APPLYING THE AHP TO RESEARCH PRIORITY SETTING IN AGRICULTURAL BIOTECHNOLOGY: THE PHILIPPINE CASE[1]

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Summary*:* *The potential of agricultural biotechnology has attracted considerable attention in many developing countries. However, without clear focus and coherent research policies the public sector is unlikely to reap the full benefits of the new technology. This paper reports on a priority-setting exercise for agricultural biotechnology research in the Philippines, based on the analytic hierarchy process. Eight crop biotechnology research programs have been prioritized using a decision model that consists of three hierarchies to evaluate their potential contribution to national development objectives, chances of research success, and expected adoption rates, respectively. The final ranking shows a clear grouping of the research alternatives, with the rice program way ahead. The participatory exercise further included stakeholder analysis, a pre-selection process, and a conceptual framework to develop decision criteria. All proved to be useful tools to improve the priority-setting process.*

1. Introduction

In several developing countries, an awareness of the enormous potential of biotechnology has led to the creation of national research programs, that give high priority to this new technology. In contrast to industrialized countries, however, the activities in such national research programs are funded and executed predominantly by the public sector, with marginal involvement from the private sector. Moreover, in many biotechnology programs, clearly defined policies and strategies are non-existent, and there is a serious lack of focus. This was confirmed by several country reviews on the opportunities and constraints of agricultural biotechnology in the developing world (Komen and Persley, 1993; FAO, 1995; Brenner, 1996).

The Philippines has not been left behind in exploring the potentials of biotechnology. Specialized research institutes have been set up and biotechnology activities have been incorporated in the existing agricultural research agencies. The national research system, hence, gives importance to biotechnology (De Guzman et al. 1999). Biotechnology in the Philippines, on the other hand, has also experienced some growth pains. As reported in a study commissioned by Department of Science and Technology (DOST), "it, however, lacks a coherent national agenda for R&D in modern biotechnology. (…) A national biotechnology policy developed and put together by the different sectors of the government (…) is imperative to give focus to R&D and to fully exploit the country's natural resources." (SGV Consulting, 1997:41).

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The International Service for National Agricultural Research (ISNAR) developed and evaluated a priority-setting approach for biotechnology research based on the Analytic Hierarchy Process or AHP (Braunschweig et al., 1999). This paper reports on the application of the approach to prioritizing crop biotechnology research programs in the Philippines. The next section addresses methodological issues. Section 3 is devoted to the priority-setting process. Section 4 provides selected results of the exercise. Section 5 concludes the paper by summarizing the relevance of the exercise for the Philippines. The principal strengths and weaknesses of the AHP are discussed as they pertain to evaluating research in agricultural biotechnology.

2. Methodological Approach

2.1 Rationale for an AHP Approach

A lot of effort has gone into evaluating public agricultural research (Alston, Norton and Pardey, 1995). Allocating resources efficiently and selecting the most promising research activities are issues of both scarcity and choice – processes that can benefit from the work of economists. It should therefore come as no surprise that the study of agricultural research evaluation and priority setting has been dominated by economists. Consequently, most of these studies place emphasis on economic efficiency and on costs and returns that can be expressed in monetary values. This has raised concerns because externalities, distributional effects, and longer-term impacts all tend to be neglected with such a narrow focus (Dahlberg, 1988; Thompson, 1998). Moreover, in the past, economists who were involved in priority setting for public research were preoccupied with tools, devoting too little attention to the process (Norton, Pardey and Alston, 1992). Thompson (1998:50) argues along similar lines: "Too much emphasis upon technical consequences assessment diverts energy from consensus seeking and participatory planning. (...) Sometimes it can be more important to make the wrong decision in the right way." Tight research budgets and the resulting pressure for greater accountability underscore the need for more participatory and demand-driven decision processes.

