AHP IN ALLOCATING HAWAII'S AGRICULTURAL RESEARCH AND DEVELOPMENT RESOURCES

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INTRODUCTION

Research and Development Resource Allocation

Economic theory tells us that resources are allocated efficiently where the value of their marginal contribution is equal to their respective price. Optimal allocation can be guided by this principle. The utilization of resources for the research and development process (R & D) can be viewed in principle just like any other production process where several inputs are combined in a specific manner to produce an output. However, unlike most production processes, little is known and much can never be known in research about the connections between inputs and outputs. While the definition of input is in general fairly straight-forward, the definition of output is very difficult if not impossible. At the most abstract level, the immediate output of research is new knowledge which is intangible and sometimes undefinable. Since knowledge generated by public enterprises is public goods, it is free to the user once it becomes available. The utilization of knowledge by one client does not reduce the amount available to others nor does it increase the total production cost. This lack of a well-defined market of knowledge precludes us from using the usual pricing mechanism for optimum resource allocation. The difficulties of measuring knowledge and attaching a value to it have led researchers to look for different surrogates. Proposed alternative means of defining output have included published scientific and technical papers, a well specified innovation, and impacts on the production process. Each alternative has its own strengths and weaknesses.

The latter alternative - defining research output in terms of its impacts on the production process - is most commonly used because it most closely measures social benefits which is ultimately what we would like to measure. In agriculture, the most widely recognized measure is the direct increase in production. However, the appropriate measure of research output has to be related to the specified goals of the research program. Depending on its goal, the impact of research on the production process could be expressed in terms of improvements in product quality, conservation or savings of inputs, improvements in the marketing system, improvements in the supply industries, and improvements in institutions and economic policy so as to facilitate technical change. Goal specification is clearly important and will be discussed later.

Evaluation of R & D has some inherent difficulties. Research is a creative activity and output can have its beginnings in a chance discovery. The difficulty lies in predicting when such a discovery will occur. An additional and different difficulty is that the resulting stream of social benefits may be linked directly to some types of research and indirectly related to others. Some of the important side (spillover) effects are: income-distribution consequences, employment effects, environmental consequences, and improvements in the skill levels of current and future researchers.

Importance of Goal Specification

Goal setting is of critical importance in resource allocation because priorities cannot be established without specifying the goals that the research should attain. Goals can be set at various operational levels. At one extreme are rather general goals such as growth, equity and security as defined in an Iowa State University study. General societal goals might be: productivity, stability, sustainability, and equity. At the other extreme, the goals can be very specific such as to develop an insecticide to kill insect x. For public enterprises, as is the case in the present discussion, the criteria for guiding allocation decisions should reflect the public's interests if the enterprises are to survive and prosper in the long-run. This is because public expenditures for research are justified by the expectation that resulting knowledge will increase social-goal attainment. Measurement social-goal attainment would require the identification of the social welfare (objective) function as referred to by economists. The social objective function is simply a valued function generally consisting of several conflicting goals desired by society. In order to have an operational function, social values or weights are needed to indicate the relative social significance to be assigned to each goal. Thus the question arises, "who has the responsibility for formulating this social objective function?" Donald Kaldor from Iowa State University believes legislative bodies have the capacity to construct an appropriate social objective function and should devote more attention to it. In any event, if the social objective function is to be used to achieve a more efficient allocation of resources, someone has to specify this function.

Intra-Hawaii Agricultural Industry Priorities

The State of Hawaii has an State Agricultural Functional Plan (SAFP) which recommends policies and actions for agriculture in order to implement the Hawaii State Plan's overall objectives. The recommendations of the SAFP are based on the identification of the major issues affecting agriculture; e.g. government support; land; water; capital; human resources; transportation; and research and development (R&D) including promotion.

The SAFP delegates the overall responsibility for the coordination, review, and monitoring of specific agricultural programs to the Governor's Agricultural Coordinating Committee (GACC), which was established in 1977 by Act 167 of the State Legislature. The GACC members are directors of the state departments of Agriculture, Business and Economic Development, Health, Land and Natural Resources, and Transportation, the dean of the College of Tropical Agriculture and Human Resources, University of Hawaii, and 3 industry representatives, one representing the Hawaii Farm Bureau Federation (Fig 1.).

