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# Staff Paper Series

Staff Paper P82-5

May, 1982

**TECHNOLOGY ASSESSMENT  
AS A FRAMEWORK OF ANALYSIS FOR  
AGRICULTURAL PRODUCTION TECHNOLOGIES  
(Evaluation of a Pilot Project on Corn Technology  
Assessment)**

by

W. Burt Sundquist

Kenneth M. Menz

Catherine F. Neumeyer

**Department of Agricultural and Applied  
Economics**

University of Minnesota  
Institute of Agriculture, Forestry, and Home Economics  
St. Paul, MN 55108

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Department of Agricultural and Applied Economics.

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(Evaluation of a Pilot Project on Corn Technology Assessment)\*

Introduction

This paper examines the use of technology assessment as a framework within which policy questions pertaining to agricultural technology can be analyzed. Such questions include, but are not limited to, those pertaining to the establishment of agricultural research priorities and to the encouragement or discouragement of specific agricultural technologies.

At an earlier period in time, most agricultural production technologies were judged to be desirable if they either increased output or decreased total resource requirements, or both. An additional requirement was that they were profitable for producers, at least to the early adopters. Although these continue to be important criteria for technology evaluation, they have been joined by additional evaluation criteria pertaining to:

- (i) energy efficiency
- (ii) adverse environmental externalities (e.g., soil erosion and chemical pollution)
- (iii) labor displacement and utilization
- (iv) use constraints for land and water resources
- (v) capital requirements and cash flow performance and
- (vi) economics of size, including its relationship to structure in farming

Also, there are new concerns about:

- (i) a perceived leveling off in agricultural productivity,
- (ii) potential vulnerabilities of our agricultural production systems

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\* Prepared by W. Burt Sundquist, Kenneth M. Menz and Catherine F. Neumeyer as a contribution to IR-6, Interregional Research Project entitled, "National and Regional Research Planning, Evaluation, Analysis and Coordination".

(and of individual technologies) to external shocks, both natural and man made, and

- (iii) constraints on funding available for R & D for agricultural technology, particularly for public sector research.

Thus, there has been increasing frustration with the fragmented information provided by a gamut of "single criterion" evaluation techniques which provide good quantitative information about some aspects of a technology while shedding little light on the remaining aspects. And, evaluation of the trade-offs among several aspects of technology performance is often the key input required for deciding on effective policies regarding technology.

The search for a type of procedure which would provide a broad, yet systematic method of analysis in which agricultural production technology could be examined has led to the use of a framework known as technology assessment (T.A.). TA refers to a technique which has evolved over time, the most distinguishing feature of which is its' multiple criterion assessment framework. Over the past decade, a number of agriculturally related assessments have been conducted. These have ranged from very specific technologies such as twinning in Beef Cattle (Harrison, 1977) and hail suppression (Chagnon, et.al., 1977), to somewhat broader topics such as minimum tillage (Crosson, 1981) and integrated pest management (Midwest Research Institute, 1976). In addition, the literature on TA includes a number of works related to procedure (Jones, 1971; Coates, 1976; USDA, 1977; Porter, et. al., 1980; and others) and to the application of TA to research management (Kopel, 1978).

There does not appear to have been any prior TA covering a major

agricultural commodity. The Corn Production Technology Assessment which we conducted (Sundquist, Menz and Neumeyer, 1982) was designed, in part, to serve as a pilot study of this broader type of assessment. <sup>1/</sup>

The objective of this paper is to evaluate the Corn Technology Assessment project from the viewpoint of its being a pilot project of the broader-type of commodity-specific technology assessment. More specifically, the discussion will center on: a definition of TA; objectives of the TA; delineation of production systems (by commodity or by technology); a framework of analysis; and the process of identifying specific technologies.

