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PART FIVE: Developing Countries

26A. Incorporating the Strategic Component of Biotechnology into Public Sector Research Evaluation

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Chapter 26A

Incorporating the Strategic Component of Biotechnology into Public Sector Research Evaluation

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Introduction

This paper is concerned with priority setting of agricultural biotechnology research in public sector organizations of developing countries. More specifically, it focuses on incorporating into the evaluation process the strategic component as a more indirect benefit of biotechnology research activities. For the present purpose the term "strategic component" is used to denote research impacts that strengthen capacities in terms of human resources and institutional development in order to influence the efficiency of future research. The strategic component, therefore, includes such diverse impacts as better-trained people, newly generated knowledge, or improved institutional linkages. These impacts become more important as we move towards the basic end of the research continuum. However, applied research activities might still have benefit profiles with a significant strategic component. Although strategic benefits do not directly result in improved production technologies, the capacity to create, distribute, and use knowledge is rapidly gaining importance as knowledge is becoming the key strategic resource for economic development worldwide (Conceição et al., 1998).

A lot of effort has been put into evaluating public agricultural research,[2] due in part to the increasing complexity of decision problems based on a broader research agenda and in part to tight research budgets and pressure for more accountability. However, nonmarket effects are often very difficult to quantify let alone express in monetary terms because they do not directly result in changes in production or cost. Given this measurement difficulty it is not surprising that the issue has received comparatively little attention in conventional research evaluation (Norton et al., 1992). The shallow treatment of nonmarket impacts has also been criticized in a study for the American Agricultural Economics Association (Antle and Wagenet, 1995, p. 12):

> The research evaluation literature has developed increasingly refined models and estimates of economic impacts, but has virtually ignored all other social, environmental, or health impacts. . . . Indeed, an 'economically optimal' allocation of research effort would devote suitable effort to all potentially important impacts.

The research reported in this paper aimed to achieve a more balanced treatment of research of different nature (along the spectrum of basic to applied) in ex ante evaluation. In the rest of section 1, the justification to include the strategic component in priority

setting exercises is detailed. Section 2 provides a brief description of the Analytic Hierarchy Process (AHP), the methodological framework on which the priority setting approach is based. In section 3, the priority setting approach is explained and its application in the Chilean biotechnology program is outlined. Section 4 presents the results of the priority setting exercise. The section also includes a discussion on the relevance of the strategic component based on the outcome of sensitivity analysis. The concluding section assesses the present approach for research priority setting and highlights some shortcomings to be addressed in future applications.

The justification to take the strategic component into account when decisions on the most promising research alternatives have to be made can be looked upon from the perspective of (i) economic development process, (ii) the public sector, and (iii) biotechnology:

1. According to a recent World Development Report (World Bank, 1998) the inequalities between developed and developing countries in the capacity to create knowledge exceed even those in income. Given the critical role of knowledge for the development process and the increasing global competition, the need to invest substantial resources in strengthening the scientific capacity is obvious. This applies regardless of whether national science and technology policies are oriented toward the import or the in-country generation of technology. In the former case, countries need sufficient scientific capacity to absorb and adapt technologies developed elsewhere (Umali, 1992).

2. From a public sector perspective, the main justification is derived from the public good characteristics of the strategic component. Although knowledge derived from agricultural research is rarely a pure public good, it shows various degrees of 'public goodness' (Alston and Pardey, 1996). The economic argument for government intervention[3], based on the public good nature of the output of certain agricultural research activities, is that of market failure due to nonrivalness and nonexcludability – the later giving rise to the 'free rider' problem. This would lead to underinvestment in research from society's point of view. The complementarity of research and education has been offered as an additional reason for public sector involvement (Ruttan, 1982).