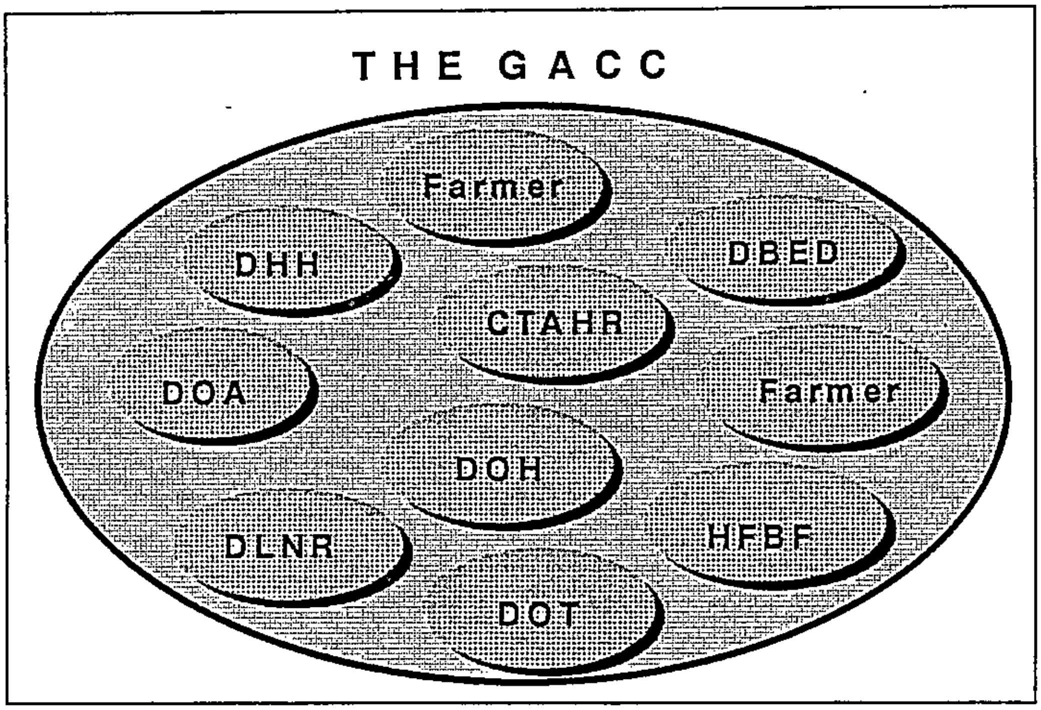

Fig. 1. Illustration identifying the membership of the Hawaii Governor's Agriculture Coordinating Committee

Beginning in 1977, the GACC and the College of Tropical Agriculture and Human Resources (CTAHR) developed a unique system called the "Industry Analysis Program (IA)" to identify bottlenecks limiting the development of Hawaii's agriculture. The parts of an industry analysis document are illustrated in Figure 2.

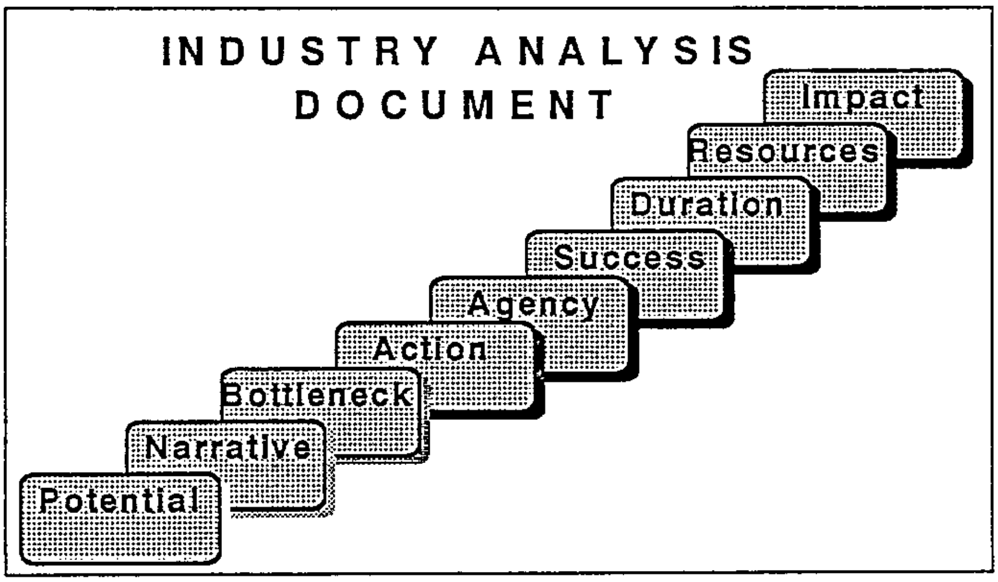

Fig. 2. Illustration showing the major components of an industry analysis document.