The AHP is a powerful and flexible approach to decision making, which provides the necessary logical/scientific foundations without ignoring the fact that solving complex decision problems is a process that involves creative thinking, learning, and revising the outcome (Dyer and Forman, 1992). AHP was identified as an appropriate decision-support tool to deal with complex multicriteria problems such as establishing research priorities for agricultural biotechnology (Braunschweig, 2000). The method helps to structure and analyze decision problems by breaking down the complex problem in a hierarchic order and by employing pairwise comparisons of its elements to determine the preferences among the set of alternatives (Saaty, 1980). The AHP has been applied to a wide range of decision problems (Zahedi, 1986; Golden et al., 1989; Vargas, 1990), including the selection of research portfolios (Lockett et al., 1986; Liberatore, 1989; Manahan, 1989). The essential components of the AHP are the creative process of constructing and analyzing a hierarchy and the analytical process of judgments.[2] The former provides detailed insights and helps to achieve a common understanding of the important factors of the decision problem whereas the latter offers a sound technique to elicit and quantify the decision makers' preferences.

2.2 The Model

The AHP model employed in the Philippine exercise is based on the model developed for a similar study in Chile (Braunschweig 2000). It consists of three different hierarchies and the selective aggregation of their outcome. The first hierarchy (H1) estimates the potential impact of each biotechnology research program, measured as the importance of the program's contribution to the national development objectives. The hierarchy is structured around four levels. The overall goal is placed at the top of the hierarchy. The second level consists of the main decision criteria. In order to introduce more precision in the analysis, the criteria have been detailed by defining a third level with subcriteria. The bottom level of the hier-

[2] Harker (1989) provides an excellent introduction of the method and its theoretical foundations.

archy contains the research programs. The priorities of the alternatives with respect to H1 were computed using the principle of hierarchic composition (Saaty, 1980). Thus,

$$P_l^{H1} = \sum_{m=1}^{M} \sum_{n=1}^{N(m)} p_{ln} v_m s_{mn} \tag{1}$$

where:

P_l^{H1} = priority of program l for H1, $l = (1, \ldots, L)$

p_{ln} = priority of program l with respect to subcriterion n, $n = (1, \ldots, N)$

v_m = weight of criterion m, $m = (1, \ldots, M)$

s_{mn} = weight of subcriterion n from criterion m

Uncertainty regarding the success of agricultural research, and the successful adoption of the results by end users, is inherent in all research processes (Anderson, 1991). In biotechnology research, uncertainty is more prevalent due to the limited historical evidence and the accompanying lack of data. Priority setting in biotechnology research should attempt to identify the sources of uncertainty, assess their influence on research success and adoption, and explicitly evaluate the chances of success of each research alternative vis-à-vis the individual sources of uncertainty. Saaty (1995) suggests the use of a separate hierarchy to introduce risk in an AHP-based model. Therefore, a second hierarchy (H2) was developed to evaluate the chances of the research programs to be successful in achieving the intended results. The third hierarchy (H3) evaluates the programs' chances that the results are adopted by the end users. Both hierarchies have the same structure as H1.

To compute the final priorities P_l, the program priorities with respect to the subcriteria (p_{ln}) were multiplied with the chances of research success of the programs (α_l) and, selectively, with the chances of successful adoption (β_l) and then summed up. The selective multiplication by β_l is necessary because not all potential impacts of the programs are subject to successful adoption. More precisely, the program impact on strengthening the science and technology (S&T) capacity depend on α_l but not on β_l. Thus,

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

where:

$$\sigma = \begin{cases} {}^{1}/\alpha_{ln} & \text{if impact of program } l \text{ on subcriterion } n \text{ is not subject to successful adoption} \\ 1 & \text{otherwise} \end{cases}$$

