RESEARCH EVALUATION CONSIDERATIONS FOR AgRISTARS

CHARLES E. CAUDILL and RICHARD C. McARDLE

Economics, Statistics, and Cooperatives Service
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ABSTRACT

AgRISTARS (Agriculture and Resource Inventory Surveys Through Aerospace Remote Sensing) is an extensive six-year research program (October 1, 1979 - September 30, 1985) designed to determine applications of aerospace remote sensing for answering agricultural resource questions and meeting identified information needs of the U.S. Department of Agriculture. The program is a cooperative effort of the Departments of Agriculture, Commerce, and Interior, the National Aeronautics and Space Administration, and the Agency for International Development. AgRISTARS will emphasize development of an early warning system to detect conditions affecting crop production and quality and to provide more accurate domestic and foreign crop forecasts, with additional effort devoted to land use and resource inventories.

Benefits of research are extremely difficult to quantify. A complex research program, such as AgRISTARS, which seeks to improve the information provided to decision makers, raises significant problems related to the "value of information." Improved information, in terms of objectivity, timeliness, and accuracy, is intuitively judged to be more valuable information--and may justify additional cost of acquisition. Ultimately the user must evaluate the information flowing from procedures developed in AgRISTARS based on the responsiveness of the information to his specific and perceived needs. Evaluation of the information then can determine the "value" of AgRISTARS research.

Evaluation guidelines for research should avoid rigid specifications of performance characteristics, provide flexibility in adjustments of system components, and maintain alternative options until uncertainties can be reduced.

1. INTRODUCTION

In preparing our paper we followed the time-tested traditional research approach and reviewed the literature first. Naturally, two of our principal source documents were the Proceedings of the two previous Conferences on the Economics of Remote Sensing.

We noted with interest that last year's Conference Co-Directors suggested that "remote sensing technology has reached a level of

maturity where certain hard economic questions of costs and expected results may properly be asked." Although we might defer judgment on their assertion that "the major issues of feasibility and potential have now been resolved," we have no quarrel with their conclusion 22 months ago that "the principal questions remaining concern both cost-benefit and cost-effectiveness of remote sensing."

The related issues of costs and benefits, which by the way need not always be linked in a hyphenated phrase, are significant issues in an extensive research and development program designed to determine applications of aerospace remote sensing for answering agricultural resource questions and meeting identified information needs of the U.S. Department of Agriculture (USDA).

The new research program is AgRISTARS (Agriculture and Resource Inventory Surveys Through Aerospace Remote Sensing).[1] It officially began last month (October 1, 1979) and will continue for six years. AgRISTARS is a cooperative effort of the Departments of Agriculture, Commerce, and Interior, the National Aeronautics and Space Administration, and the Agency for International Development.

Our presentation today will:

1. Describe AgRISTARS--a research program.

2. Discuss "value of information"--and the complexities of quantifying such value.

3. Raise questions concerning evaluation guidelines for AgRISTARS--linking research efforts in remote sensing to the value of improved information to users.

2. AgRISTARS--APPLICATION OF AEROSPACE TECHNOLOGY TO INFORMATION NEEDS

The goal of the AgRISTARS program is to determine the usefulness, cost, and extent to which aerospace remote sensing data can be integrated into existing or future USDA systems to improve the objectivity, reliability, timeliness, and adequacy of information required to carry out USDA missions. In a sense the stated goal of the AgRISTARS program closely parallels the theme and purpose of today's conference, which is to examine the cost, effectiveness, and benefits of information systems involving remote sensing technology. Costs, whether in terms of money, people, or equipment, are very important to us. We know that the benefits will most likely result from greater objectivity, reliability, and timeliness of data--even if we can not now put a price tag on those benefits.

The overall approach in AgRISTARS is a balanced program of remote sensing research, development, and testing which addresses domestic resource management, as well as global commodity production information needs.

The program addresses the following categories of information needs identified by the Secretary of Agriculture:

1. Early warning of change affecting production and quality of commodities and renewable resources;

2. Commodity production forecasts;

3. Land use classification and measurement;

4. Renewable resources inventory and assessment;

5. Land productivity estimates;

6. Conservation practices assessment; and,

7. Pollution detection and impact evaluation.

While all seven are important to the Department, the first two-early warning and commodity production forecasting--have been given emphasis because of the immediate need for better and more timely information on crop conditions and expected production.