The potentials of production, marketing, and profitability perceived by an industry are defined. In order to reach these potentials, the bottlenecks are identified with the background information in the narrative section which summarizes existing knowledge. Actions necessary to alleviate the major bottlenecks to the agricultural industry reaching its expected potential are identified and prioritized by the industry in a public meeting. The impacts on the industries potential by not implementing the actions are defined as quantitatively as possible. The resources required to implement actions are specified along with the agency(ies) responsible. Therefore, a set of R & D resource priorities with costs in terms of resources, time (duration), estimation of success, and impact are established for each of Hawaii's agricultural industries.

While the IA established priorities within each industry analyzed, an acceptable method for systematically establishing priorities between the various agricultural industries has not been found. The application of the Analytic Hierarchy Process (AHP) (4) to establish priorities for R & D for the total agricultural system is the subject of the present paper.

PROCEDURES AND PRELIMINARY RESULTS

Defining Hawaii's Total Agricultural Industry R and D Resource Allocation Problem--An On-going Exercise

The authors have been working with the Dean of the College of Tropical Agriculture and Human Resources, University of Hawaii, and the college advisory group composed of selected leaders of commercial agriculture in Hawaii and commercial agricultural infrastructure in setting priorities between agricultural industries. We would like to stress the point that this exercise is still evolving and comments and suggestions are welcome. The focus of this exercise is on setting priorities between agricultural industries and not within a single industry (e.g. pineapple) as in the IA. Obviously, this is an ex ante or forward-looking allocation decision. Several common approaches used to evaluate public agricultural research investment have been identified. A good review of these approaches is in a 1981 American Journal of Agricultural Economics article by Norton and Davis (3). In the present exercise, we adopted the more recently developed multiple criteria decision making (MCDM) framework called the Analytic Hierarchy Process (AHP). As the name implies, AHP structures a problem as a hierarchy reflecting the natural tendency of the mind to sort elements of a system into different levels and to group like elements in each level. Among the many advantages of AHP, the most important is that it provides a scale for measuring intangibles and a simple mathematical method (using matrix operations) for establishing priorities. These features, together with its ability to handle multiple goals, make AHP a very attractive tool for the problem at hand.

Several assumptions are made in applying AHP to the basic information in the IA. These are:

1. The current IA does, in fact, indicate the important constraints to the industries future potential and lists the actions necessary to alleviate the constraints.
2. The action durations, estimates of success, and resources required to alleviate each action are valid as listed in the analysis.
3. Partial allocation of resources to an action assumes non completion until additional resources are allocated.
4. Actions requiring capital improvement are included when identified as a resource necessary to address the action.
5. Marketing actions are included in R&D.

We started by including all possible goals or criteria that we could think of and structured the problem using Expert Choice, the microcomputer implementation of AHP. The model is illustrated in Fig. 3.