3. Biotechnology is knowledge-intensive. Developing countries therefore have to create a local scientific base if they want to capture the potential benefits of agricultural biotechnology. However, the lack of adequate national research capacities in developing countries has been identified as one of the major constraints to exploit the potential of biotechnology developments (Brenner, 1996; Bhagavan, 1997). As a consequence, developing countries should invest in institutional development and human resources. The ability of biotechnology to produce enabling techniques (e.g. genetic markers as diagnostic tools) besides end products (e.g. transgenic plants) underpins the relevance of incorporating into research evaluation scientific capacity building as an important output. In addition to scientific and technical capacities for direct application in biotechnology research, there is a need for many developing countries to acquire

expertise and experience to cope with issues such as biosafety and intellectual property rights.

The political pressure to show immediate results may lead to the selection of research projects with more tangible impacts, at the expense of projects with less immediate and more strategic impacts. However, as Dasgupta and David (1994, p. 493) pointed out:

> Short-run policies aiming to shift resources towards commercial applications of scientific knowledge . . . may seriously jeopardize a nation's capacity to benefit from a sustained flow of innovations based upon advances in scientific and technological knowledge.

It is important, therefore, to inform decision makers about the complete benefit profiles that can be expected from individual projects. Explicitly accounting for the strategic component in research priority setting can help them to get a more accurate picture of the consequences of their choices. This might be particularly relevant for competitive grants which are gaining popularity as funding scheme for agricultural research (Echeverría et al., 1996; Janssen, 1998). These funds are open to various organizations involved in a wide range of activities along the basic-applied research continuum.

Methodological Framework

At the heart of our approach to incorporate strategic impacts is the Analytic Hierarchy Process (AHP). The method is described by Saaty and Vargas (1991, p. 14) as a

> Multiobjective multicriteria decision-making approach which employs a pairwise comparison procedure to arrive at a scale of preferences among a set of alternatives. To apply this approach, it is necessary to break down a complex unstructured problem into its component parts and arrange these parts, or variables, into a hierarchic order.

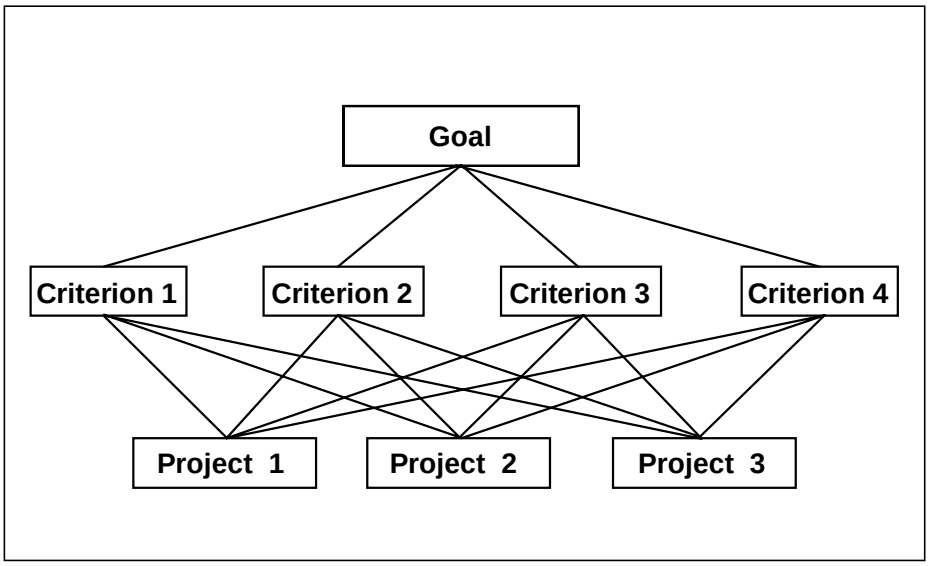
The AHP was initially developed by Saaty (1980) and has become a widely used decision support tool. Its numerous applications have been surveyed by Zahedi 1986, Golden et al. 1989, and Vargas 1990.[4] AHP provides a consistent framework to formally incorporate subjective judgments in group decision making (Dyer and Forman, 1992). A software package called Expert Choice is available that considerably facilitates the application of the method.

The procedure of the AHP is based on three principles: (1) decomposition of a complex unstructured problem, (2) comparative judgments about its components, and (3) synthesis of the judgments into priorities.