3. The Priority-Setting Process

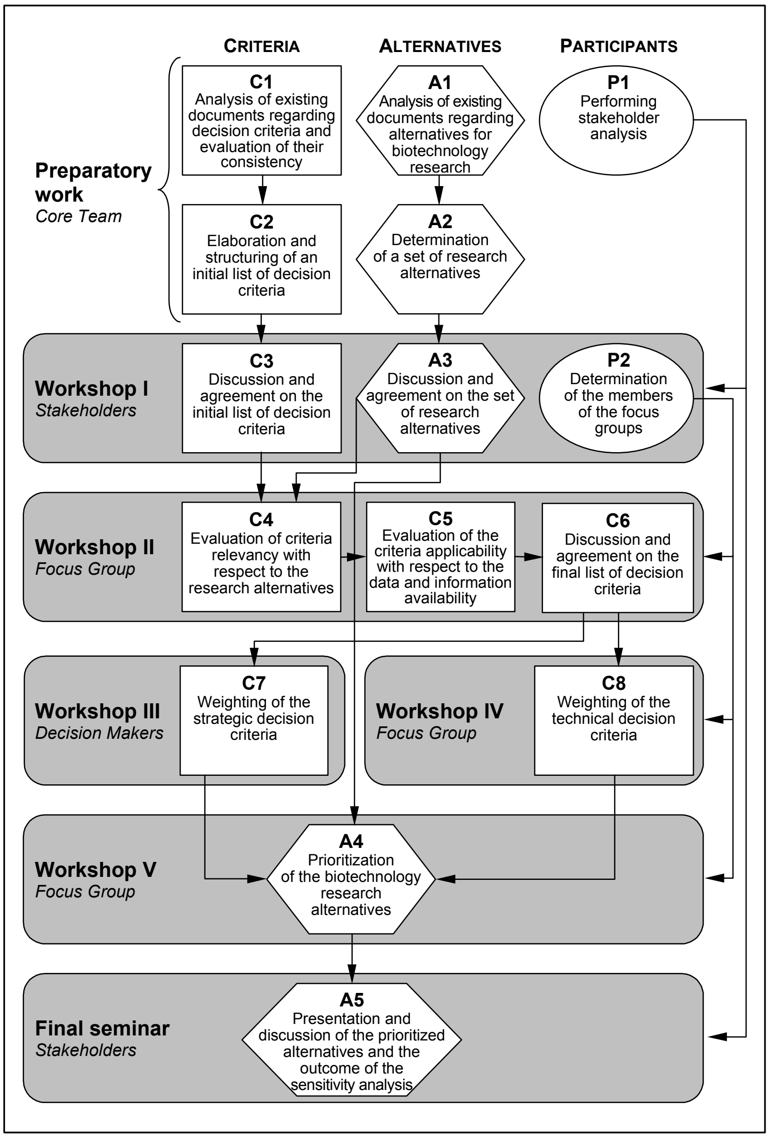
3.1 Procedure

Figure 1 shows the procedure that was used in the Philippines to set priorities for crop biotechnology research programs. It consists of three sets of steps, one each to determine the participants of the exercise, to evaluate the research alternatives, and to develop the decision criteria. The procedure is structured around the preparatory work by the Core Team (CT) consisting of research managers from the main agencies involved in public agricultural research, several workshops and the final seminar. The exercise spanned over a period of 7 months. The participants of the process were identified and selected in step P1 and P2. The research alternatives were defined and assessed throughout steps A1 to A4. The decision criteria were developed and weighted in the steps C1 to C8. The criteria weights were then fed into step A4 where the research alternatives have been evaluated. Finally, the project results were presented to the stakeholders (A5).

3.2 Stakeholder Analysis

The CT conducted formal stakeholder analysis to determine the participants for workshop I and the final seminar (P1 in figure 1). The first step involved the listing of groups such as producers, policy makers, industry, donors, or technology transfer agents. The groups were then classified into five categories. Next, criteria were generated to serve as basis for determining the strength with which each category should be represented in the workshop. The criteria used in the assessment were (i) contribution to decision making, (ii) legitimacy, (iii) decision power, and (iv) function. In a consensus-based process, the CT members determined the importance of each stakeholder category, using a scoring method with a three-point scale. As further shown in figure 1 (P2), the participants of workshop I determined the members of the focus group to be invited for workshops II, IV, and V. The same approach was applied but, the total number of participants was limited to 15 to ensure an efficient process. Additional details on the stakeholder analysis are reported elsewhere (Braunschweig and Reyes, 2000).