#### Definition of Technology Assessment

The definition of TA which we considered to be useful was a broad, inclusive definition taken from a USDA Workshop on Technological Assessment (U.S. Department of Agriculture, 1977):

"Technology assessment is the formal, systematic, interdisciplinary examination of an existing, newly emerging or prospective technology with the objective of identifying and estimating first and second order costs and consequences, over time, in terms of the economic, social, demographic, environmental, legal, political, institutional and other possible impacts of the technology, including those consequences which may not have been anticipated, intended or desired by the inventors, and of specifying the full range of alternative courses of action for managing, modifying, or monitoring the effects of the technology".  
(p. 152)

This definition provided a useful reference point from which to design a framework of analysis. Since it is a very broad definition it is not realistic to expect that all included criteria can be assessed equally.

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<sup>1/</sup> The Corn Technology Assessment project referred to here was supported by SEA and ERS, USDA and by the Minnesota Agricultural Experiment Station.

Rather, it is necessary to define the objectives of a specific TA in order to collapse this definition into a workable framework. Other than the multiple assessment criteria, the distinguishing features of technology assessment are: the identification of uncertainties and externalities associated with the technology and the specification of alternative technology options for achieving objectives (Sundquist, Menz and Neumeyer, 1982).

### The Assessment Process

#### Stage I - Identifying the Objectives of the TA

As noted above, the first stage of an assessment is to clearly define the objectives of the assessment. Because of the inherent breadth of this type of analysis (particularly with technologies which themselves include a broad subject matter component) it is necessary to work from a very well defined objective or set of objectives. The specified framework of the TA should "fall out" of the end purpose of the TA (e.g., evaluation of potential production capacity, allocation of research funds, evaluation of environmental impacts, etc.)

The pilot study clearly indicated a need for the end uses of the assessment to be well defined. "General purpose" types of assessments are virtually impossible for a research team of modest size (perhaps 2 or 3 persons) to carry out unless the technology itself is rather specific or unless rather specific assessment guidelines can be developed.

Stage II - Delineation of the Production Technology Components

In order to effectively assess a broad topic such as corn production technology, the topic must be subdivided into manageable segments. The Technology Assessment Committee of the Joint Council on Food and Agricultural Sciences of SEA (1980) proposed delineation of the agricultural production system along two possible lines (i) by commodities across technological functions, (ii) by technological functions across commodities (Table 1). The committee also outlined the reasons for choosing between these two alternatives and showed some preference for the commodity categorization because:

- (i) research and development tends to become specialized along commodity lines -- e.g., corn breeding rather than plant breeding in general, or cattle nutrition rather than animal nutrition in general.
- (ii) industries tend to be organized along commodity or product lines.
- (iii) available statistical data, especially on production, prices and consumption, are oriented towards commodities.

The delineation by commodities does pose problems of possible duplication, where the same technologies cut across more than one commodity, or possible omission, in cases where significant technology is not applied to a specific commodity under assessment. It seems, however, that there is no inherent advantage in either method. The choice depends on the objectives of the TA itself. Some policy questions may be best analyzed by an assessment along commodity lines. For example, this method of analysis facilitates the examination of alternative technologies for achieving a particular yield goal for a crop. In some other cases, the technological function deline-





ation is clearly more desirable. An example of this would be that of examining the future impact of soil erosion on agricultural production capacity.

Some lessons were learned from the pilot study which was delineated along commodity lines (corn). We believe that with a minimum of additional effort the total corn-soybean production system (rather than only corn) could have been analyzed. The additional information on soybeans could have been gleaned at little additional cost, and a more complete analysis of corn production technology would have been facilitated (since there are important interrelationships between the two crops). As a result, we recommend that, where appropriate, TA's be oriented toward agricultural production systems (e.g., dairy-forage, corn-soybean, etc.) which may, but often will not, involve more than one commodity.

### Stage III - The Framework of the Analysis

Once the objectives of a particular TA are defined and the appropriate delineation is decided upon, the framework of analysis for the particular assessment must be established. The framework outlines in detail which criteria will be used and the specific form(s) that the assessment will take. Some flexibility should probably be provided while maintaining a degree of consistency among assessment criteria and analytical procedures. The particular framework chosen will differ depending upon the objectives and scope of the TA. There is necessary trade off between the scope of the TA and the depth with which it can be analyzed.