(1) Stating the problem in a hierarchical structure. Figure 1 presents a basic hierarchy, made up of three levels. The top level is the general goal of the exercise, such as

"selecting projects that best contribute to the development of the agricultural sector." The second level consists of the criteria (e.g., the research objectives) relevant for this goal and the bottom level encompasses the alternatives (research projects). To introduce more precision in the evaluation process, criteria can be divided in subcriteria, inserting an additional level to the hierarchy.

FIGURE 1 The Basic Structure of a Hierarchy



(2) Criteria are weighted and projects are evaluated. The projects are compared in pairs to assess their relative preference with respect to each of the criteria at the next higher level. Similarly, the criteria are compared in pairs to define their importance with respect to the goal. The verbal terms of the fundamental scale presented in Table 1 are used to assess the intensity of preference between two elements. The ratio scale and the use of verbal comparisons facilitate the weighting of criteria as well as the evaluation of projects regarding non-quantifiable criteria. Once the verbal judgments are made, they are translated into numbers by means of the fundamental scale.

TABLE 1 The Fundamental Scale for the Comparative Judgments

Numerical values	Verbal terms
1	Equally important, likely or preferred
3	Moderately more important, likely or preferred
5	Strongly more important, likely or preferred
7	Very strongly important, likely or preferred
9	Extremely more important, likely or preferred
2, 4, 6, 8	Intermediate values to reflect compromise

(3) The judgments are synthesized. Using the eigenvector method (Saaty, 1977), the weights of the criteria and the priorities of the alternatives with respect to each criterion (the so-called local priorities) can be estimated. The final priorities of the alternatives are computed by synthesizing the local priorities throughout the hierarchy. The principle of hierarchic composition is applied for this task (Saaty 1980). The principle simple states that for each project, its local priorities are multiplied by the corresponding criterion weight and the results summed up to get the global priority of the project with respect to the goal stated at the top level. Thus,

(1) $$P_l = \sum_{m=1}^{M} p_{lm} v_m \qquad \text{with } \sum_{l=1}^{L} p_{lm} = 1 \text{ and } \sum_{m=1}^{M} v_m = 1$$

where:

P_l = final priority of project l
p_{lm} = priority of project l with respect to criterion m
v_m = weight of criterion m
l = (1, . . . , L)
m = (1, . . . , M)

The Approach and Its Application in Chile

Recently, Chile established a National Program for the Development of Agricultural Biotechnology (PNB) based on the initiative of the Ministry of Agriculture. The National Institute of Agricultural Research (INIA) was put in charge of the elaboration of the biotechnology initiative. With the assistance of international experts, a proposal for the PNB was formulated and well received by political and scientific authorities. However, the planning exercise failed to identify specific research areas and well-defined criteria for the assessment of individual project proposals (Muñoz, 1997). In this situation, a priority setting exercise was carried out to provide Chile's biotechnology program a possible procedure for selecting research projects (Braunschweig and Janssen, 1998; Braunschweig et al., 1999). Researchers from INIA developed the following seven project proposals in the field of plant biotechnology for prioritization (they are named after the crop to which they relate).[5]

CHIRIMOYA[6]:	genetic transformation to obtain fruits with delayed ripening.
GRAPE:	genetic transformation to induce resistance against phytopatogene fungi.
POTATO:	use of ligament maps of RFLP with the gene H1 marker to improve resistance against cyst nematodes in Chile.
TOMATO:	use of molecular markers to study the diversity of native germplasm.
WHEAT:	implementing genetic engineering to manipulate fungus based diseases.
NOTHOFAGUS[7]:	biochemical, molecular and dasometrical characterization of six species of the genus *nothofagus*.
FLOWERS:	characterization and selection of native flowers with export potential.