Figure 1: Procedure for Research Priority Setting in the Philippines



3.3 Research Alternatives

Based on a literature review on ongoing and planned biotechnology research activities (A1), consultations with the CT members (A2), and discussions at workshop I (A3), an initial list of 19 potential crops research programs was identified. Some of the crops (e.g., specific vegetables) were only of marginal importance from a national point of view. It was obvious that they would rank very low compared to the major crops and, including them in a full-blown priority-setting exercise was not deemed worthwhile. Thus, the CT decided to use a pre-selection to shortlist the crop research programs (not shown in figure 1). The approach is explained below.

A set of binding conditions (also called 'killer criteria') was developed to screen the initial list of crops. The principle of applying a set of binding conditions is that, any alternative must comply with all of them to be further considered for prioritization. The members of the CT were asked to assess the crop research programs with respect to their economic importance, relevance in terms of addressing major constraints, existence of private-sector research, and available R&D capacity. Crops were removed from the list if they failed to comply with any one condition in the assessment of more than half of the CT members. The eight crops included as research alternatives in the main exercise were abaca, banana, coconut, corn, mango, papaya, rice, and sugarcane.

For the evaluation of the research alternatives (A4), profiles for each crop research program were prepared. The project team faced considerable difficulties in compiling relevant research information. For the assessment of the potential impact of the research programs (H1), the importance of the crops vis-à-vis the defined criteria has been used as proxy. This concept is based on an extended congruence approach (Contant and Bottomley, 1988). For a meaningful assessment of the chances of research and adoption success (H2 and H3), however, the research programs appeared to be too aggregated. Thus, the three major constraints of each crop that can be tackled by biotechnology research were defined. Potential research activities related to each constraint were then evaluated vis-à-vis the criteria defined for H2 and H3.

3.4 Decision Criteria

Good criteria have two characteristics (Mills and Omamo, 1998): they are logically related to the objectives and, they should be able to credibly discriminate between the research alternatives. Braunschweig et al. (forthcoming) developed a conceptual framework to identify and structure decision criteria for public agricultural research. The concept was incorporated in the priority-setting process. It is divided into three phases: the criteria generation (C1 to C3), the evaluation of criteria relevancy (C4), and the evaluation of criteria applicability (C5). The first phase aims to develop an initial list of decision criteria derived from national development goals, relevant sector objectives, and research objectives. In the second phase, this criteria list is evaluated regarding its relevancy for the specific set of research alternatives, resulting in a reduced list of criteria. The third phase assesses the availability of information necessary to apply the criteria. The principle to follow is to narrow down an originally broad list of possible criteria to the point where the relevant contributions of the research alternatives are captured by a minimum number of operational criteria. The criteria and its hierarchical structure are presented in the next section.

The relative importance of the criteria was determined in two steps (C7 and C8). The main (i.e. strategic) criteria of H1 were weighted by senior decision makers from key stakeholder groups. Their judgements were elicited in individual interviews by means of a questionnaire using the AHP's pairwise comparison procedure. The remaining – more technical – criteria were weighted by the participants of workshop IV (see figure 1). It is worth noting that, the members of the group felt more comfortable in directly assigning percentages to the criteria to express their relative preferences, rather than using pairwise comparisons.