3. MAJOR RESEARCH PROJECTS AIMED AT INFORMATION NEEDS

The AgRISTARS Technical Program is structured into eight major projects as follows:

1. Early Warning/Crop Condition Assessment (EW/CCA);

2. Foreign Commodity Production Forecasting (FCPF);

3. Yield Model Development (YMD);

4. Supporting Research (SR);

5. Soil Moisture (SM);

6. Domestic Crops and Land Cover (DCLC);

7. Renewable Resources Inventory (RRI); and,

8. Conservation and Pollution (C/P).

The Early Warning/Crop Condition Assessment research effort is designed to develop and test the basic techniques required to support the operational Crop Condition Assessment Division (CCAD) of the Foreign Agricultural Service in USDA. The EW/CCA addresses 20 crop/region combinations in the U.S. and 7 foreign countries (USSR, Argentina, Brazil, Canada, People's Republic of China, Mexico, and Australia) and 6 major commodities (wheat, barley, corn, soybeans, rice and cotton).

The Foreign Commodity Production Forecasting activity addresses 12 crop/region combinations in the U.S. and 6 foreign countries (USSR, India, Argentina, Brazil, Canada, and Australia) for 5 major commodities (wheat, barley, corn, soybeans, and rice). This project will develop and test procedures for using aerospace remote sensing technology to provide more objective, timely, and reliable crop production forecasts several times during the growing season and improved pre-harvest estimates for the crop/regions of interest.

The Yield Model development activity will support USDA global crop production forecasting. Activities under this project include selection, evaluation and improvement of existing models. New independent variables such as solar insolation, spectral measurements, remotely measured soil moisture, will be developed and studied for possible inclusion in these models along with adjustments for crop phenology and technology. Also, the basic research required for developing physiological models which more accurately reflect plant growth processes will be a major part of the yield modeling project.

The Supporting Research project covers research, development, and testing of new and/or improved remote sensing technology. Research will be conducted in the following areas, as related to applications of remote sensing technology: sampling and aggregation; area estimation; crop development stage estimation; spectral crop appearance in yield estimation; crop stress; and, soils.

Soil Moisture research is directed toward development of the measurements of soil moisture (in-situ as well as aircraft and space sensors) for potential use in other applications, such as early warning uses, crop yield estimation, watershed runoff, and vegetative stress assessments.

Domestic Crops and Land Cover objectives are directed at automatic classification and area estimation of land cover with emphasis on major crops. Landsat and advanced sensor data will be used in conjunction with ground data to improve the precision of estimation and classification procedures at the substate level and to investigate change monitoring techniques.

The Renewable Resources Inventory Project involves requirements in 4 main categories: Large area renewable resources inventories; detection, classification and measurement of disturbances; classification, modeling and measurement of renewable resources; and, determination of site suitability and land management planning processes.

The Conservation Assessment portion of the Conservation and Pollution Project addresses applications in 4 areas: inventory of conservation practices; estimation of water runoff using hydrologic models; determination of physical characteristics of snowpacks; and determination of soil moisture utilizing thermal infrared data.

The Pollution portion of the Conservation and Pollution Project will provide an assessment of conservation practices through use of remote sensing techniques to quantitatively assess sediment runoff; to detect gaseous and particulate air pollutants, and to assess their impacts on agricultural forestry resources.

4. "INFORMATION IS AN EXPENSIVE COMMODITY AS WELL AS A VALUABLE ONE"

"Social returns on the investment in data for improved coordination and management of specialized industrial processes are usually very high. In very competitive unconcentrated industries such as agriculture these gains are only realizable through public investment.....Information is an expensive commodity as well as a valuable one." [2]

We believe there is general consensus with the preceding statements by Bonnen (1977, pp. 402, 407) particularly among those dealing with global agriculture and its associated myriad policy problems. Because of its intangible nature and the impossibility of enumerating the total population of "information users" producers of information face an extremely difficult task in arriving at the value or benefits of information. The literature contains a number of suggested approaches for measuring "value of information." [3] However, our impression is that there is still not a general consensus [4] on the appropriate approach or methodology for conducting cost-benefit studies dealing with this problem.

And the problem of valuing information is certainly not simplified when one adds the task of evaluating research being done to improve the information product.

One might assume that benefits from research will be included in the final value assessed by the decision maker using the information. But the real-life situation is far more complex: research extends into other applications areas, there are delays in application of research findings, and the decision maker may choose not to use the "improved" information.