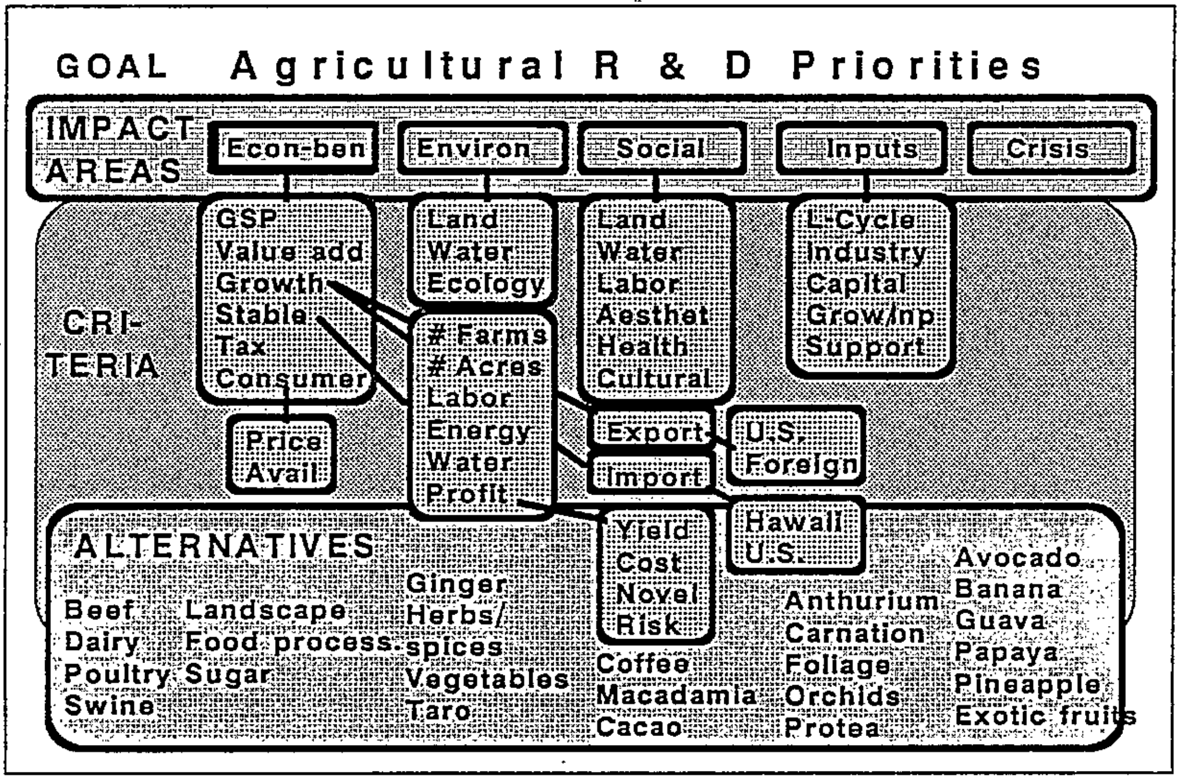

Fig. 3. Illustration of Expert Choice hierarchical model of all possible criteria that might be considered in allocation of agricultural research and development resources.

After several meetings with the advisory group, we reduced the impact areas and criteria down to include two major impact areas: economic, and, environmental and social benefits with their associated criteria as illustrated in Fig. 4.