Two groups participated in the exercise. The 'strategic' group consisting of research leaders and policy makers defined and weighted the decision criteria. The 'technical' group with the project leaders and representatives from INIA's planning unit assisted in the structuring process and evaluated the research proposals. Due to time constraints of the members of the strategic group, their judgments were elicited in individual interviews whereas the technical group gathered in two workshops, which were facilitated by a moderator. The outcome of the exercise encompassed a structured list of weighted decision criteria, a rank order of the evaluated projects, and a set of scenarios to accommodate the different criteria weights.

The approach for the priority setting exercise is made up of three hierarchies, one each for estimating the potential impact of the research projects, their chances of research success (α_l), and their chances of successful adoption by the end users (β_l). The outcome of the individual hierarchies (P_l, α_l, β_l) were then selectively combined to obtain the final rank order of the projects (P_l). The model can be formally expressed as:

$$P_l = \sum_{m=1}^{M} \sum_{n=1}^{N(m)} \theta_{ln} p_{ln} v_m s_{mn} \tag{2}$$

where:

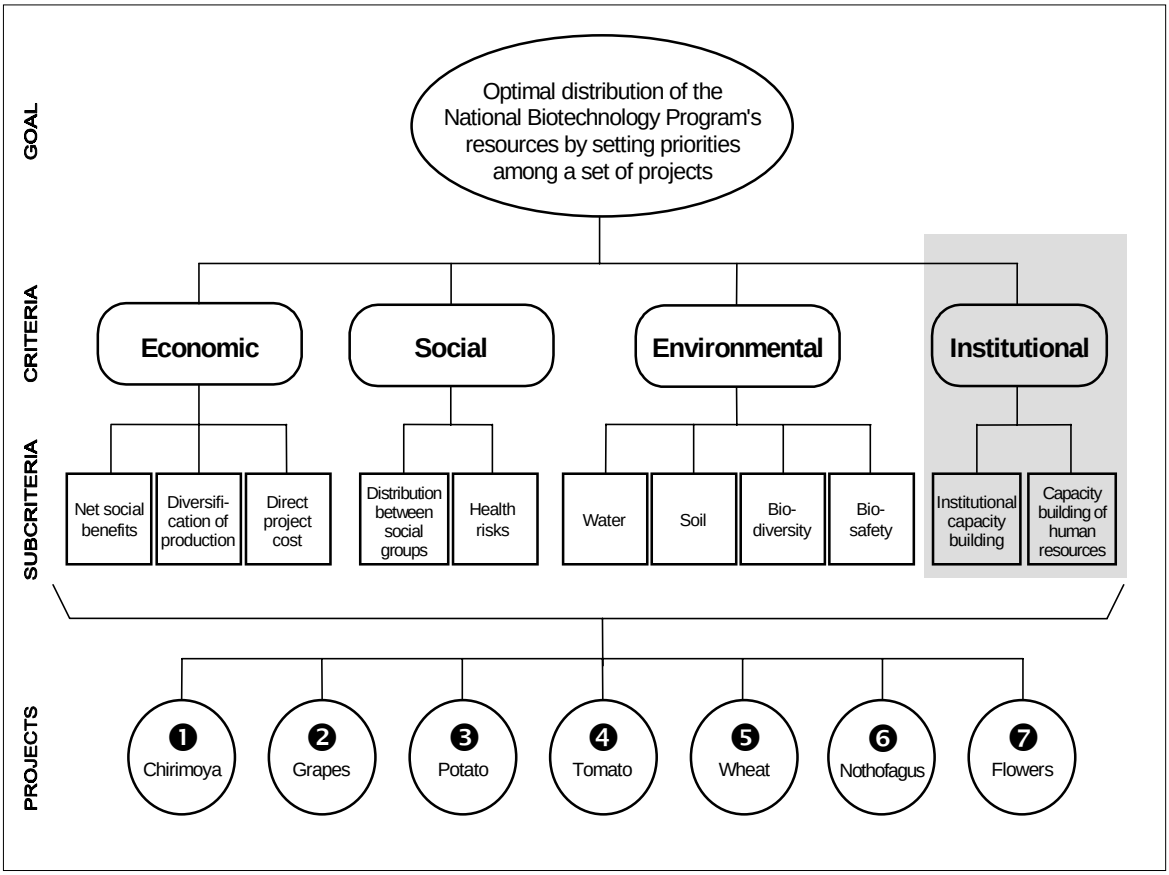
P_l = final priority of project l
p_{ln} = priority of project l with respect to subcriterion n
v_m = weight of criterion m
s_{mn} = weight of subcriterion n from criterion m
$l = (1, \ldots, L)$
$m = (1, \ldots, M)$
$n = (1, \ldots, N)$