We bring up the question of derivation of benefits not to complicate an already complex situation, but rather to put all of the components into perspective. Sometimes it is a little easier to examine different stages of the process for clues which may help in evaluating the whole.

AgRISTARS is a research program aimed at improving information. How does the research effort contribute to greater objectivity, timeliness, and reliability of the information? How does the improved information impact decisionmaking? Improvements in information systems take place slowly and are judged subjectively.

Research which results in an improved variety of wheat or corn may be quickly and objectively evaluated in terms of increased

number of bushels per acre, resistance to disease, tolerance to drought and the like. Competition in the market place encourages rapid adoption of improved varieties.

On the other hand, research to improve information, either quantitatively or qualitatively, faces much greater difficulty in determining the value of its research findings. This problem is compounded by the fact that improvements or changes in information systems, supported by research, are seldom if ever implemented as soon as researchers think they should be. Historically, indicated research changes or improvements in USDA agricultural information systems have taken a decade or more to be implemented and accepted as integral parts of the operational system. There are many reasons for the long lead time required for operational implementation of research results, such as resistance to change, need for training operations staff, and perhaps most critical in the delay, particularly for public information systems, is the problem of acquiring the additional resources required for the new technology to be implemented. For example, producers of public information tend to take the approach that assigns the maximum returns while political decision makers, consciously or unconsciously, place the minimum value on information by steadfastly refusing to assume the costs required for changing or improving information.

In both cases the assigned benefits are apt to be based on somewhat subjective approaches picked to support predetermined positions of the involved individuals. In spite of the difficulty in performing rigorous cost-benefit studies, there are increasing demands being made on data producers to support budget requests with cost/benefits analyses. While this may be appropriate for operational programs, it is in our opinion extremely questionable to use this approach for research budgets.

5. AFTER RESEARCH, APPLICATION OF FINDINGS

Moving to the next stage, that is, determining the implications of improved information in decision making, we were somewhat surprised by the statement of Deacon, Simonett, and Smith (1978, p. 138), "that the best developed methodology for estimating such benefits lies in the area of improved crop forecasts." [5] After a selective review of the literature we do not disagree with the statement. Our initial impression of surprise was based on some knowledge and on questions which have been raised concerning the validity of the explicit and implicit assumptions underlying most of these studies. For example, Bullock (1976, pp. 76-80) in a note on social costs caused by errors in domestic agricultural production forecasts, arrives at the conclusion that estimating social benefits from improved forecast accuracy is not a promising area of research. He reaches this conclusion due to the complexities of obtaining the necessary estimates in a world characterized by many sources of uncertainty other than the production forecast errors. He agrees

that, in general, accurate forecasts are preferable to inaccurate forecasts, but he concludes that large forecast errors are not sufficient grounds to argue for additional expenditures to improve the accuracy of domestic forecasts. [6]

6. PRELIMINARY EVALUATION GUIDELINES HAVE BEEN PREPARED FOR AgRISTARS

With the preceding background, the difficulty USDA faces in evaluation of AgRISTARS research is apparent. In developing the technical program plan, plans for and approaches to evaluation and benefit analysis have not received as much attention as we would like. We are just now beginning to address this long recognized component of the program. The USDA as "end user," of the program output has prepared preliminary evaluation guidelines for AgRISTARS. The following excerpts from these guidelines will provide some insight into the current thinking of the Department regarding research evaluation.

> The joint activity in question is a research program... Carrying out the research process is not a question of success or failure, and results should not be defined in these terms...
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> The philosophy that will be followed by the Department in evaluating any results from the program is that the research and experiments conducted must show tangible results which are repeatable, and which provide information of value to the Department in a cost-effective manner when compared with or incorporated into existing methods for obtaining the same information...
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> ...User evaluations will be the sole responsibility of USDA. The user agency technicians participating in the evaluation will use the evaluation plan and criteria developed prior to the start of the research as a guide in evaluating the research results.
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> ...The final user evaluation will address the following:
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> 1. To what extent does the new technology provide new improved or more timely information when compared to existing USDA user agency information systems?
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> 2. Will the information be of value to the USDA user agency decision makers on a continuing basis?
>
> 3. Can the new technology be easily adopted, adapted or integrated into existing USDA information systems?