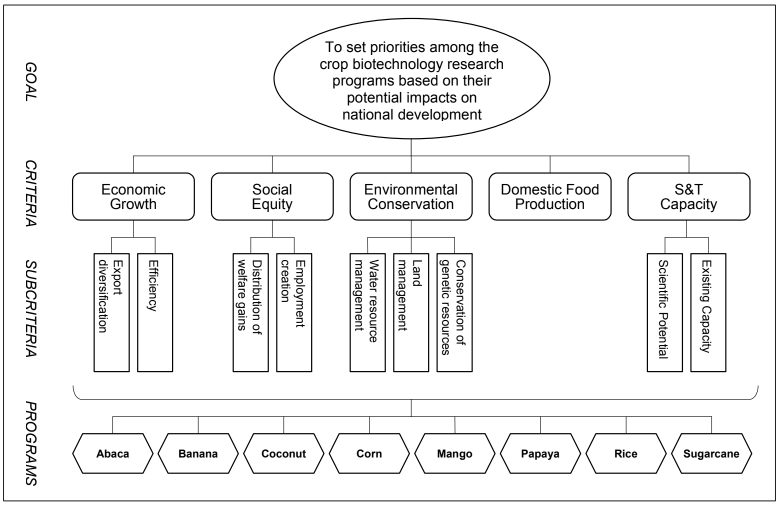
4. Results and Discussion

4.1 Hierarchies

Figure 2 shows the main hierarchy (H1) of the priority-setting model. The top level states the goal or the focus of the evaluation, followed by the level of major decision criteria. *Economic Growth*, S*ocial Eq-*

uity, *Environmental Conservation*, and *Domestic Food Production* refer to the most commonly stated development objectives (Collion and Kissi, 1995). The fifth criterion, *S&T Capacity* to create, acquire, distribute, and use knowledge is rapidly gaining importance as knowledge is becoming the key strategic resource for economic development (Conceição et al., 1998; World Bank, 1998). The critical role of S&T capacity for the national development has also been recognized by the Philippine Government (DOST, 1993; Republic of the Philippines, 1997).[3] The third level of the hierarchy consists of subcriteria to specify the meaning of the criteria. The eight biotechnology research programs are given at the bottom level of H1.

Figure 2: First Hierarchy on the Potential Research Impact



The hierarchy to evaluate the expected research success of the crop programs has a similar structure, i.e., consisting of four levels. *Human Resources*, *Infrastructure and Equipment*, *Institutional Setting*, and *S&T Challenges* are seen as the major determinants of research success. Only two out of the four criteria are further broken down into subcriteria. The third hierarchy of the model was used to estimate the adoption rate of the research results. Similar to H2, the evaluation was performed for individual research activities within each program. The critical factors influencing the adoption rate are grouped into the broad criteria *Technology Demand* and *Technology Supply*.

4.2 Criteria Weights

Nine senior decision makers were asked to give their relative preferences for the five main criteria of H1. The individual and average criteria weights are depicted in table 1. It is interesting to note that, *S&T Capacity* is considered the most important criterion when it comes to the allocation of research resources for crop biotechnology programs. Second is the criterion *Domestic Food Production*, i.e., the concern for national food security. The potential impact on *Environmental Conservation* is considered slightly more important for the selection of research programs than *Economic Growth*. The relatively low weight of the criterion *Social Equity* indicates that, the decision makers do not think biotechnology research should be primarily targeted to social goals.

As shown in table 1, the average weights mask the significant variation among the decision makers regarding the relative importance of the strategic criteria. There is considerable variation in the individual weights for all criteria. The lowest and the highest value differ by roughly a factor of 6 for each criterion. The standard deviation is highest for the criteria *Domestic Food Production* and *S&T Capacity*, which points to the stronger disagreement about the importance of these two criteria. The strategic nature of the

[3] See Braunschweig and Janssen (1999) for a theoretical discussion on the rationale to include capacity building in research priority setting.

criteria requires value judgments on their importance. This is seen as a major reason behind the diversity of views as evidenced by the variation in the individual weighting. But part of the variability may also be due to misunderstandings, different interpretations of the criteria, not sufficient information on the research programs, and lack of the opportunity to exchange arguments. Direct interactions among the group, therefore, might have been useful to initiate a 'constructive conflict' that could have led to a greater consensus retaining the diversity of views.