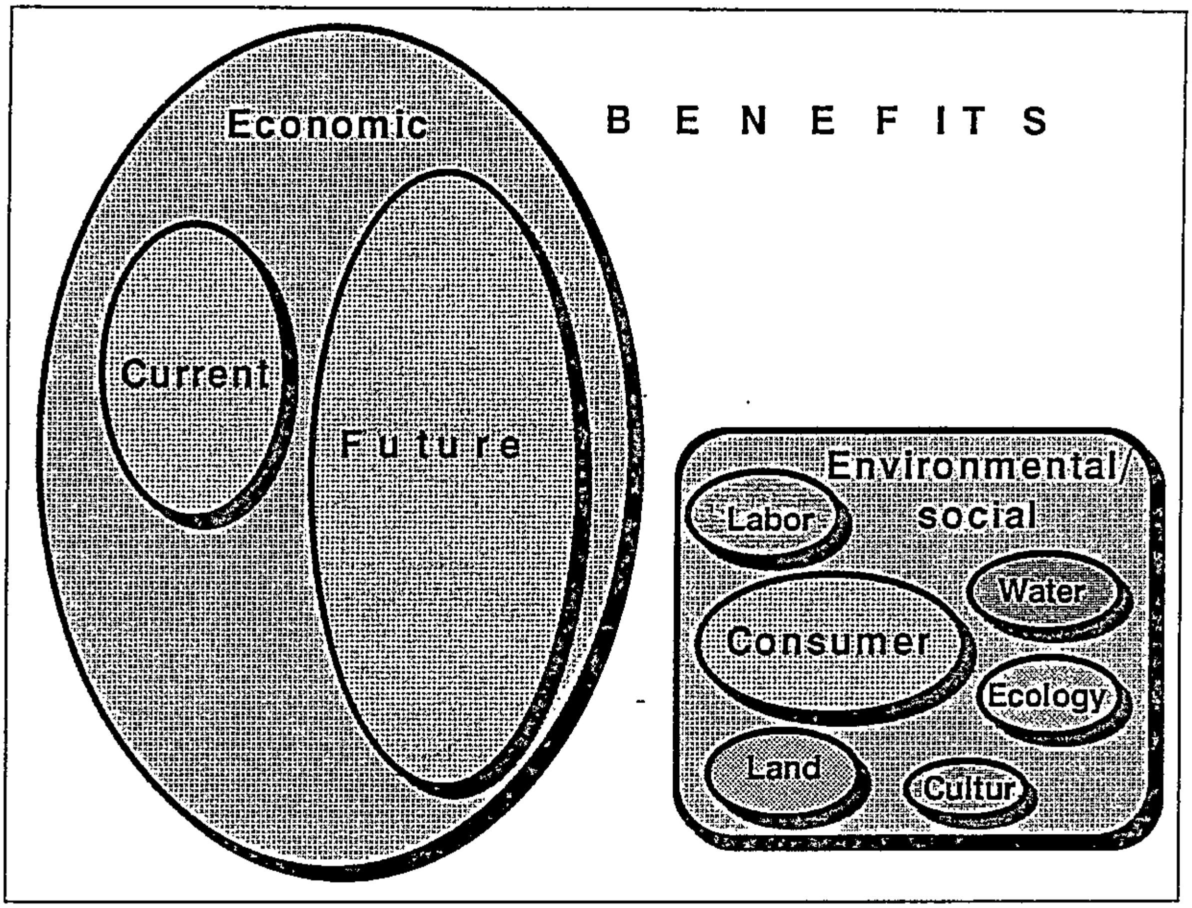

Fig. 4. Economic and social/environmental benefits of allocation of research and development resources with the associated criteria. The relative weighting are shown by the diagram size.

The criteria under the impact area of economic benefits to the state are current benefits measured as 1990 farm values (or value added for Food Processing and Landscape) and future benefits measured as the projected 1995 farm values based on the potential identified in the IA. adjusted by the probability of success. The criteria under the impact area environmental and social consideration are land conservation, water conservation, ecological balances, labor utilization, cultural aspects, and consumer benefits. The advisory group assessed the relative importance of these criteria and sub-criteria (See Fig. 4). Also, preliminary assessment of the relative preference of each commodity with respect to each criteria was completed in order to test the model. An index of benefits for each commodity can now be obtained through the AHP. This index provides a relative measure of benefits with respect to the criteria among the commodities. Similarly, a relative index of cost can be calculated using the projected costs from the IA. Lastly, a benefit-cost ratio can be calculated for each commodity and priorities can then be established among the commodities. Economic benefits to the state was also evaluated from current benefits measured as 1990 farm values (or value added) and future benefits measured as the projected 1995 values minus 1990 values adjusted by the probability of success. Preliminary results are illustrated in Table 1.

Table 1. Expert Choice ranking of benefits to Hawaii's agriculture from research and development resources and the expected added benefit cost ratios.

Current value ranking	Agricultural industry	Benefits	Cost	Benefit cost ranking	Added benefit 1/ cost ranking
1	Landscape	0.177	0.033	4	1
2	Food processing	0.083	0.155	21	20
3	Sugar	0.084	0.252	25	25
4	Pineapple	0.046	0.058	20	12
5	Macadamia nut	0.025	0.028	18	20
6	Dairy	0.036	0.099	24	15
7	Beef	0.039	0.034	16	8
8	Poultry	0.032	0.003	1	3
9	Foliage plants	0.067	0.034	10	2
10	Papaya	0.022	0.057	23	20
11	Leafy vegetables	0.036	0.020	11	11
12	Orchids	0.019	0.008	9	20
13	Swine	0.023	0.005	5	6
14	Anthurium	0.018	0.042	22	20
15	Sol./cucurb. veg.	0.028	0.032	19	14
16	Coffee	0.066	0.051	14	4
17	Ginger	0.031	0.010	8	7
18	Banana	0.021	0.018	15	13
19	Exot. cut flowers	0.018	0.002	2	20
20	Guava	0.028	0.006	6	5
21	Taro	0.021	0.019	17	20
22	Carnation	0.021	0.005	7	10
23	Herbs & spices	0.021	0.004	3	20
24	Protea	0.018	0.012	13	20
25	Avocado	0.021	0.012	12	9

[1]Economic benefits are current benefits measured as 1990 farm values and future benefits measured as the projected 1995 farm values minus 1990 farm values adjusted by the probability of success.