$$\theta_{ln} = \begin{cases} \alpha_l & \text{if impact of project } l \text{ on subcriterion } n \text{ is subject to only chances of research success} \\ \alpha_l \beta_l & \text{if impact of project } l \text{ on subcriterion } n \text{ is subject to chances of research and adoption success} \\ 1 & \text{if impact of project } l \text{ on subcriterion } n \text{ is neither subject to chances of research nor adoption success} \end{cases}$$

α_l = chances of research success of project l
β_l = chances of adoption success of project l.

It is important to explain the implications of the model used for combining the results from the individual hierarchies. Institutional impacts are dependent on the chance of research success but not on the chance of successful adoption (i.e. $\theta_{ln} = \alpha_l$). If the scientific results have been achieved, the institutional and human resource impact is assumed also to have been achieved. On the other hand, economic, social, and environmental impact will normally depend on successful research and adoption.

FIGURE 2 Hierarchy to Evaluate the Potential Impact of the Research Projects



All three hierarchies were structured along four levels: goal, criteria, subcriteria, and projects. The hierarchy to evaluate the potential project impact is depicted in Figure 2. In order to capture the strategic component of the project, a criterion named 'Institutional' was included along with criteria representing conventional research objectives. The criterion is broken down into two subcriteria named 'Institutional capacity building' and 'Capacity building of human resources'.

Table 2 presents the definition and the indicators of the two subcriteria. The table also indicates the sources from where the information is drawn to measure the projects' performance against the indicators. The external peer review of the project proposals provided the necessary information for the indicators 1-3 of the subcriterion named 'Institutional capacity building'. The reviewers used a 5-point scale (very high, high, medium, low, irrelevant) to specify the contribution of the projects to these indicators. The information for the last indicator of this subcriterion and for all indicators of the subcriterion 'Capacity building of human resources' was directly extracted from the project proposal. The technical group then compared in pairs the projects using this information.

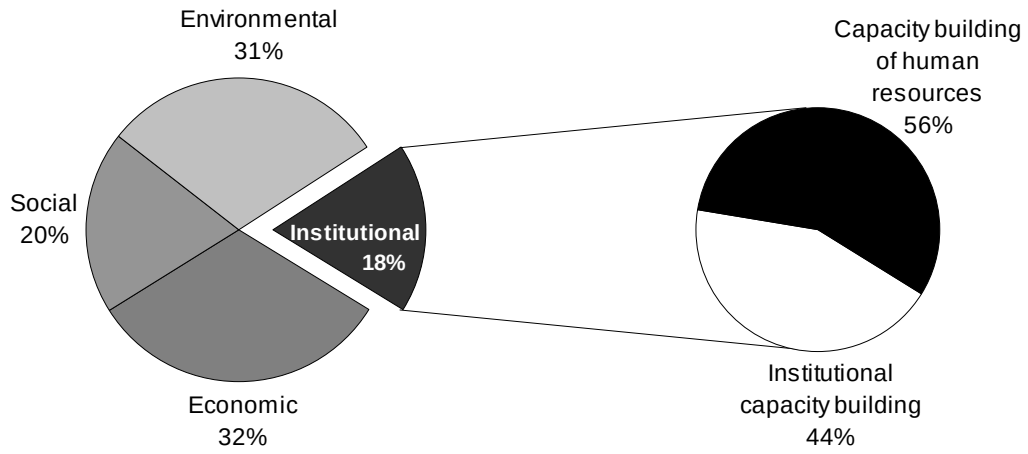
TABLE 2 Subcriteria, Their Definition and Indicators, and Sources of Information