Table 1: Individual and Average Criteria Weights for H1

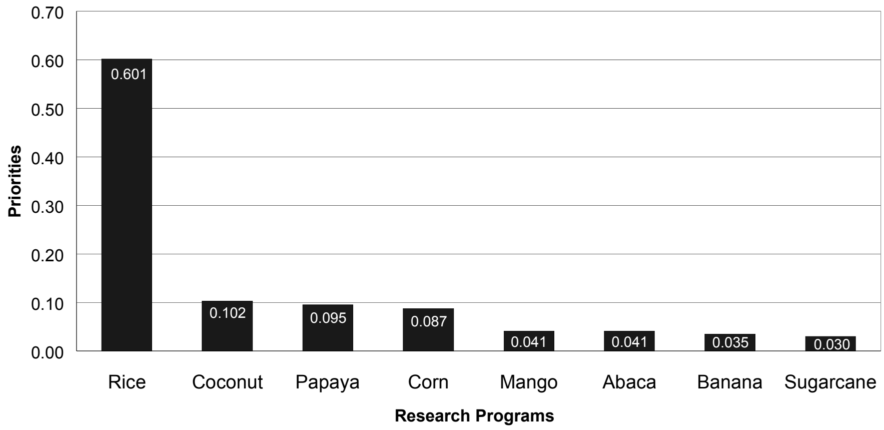
Criteria	Decision-Makers' Criteria Weights (%)									Min.	Max.	Standard Deviation	Average Weights
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**				
Economic Growth	10	10	31	20	14	5	8	22	19	5	31	8.1	15
Social Equity	6	6	13	20	31	10	5	16	4	4	31	8.9	12
Environmental Conservation	25	25	23	20	29	12	15	4	6	4	29	9.1	18
Domestic Food Production	42	42	28	20	12	23	44	8	11	8	44	14.4	26
S&T Capacity	16	16	6	20	14	51	28	50	61	6	61	19.7	29

The weights of the four main criteria of H2 are quite balanced, with a slightly higher importance for the criterion *Institutional Setting* (30%). For the successful adoption of the research results (H3), the *Technology Demand* is seen as more important than *Technology Supply*, in a ratio of 3:2. This may reflect the general trend towards more demand-driven research agendas. The much debated issue on *Public acceptance* of genetically modified foods influences the adoption success by 15%, according to the focus group.

4.3 Research Priorities

The alternative biotechnology research programs were assessed using the rating mode i.e., absolute measurement (Saaty, 1986). First, scales with three to five intensities were developed and defined. The relative importance of the intensities was determined using pairwise comparisons. The alternatives were then evaluated by identifying for each criterion the relevant rating (intensity) which describes that alternative best. Figure 3 shows the final priorities of the eight crop research programs. The ranking can be divided into three groups. Rice is way ahead and surpasses the second-ranked crop by a factor of 6. The second group consists of Coconut, Papaya, and Corn, with priorities around 0.1. The third group – Mango, Abaca, Banana, and Sugarcane – comprises the lowest-ranked research programs with priorities between 0.03 and 0.04. A look at program performance vis-à-vis the individual criteria of the three hierarchies allows a more detailed analysis of the final ranking. However, due to limited space it is not reported here. Instead, the outcome of the sensitivity analysis is briefly discussed below.

Figure 3: Final Ranking of the Crop Biotechnology Research Programs



4.4 Sensitivity Analysis

The variation in the individual criteria weights elicited from the decision makers calls for an examination of the robustness of the final ranking for different weighting schemes. Thus, sensitivity analysis was performed based on the individual weightings of the main criteria of H1. The outcome indicates a stable final ranking with respect to the three groups mentioned above. Rice is dominant in all scenarios. Its overall priority increases the higher the weight for the criterion *S&T Capacity*. Coconut, Papaya, and Corn form the second group under all weighting schemes. However, there are changes in the ranking within the group. Papaya takes over as second-best research program for the weightings of decision makers 6-9 where the criterion weight of *S&T Capacity* is high and/or the one for *Environmental Conservation* is low (or at least below average). On the other hand, Corn performs better than Papaya when weights of the criterion *Social Equity* are above average (decision makers 3-5). A similar situation prevails for the third group (Mango, Abaca, Banana, and Sugarcane). Rank reversal occurs among Mango and Abaca for the weightings of decision makers 3-5, i.e., for higher weights of the criterion *Environmental Conservation*. For high weights of *S&T Capacity,* Sugarcane takes the lead in this group due to its relatively strong performance vis-à-vis this criterion. Overall, however, the changes are marginal and only occur for weighting schemes that substantially deviate from the average.

