored to enable learning so that any necessary mid-course adjustments can be made.

The information given in this chapter serves as an exemplar illustrating the assessment and prioritization of research projects, as per the differential nature of specific institutes. It demonstrates the need for more comprehensive measures that could be used to evaluate research priorities by taking into account the broad and diverse nature of research objectives today.

ACKNOWLEDGEMENT

We gratefully acknowledge the assistance of Anand Babu for the literature search and collection of expenditure data.

REFERENCES

Alston, J.M., Edwards, G.W., and Freebairn, J.W. 1986. The effects of protection policies on research benefits. Economics and Marketing Branch Working paper series no. 20, Victoria Department of Agriculture, Melbourne, Australia.

Alston, J.M., Norton, G.W., and Pardey, P.G. 1995. *Science under Scarcity: Principles and Practices for Agricultural Research Evaluation and Priority Setting*. Cornell University Press, Ithaca, NY.

Bantilan, M.C.S., Anupama, K.V., and Joshi, P.K. 2005. Assessing economic and environmental impacts of NRM technologies: An empirical application using economic surplus approach, Chapter 11. In: Shiferaw, B., Freeman, H.A., and Swinton, S.M. (eds.) *Natural Resource Management in Agriculture: Methods for Assessing Economic and Environmental Impacts*. CAB International, Wallingford, UK.

Bantilan, M.C.S., and Davis, J.S. 1991. Across-Commodity Spillover Effects of Research and Opportunity Costs in a Multi-product Production Environment. ACIAR/ISNAR Project Paper No. 30. Australian Center for International Agricultural Research. Canberra, Australia/ International Service for National Agricultural Research, The Hague, Netherlands.

Bantilan, M.C.S., Deb, U.K., Reddy, B.V.S., Obilana, A.B., and Gowda, C.L.L. 2004. *Sorghum Genetic Enhancement: Research Process, Dissemination and Impacts*. International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India.

Bantilan, M.C.S., and Johansen, C. 1995. Research evaluation and impact analysis of biological nitrogen fixation. *Plant and Soil: International Journal on Plant–Soil Relationships* 174(1–2): 279–286.

Bantilan, M.C.S., and Ryan, J.G. 1996. Using impact assessment in research priority setting: Developments at ICRISAT. Paper presented at the International Conference on Global assessment for science policy, 26–28 August 1996, Melbourne, Australia.

Bantilan, M.C.S. 2000. Linkages among measurable criteria and sensitivity analysis for research priority setting: Learning from the experience of ICRISAT. In: Pal, S. and Joshi, P.K. (eds.) *Priority Setting, Monitoring and Evaluation in Agricultural Research*. National Center for Agricultural Economics and Policy Research, New Delhi, India, pp. 22–34.

Braunschweig, T. 2000. Priority setting in agricultural biotechnology research supporting public decisions in developing countries with the analytic hierarchy process. Research report series no. 16. International Service for National Agricultural Research, The Hague, The Netherlands.

Brennan, J.P., and Bantilan, M.C.S. 2003. Price and yield effects of spillovers in international agricultural research: Evidence from ICRISAT and Australia. *Agricultural Economics* 28(2): 87–97.

CGIAR (Consultative Group on International Agricultural Research). 1988. *Medium Term Program Plans and Funding Requirements, 1989–93*. CGIAR, Washington DC.

CGIAR (Consultative Group on International Agricultural Research). 2005. *Agricultural Research Matters: Achieving the Millennium Development Goals*. CGIAR, Washington DC. http://www.cgiar.org/pdf/cgiar_mdgs_brochure_2005.pdf

Contant, R.B., and Bottomley, J.A. 1988. Priority setting in agricultural research. Working paper 10. International Service for National Agricultural Research, The Hague, The Netherlands.

Davis, J.S., Oram, P.A., and Ryan, J.G. 1987. Assessment of agricultural research priorities: An international perspective. ACIAR Monograph no. 4. Australian Centre for International Agricultural Research, Canberra, Australia.

Deb, U.K., Bantilan, M.C.S., Bantilan, F.T., and Gowda, C.L.L. 2004. Spillover impacts of sorghum research. In: Bantilan, M.C.S., Deb, U.K., Reddy, B.V.S., Obilana, A.B., and Gowda, C.L.L. (eds.) *Sorghum Genetic Enhancement: Research Process, Dissemination and Impacts*. International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India, pp. 237–262.

Fan, S. and Hazell, P. 2000. Should developing countries invest more in less-favoured areas? An empirical analysis of rural India. *Economic and Political W*eekly 35(17): 1455–1464.

Haddad, L., and Hazell, P. 2001. CGIAR research and poverty reduction. Paper prepared for the Technical Advisory Committee of the CGIAR. International Food Policy Research Institute, Washington DC.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1992. *ICRISAT Medium Term Plan, 1994–1998*. ICRISAT, Patancheru, Andhra Pradesh, India.

ILRI (International Live Stock Research Institute). 1999. *Making the Livestock Revolution Work for the Poor*. ILRI, Nairobi, Kenya.

IRRI (International Rice Research Institute). 1997. *Annual Report 1995–1996: Listening to the Farmers*. IRRI, Metro Manila, Philippines.

Janssen, W. 1995. Priority setting as a practical tool for research management. In: Bosch, M. and Preuss, H.J.A. (eds.) *Management Issues in National Agricultural Research Systems: Concepts, Instruments, Experiences*. Studies of the Center for Research on Regional Development, Justus-Liebig-University. LIT Verlag Münster-Hamburg, Giessen, Germany.

Joshi, P.K., and Bantilan, M.C.S. 2000. Institutionalization of research prioritization, monitoring and evaluation. In: Pal, S. and Joshi, P.K. (eds.) *Priority Setting, Monitoring and Evaluation in Agricultural Research*. National Center for Agricultural Economics and Policy Research, New Delhi, India, pp. 65–81.

Kelley, T.G., Ryan, J.G., and Patel, B.K. 1995. Applied participatory priority setting in international agricultural research: making trade-offs transparent and explicit. *Agricultural Systems* 49(2): 177–216.

Lubulwa, A.S.G., Menz, K., White, D.H., Chudleigh, P., McMeniman, S., and Hill, D. 2000. Determining international agricultural research priorities. Australian Centre for International Agriculture Research IAP Working paper series no. 37. Australian Centre for International Agriculture Research, Canberra, Australia. http://www.aciar.gov.au/web.nsf/att/JFRN-6BN8XF/$file/wp37.pdf

Norton, G.W., Pardey, P.G., and Alston, J.M. 1992. Economic issues in agricultural research priority setting. *American Journal of Agricultural Economics* 74(5): 1089–1094.

Reardon, T. 1997. Using evidence of household income diversification to inform study of the rural non-farm labour market in Africa. *World Development* 25(5): 735–747.

Ryan, J. 2004. Agricultural research and poverty alleviation: Some international perspectives. ACIAR Working paper no. 56. Australian Centre for International Agricultural Research, Canberra, Australia.

Scobie, G. 1984. Investment in agricultural research: Some economic principles. Working paper. International Centre for Research on Maize and Wheat (CIMMYT), El Batan, Mexico.

Shumway, C.R. 1981. Subjectivity in ex-ante research evaluation. *American Journal of Agricultural Economics* 63(1): 169–173.

Shumway, C.R. 1983. Ex-ante research evaluation: Can it be improved? *Agricultural Administration* 12: 91–102.

UN (United Nations). 2002. The millennium development goals and the United Nations' role. United Nations, New York. http://www.un.org/*millenniumgoals*/*MDGs-FACTSHEET1.pdf*