Subcriteria	Definition	Indicators	Sources of information
Institutional capacity building	Strengthening the institutional capacity in order to improve the efficiency and effectiveness of future research, and the reputation of the institution.	1) novelty of the generated technology	peer review
		2) scientific significance of the generated knowledge	peer review
		3) spill-over effects of the generated knowledge	peer review
		4) amount of hours spent in the project by the researchers of each institutions	project proposal
Capacity building of human resources	Contribution to the formation of professionals of different areas, from within as well as outside of the institution.	1) total amount of personnel involved in the project (full-time equivalent)	project proposal
		2) weekly hours of teaching at universities of project staff	project proposal
		3) relevance of the generated knowledge for teaching purposes and for non-research institutions	project proposal

Results and Discussion

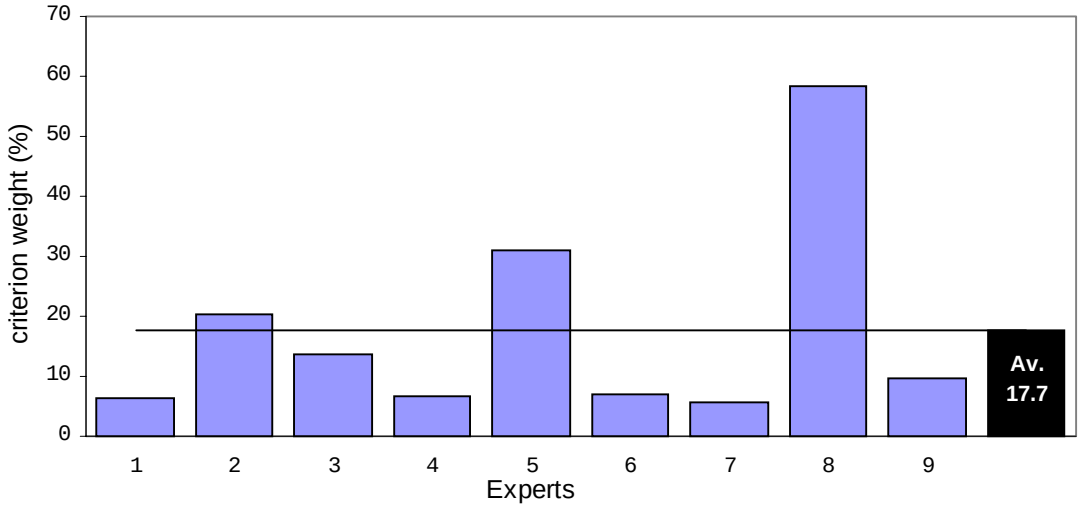
This section presents the results of the priority setting exercise. The focus is on the strategic component as captured by the criterion 'Institutional'. Figure 3 depicts the relative weights of the criteria in the main hierarchy and the weights of the two subcriteria. The relative weight for the criterion 'Institutional' is 18%, distributed between the subcriteria 'capacity building of human resources' and 'institutional capacity building' which captured 56% and 44%, respectively, of the total 'Institutional' weight.[8] However, the effect of the strategic component on the final project priorities is even more significant than the criterion weight would suggest, since the score for the 'Institutional' impact is not dependant on the chance of successful adoption as are the scores for the impact of the other criteria (see previous section). The average contribution of the strategic component to the final project priority is 25%.