5. Conclusion

Eight crop biotechnology research programs were assessed in an AHP-supported priority-setting process. The final ranking, based on their expected contribution to the development goals of the Philippines shows the programs divided in three clear groups. Sensitivity analysis was performed to test the stability of the final ranking for varying criteria weights. The outcome of the exercise might help the Philippines to strengthen the focus of their research activities in agricultural biotechnology. The priority-setting process generated a range of additional results that could be of interest to Philippine research managers, including criteria-specific priorities of the crop programs, a structured list of weighted decision criteria, and detailed indicators to measure the programs' contribution to these criteria.

The focus of the priority setting exercise was on the relative attractiveness of the individual programs in terms of their contribution to the national development objectives. At the chosen level of analysis, the interest in the relevance of a biotechnology research program in addressing major societal concerns might be more pertinent than considerations on returns on investment. Accordingly, the costs of the programs have not received major attention. If they differ widely, however, the crop priorities have to be subjected to the costs before they can be meaningfully used for resource allocation purposes. But there was also the more practical problem of lack of information. Under the existing time pressure and given the somewhat crudely specified research activities, it was impossible to get the necessary data that would have allowed estimating their cost with any reasonable level of accuracy.

Several innovative approaches were used in the priority-setting process. First, a pre-selection process using a set of binding conditions was applied to eliminate less promising crop research programs from the initial list of alternatives. The screening process proved to be very effective. Second, formal stakeholder analysis was incorporated into the process in order to identify the participants for the workshops. It contributed to the credibility of the process and helped to ensure that the results carry the ownership of key actors in the field of biotechnology research. In future applications, stakeholder analysis might be extended to the selection of decision makers that are involved in the criteria weighting. For a more systematic approach, stakeholder analysis could make use of the AHP to solve the selection problem. Third, the conceptual framework for the identification of decision criteria was explicitly integrated into the process design. It was considered a valuable addition to the AHP that helped to minimize overlaps of criteria and substantially facilitated the structuring process.

Overall, the AHP proved to be a suitable decision-support tool in the Philippine exercise. Its simplicity and transparency allowed stakeholders with very different backgrounds to actively participate in the priority-setting process. Moreover, because the AHP provides a consistent framework to formally incorporate subjective judgements, it is particularly suited for situations where decision makers face a poor information base, such as in agricultural biotechnology research evaluation. On the other hand, it might be quite tempting to excessively use subjective judgements based on mere guessing even when more reliable information could be gathered. Similarly, the attractive and straightforward structuring process bears the risk to oversimplify the modeling of the decision problem. AHP's flexibility in modeling the decision problem, however, enabled the accommodation of context-dependent variables. The use of three different hierarchies in the Philippine exercise is prove of this flexibility. In this way, the research programs could be explicitly assessed vis-à-vis the critical determinants of research and adoption success.

The pairwise comparison procedure of AHP is very appealing. It was used to elicit preferences for the main criteria of H1. Decision makers were comfortable with this way of assessing the relative importance of criteria. Except in one case where the pairwise graphical mode was preferred, they also coped well with the pairwise verbal mode of comparison. According to them, the resulting criteria weights adequately reflected their value judgments on the relevance of the criteria. It came rather as a surprise, therefore, that the participants in workshop IV indicated difficulty in using the pairwise verbal mode for the comparisons of the remaining criteria. They preferred to directly assign percentage values to the criteria. Reasons that may have contributed to the observed difficulty could have been due partly to poorly defined criteria and the lack of practice in applying pairwise comparisons. This points to the critical need to properly define all elements of the hierarchy and to develop a common understanding of its meaning.

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