The entire analysis process is summarized in Figure 4.

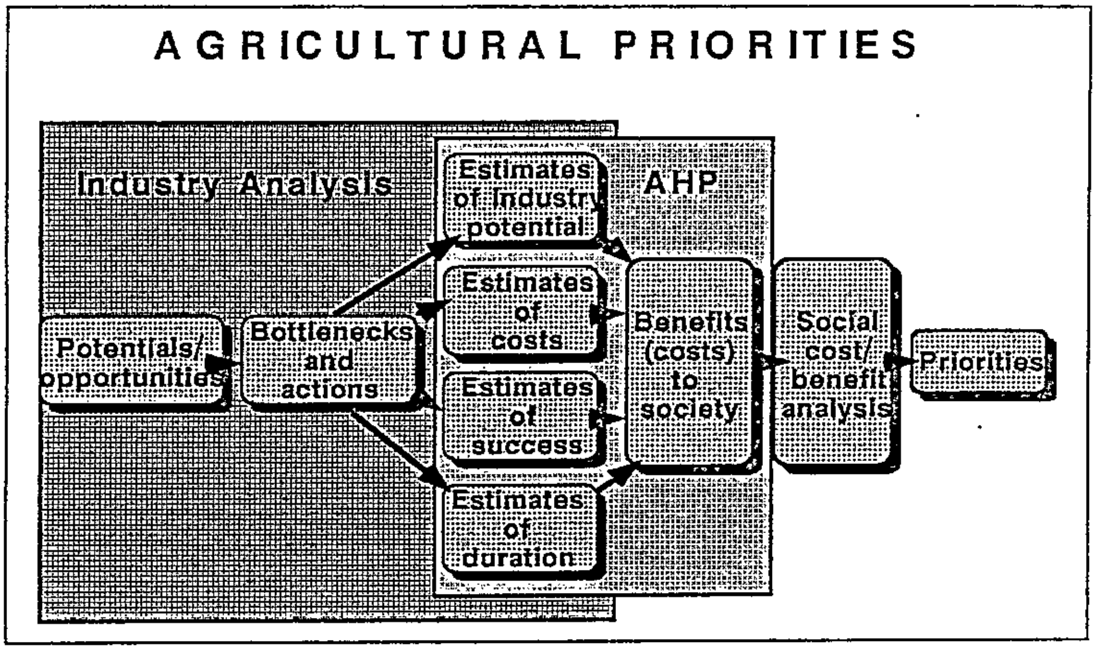

Fig. 5. Illustration showing the origin of information from the IA and its use in AHP to arrive at agricultural priorities.

Since we have not yet completed our exercise, we have not drawn any conclusions about the process itself or of the preliminary results. There are obvious problems with the measurement of benefits. Is farm value the appropriate measure of economic benefits? We are sure some of our economic colleagues would disagree with the use of farm value as a measure of economic benefits. If not, what available information would provide an appropriate measure? Another issue would be the measurement of long-run benefits versus short-run benefits. The model as it stands is static and we assume all the benefits will occur in 1995. These and many other problems will arise as we scrutinize our model. There is a definite tradeoff between more realism and practicality.

RELATION OF RESOURCES ALLOCATION MODELS TO DECISION MAKING

In closing, we would like to stress the point that resource allocation models as well as all other quantitative models are not intended to yield a decision, but rather information that would facilitate decision making. To further emphasize the point, we would like to paraphrase Cetron and Johnson (1), "Data plus analysis yield information. Information plus judgement yield decisions... It is wrong to say that one must select intuitive experience over analysis or minds over machines; really they are not alternatives; they complement each other. Used together, they yield results far better than if used individually." The fundamental question is whether systematic analysis by means of quantitative models can improve the decision-making that inevitably takes place. Only the decision-makers can answer this question.

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