FIGURE 3 Average Weights of the Criteria and the Two Subcriteria



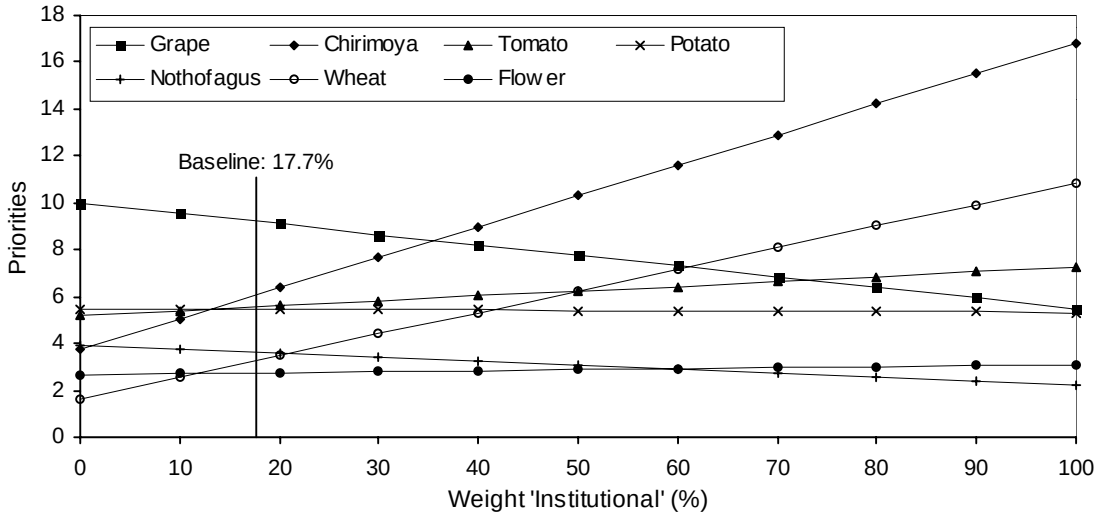
The weights depicted in Figure 3 are averages computed from the weights elicited from 9 members (principal subgroup) of the strategic group. However, the variation in the weighting by the individual experts is considerable, ranging from just 6% to 58% (Figure 4).

FIGURE 4 Weight of the Criterion 'Institutional' as Elicited from the Individual Experts



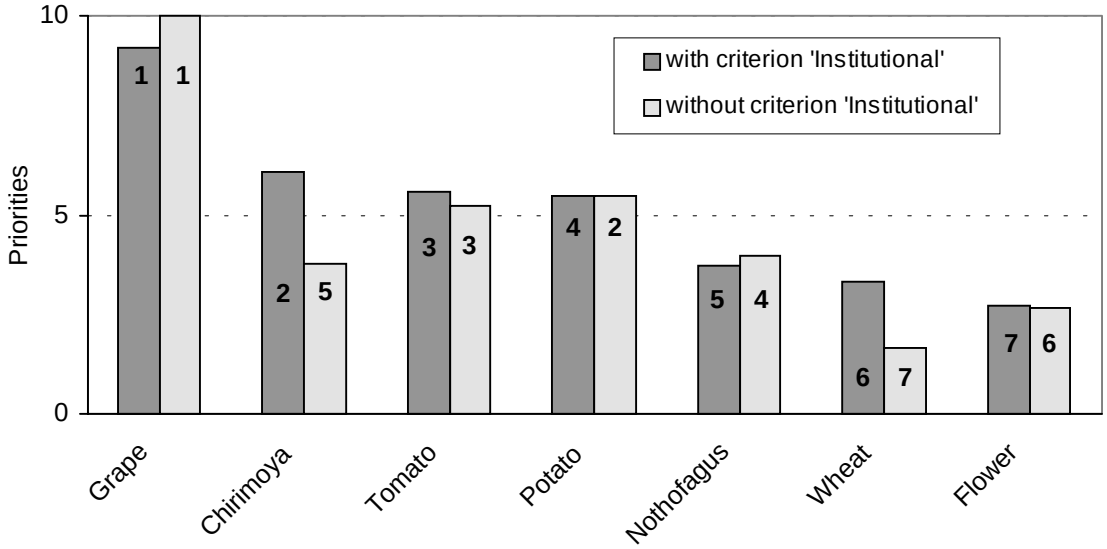
Sensitivity analysis has been performed to accommodate the high variation of the individual weightings. Figure 5 shows the development of the projects priorities under varying relative weights of the criterion 'Institutional'. According to the high proportion of the strategic component in the final priorities of CHIRIMOYA and WHEAT, the ranking already changes for weights slightly different from the baseline. CHIRIMOYA takes over as the most preferred project when the 'Institutional' weight increases over 35%. On the other hand, CHIRIMOYA rapidly loses ranks for lower 'Institutional' weights.