4. Can the cost of modifying, integrating and implementing the new system in USDA be justified? ...

7. RESEARCHERS MUST BE INVOLVED IN EVALUATION EFFORTS

As researchers, planning a research program, we have to some extent "passed the buck" and operated under the concept that end users of the research results and developed technology are responsible for evaluation. While ultimately this is true, as we seriously address "evaluation," it is becoming apparent that we, as researchers, should have more responsibility in this process than we have been permitted to assume by the preliminary guidelines. Now evolving is the concept that joint (researcher-user) teams need to be involved in the research program and in the evaluation process. There is also the recognized need for additional independent work, particularly by economists outside of AgRISTARS, on the more general problem of determining social returns to agricultural information. AgRISTARS is a very large research program designed to improve or add to existing agricultural information, therefore, it seems entirely appropriate that some portion of future funding be devoted to addressing this problem.

The problem of designing and implementing an overall evaluation plan is compounded because AgRISTARS is a multi-agency program, with each agency having unique approaches to research. Some researchers want to establish their own evaluation criteria as part of their experiment design. Others want evaluation criteria specified by end users prior to experiment design. Even within USDA, the different agencies do not as yet have complete agreement on how or by what criteria, research results from AgRISTARS should be evaluated.

8. RIGID APPROACH TO EVALUATION A MISTAKE

By now some of you will be impatient with the broad approach I have taken to the question of evaluation. To the econometricians, operations researchers, and budget analysts in the audience, may I say that as a statistician, I too, am anxious to get our work "quantified," that I, too, want to deal with the objectivity inherent in numbers, and that I, too, want to be able to give a solid dollars and cents benefit figure to our budget examiner.

At the same time, however, I would be remiss if I did not acknowledge that as a statistician I am all too much aware that dubious equations and linkages can be created, from which erroneous inferences can be drawn.

Expressed in very basic terms, we intend to compare accuracy of crop acreage and production estimates with and without the data from AgRISTARS, and we intend to keep records which will help

determine advantages in timeliness. (Remember, AgRISTARS is research, not an operational program, and "timeliness" will be indirectly obtained.) Further, we will attempt where feasible, to compare cost effectiveness of different remote sensing systems.

We are not ignoring objective measures (numbers, if you will). But as we have indicated, standards and tolerances will vary from crop to crop, will depend on time of acquisition, and will be influenced by whether the coverage is domestic or foreign. An information system must be tailored to fit the needs of its users, just as we have insisted that technology be designed to meet user requirements, not the other way 'round.

9. BROAD PERSPECTIVE ESSENTIAL IN RESEARCH

The "success" of AgRISTARS--and I am not sure success is the best word to use--will be ultimately determined by the "user" of the research products in changing or improving the existing USDA agricultural information system. A good answer to the question, "Was it worth the money?", may take a decade, possibly longer.

In the meantime, as we set up our evaluative guideposts and checklists, we are optimistic that we can give some interim answers, provided that the following premises and research policy prescriptions are understood and agreed to by the involved researchers, managers, and political decision makers: (1) Research goals are not uniquely set; new techniques, methodologies, or products that outperform the present capability in several respects or dimensions are important, but there is a wide range of performance characteristics that would be satisfactory; moreover, there is not an attempt to ascertain the most desirable combinations of characteristics until a capability with such characteristics has been developed and tested; (2) in proceeding to the goal, there are very large uncertainties, and one of the principal concerns must be the reduction of these uncertainties before committing the bulk of the resources.

These premises imply the following research policy prescriptions:

1. Rigid specifications of the performance characteristics of the desired product should be avoided.

2. When the desired product is a "system" containing several components, there should similarly be no rigid stipulation in advance about the way in which the components are to be adjusted to each other as it is important to give each team working on a component the maximum freedom of movement even though subsequently a special effort will have to be made by the user to fit the various pieces of the system together.

3. In considering alternative approaches to research and development of a desired capability, the correct procedure is not necessarily to decide which is the best prospective approach on the basis of the most sophisticated benefit-cost analysis available; in view of the large uncertainties surrounding all approaches at an early stage of research and development, it may be advisable to try out in practice several approaches until the uncertainties have been sufficiently reduced and to delay until then the decision as to the best approach.*

We feel that the Evaluation Plan for AgRISTARS can be generally based on the preceding premises and research policy prescriptions.

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*After premises suggested by Hirschman (1967) [7] based in turn on ideas articulated in RAND Corporation studies in the late 1950's about "the conditions for R & D progress." [8]

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