FIGURE 5 Development of Project Scores Under Different 'Institutional' Weights



Finally, a scenario is presented where the strategic component has been ignored. Figure 6 shows the project ranking with and without the criterion 'Institutional'. GRAPE clearly remains the most preferred project under this scenario. But a major change occurs for CHIRIMOYA which falls back from the second to the fifth rank and for POTATO which gains two ranks. Smaller changes can also be observed for the three projects at the end of the ranking. Overall, the final project ranking looks quite different for the "with" and "without" case.

FIGURE 6 Final Project Ranking With and Without the Criterion 'Institutional'



Conclusions

The purpose of this paper has been to shed light on a generally neglected issue in research priority setting: the incorporation of the strategic component. The need to include strategic concerns has been justified from different perspectives. Devoting more attention to the expected impacts in terms of strengthening the capacity of institutions and human resources helps to eliminate the existing bias against research activities with more indirect benefits.

The priority setting approach presented in this paper is a step in this direction. It explicitly accounts for the strategic component of research activities by employing a criterion named 'Institutional'. The demonstrated relevance in the Chilean biotechnology program points to the usefulness of the approach, compared to other priority setting procedures.

Several conclusions emerge from this experience. First, the strategic concerns can make a difference in selecting research activities. Second, it is even more likely that it does so because the strategic impact is not subject to the chances of successful adoption of the technology as opposed to the other impacts. Third, the separate treatment of scientific capacity building allows for explicitly considering the trade-off between short term and strategic objectives. This helps research managers and policymakers to develop a clear and transparent policy regarding the development of agricultural biotechnology. Fourth, exposing decision makers to these issues helps to clarify individual positions and existing disagreements and thus facilitates the achievement of a consensus. Fifth, it provides a strong case in favor of a multicriteria approach to research priority setting.

There is, of course, still considerable room to improve the approach presented in this paper. Most important, more accurate indicators have to be developed in order to increase the precision with which the strategic component is captured. For instance, the specific expertise researchers may gain in handling biosafety and intellectual property rights issues (as opposed to scientific and technical skills) requires closer attention. Also in this context, the question on how far benefits of collecting, describing, and conserving genetic material should be considered as part of the strategic component has to be tackled. Finally, more analytical work is needed to improve the grouping of the subcriteria and indicators to avoid as far as possible the overlapping of these elements. Notwithstanding these shortcomings, we believe that the presented approach provides an important step towards improved decision processes for allocating scarce resources to research alternatives that best meet national development objectives.

Endnotes

[1]Thomas Braunschweig is Research Fellow, Swiss Federal Institute of Technology (ETH) and International Service for National Agricultural Research (ISNAR), The Netherlands. Willem Janssen is Senior Research Officer, International Service for

National Agricultural Research (ISNAR), The Netherlands. The authors acknowledge the financial support from the Swiss Agency for Development and Cooperation (SDC).

[2]See Alston et al. (1995) for a comprehensive treatment of the subject.

[3]It is important to note, however, that government intervention in the case of market failure can take various forms of which financing public sector research is just one (Beynon, 1995).

[4]See Harker (1989) for an excellent introduction to AHP.

[5]For the purpose of the exercise, it was decided to use only a limited number of projects to keep the work load manageable. For the same reason, only projects from INIA were considered.

[6]Chirimoya (*Annona reticulata)*, also known as Custard Apple is a fruit tree believed to be a native of the West Indies but it was carried in early times through Central America to southern Mexico. It has long been cultivated and naturalized as far south as Peru and Brazil.

[7]Some species of Nothofagus are endemic trees from the subantarctic forests of Chile and Argentina. Nothofagus obliqua (Roble) is one of the species of greater distribution and abundance in Chile and it can live in very different habitats in his natural distribution.

[8]Note that some experts had difficulties to provide judgments on the relative importance of capacity building of human resources compared to institutional capacity building, claiming that the former is included in the latter.

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