The primary objectives of the Corn TA project were to examine the existing corn production system, assess the sources of past yield gains

and estimate likely yield gains up to the year 2000. Given these objectives and the broad criteria outlined in the definition of technology assessment earlier, a subset of criteria was established by collapsing the definition, until the following outline was obtained: 1) A component of the overall technology was delineated, defined and described; 2) Its direction and magnitude was specified; 3) Its direct effects were assessed on: a) per acre yields, costs, profitability, and aggregate production capacity; b) productivity, as measured by output/input ratios or intensity of factor use measures for specific inputs including land, energy and labor; c) input demand; d) a broad range of economic, environmental, legal, social, institutional, demographic, political, and safety considerations; 4) Other (indirect) effects of the technology were specified in order to: (a) identify gainers/losers from the technology; (b) determine long-term effects of the technology; (c) specify risks and uncertainties associated with the technology (including vulnerability to shocks from natural forces such as weather, pest, diseases, etc., and from economic forces such as major changes in supply, demand, and prices); (5) Assessment was made of the feasibility of the technology in terms of criteria listed above; also, are the required inputs available for adoption of the technology on a broad basis? (6) Alternative technology options (if any) were specified for achieving objectives (this involves mainly an examination of the opportunity costs of the technology under consideration but may also involve identifying noneconomic advantages/disadvantages of alternative technologies); and (7) Management strategies for the technology were assessed --including specification and evaluation of the alternative courses of action for promoting, demoting, managing, modifying, or monitoring the effects of this technology.

This framework provided a useful guide for following throughout the assessment. In retrospect, we believe that such a framework provides a workable procedure even for an assessment with fairly general objectives, by spelling out specific guidelines to be followed.

#### Stage IV: Identifying the Technologies

The method used to identify relevant existing and potential production technologies for corn production was to examine the literature (particularly trade publications and scientific journals), and to interview research personnel from various university departments and industry, as well as farm operators. Having completed this process, corn production technology was subdivided into the categories of (i) conventional plant breeding; (ii) fertilizer technology; (iii) soil moisture modification (irrigation, drainage, weather modification); (iv) pest control; (v) tillage practices and crop rotations; (vi) mechanical technology; (vii) on farm drying technology; (viii) emerging biotechnologies and; (ix) management of technologies. <sup>2/</sup>

In evaluating this method of identifying technologies, we conclude that it works well for those technologies which are already well developed and in use. In using the procedure for identifying emerging and potential technologies, however, there are potential biases. Some of the major ones are listed below:

(i) In selecting technologies which at the present time appear to be promising for future corn production, there is an inherent bias toward selection of those technologies which are acceptable under current trends

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<sup>2/</sup> This delineation of technologies excludes some of the more minor technologies and does not give explicit recognition to interrelationships between technologies. These factors were, however, given consideration in a subsequent integrating section of the assessment.

in the economic, institutional, a social environment.

Scientists as members of the general public are influenced by the social-economic environment in which they live. In asking scientists to identify areas within their fields which are likely to make a contribution to corn production technology, they are apt to incorporate present trends in their response. For example, in selecting promising technologies the scientists may not only take into consideration whether or not a technology is technically possible but also whether a primary feature of the technology is its economic feasibility (for example, energy efficiency). Some dimensions of current trends are, therefore, inherently built into the response of whether or not a presently emerging technology is promising.

Potential technologies which run counter to present day trends tend to be omitted. Thus, it can be difficult to identify all of the alternative technologies;

(ii) A second issue is the one of possibly overlooking some of those technologies, particularly machinery, which may be brought to the "prototype" stage by farmer innovators. Such technologies will not generally be identified through a literature search or through an analysis of research budgets. But, this may be a less important issue in the future since a higher and higher proportion of future technologies are likely to include a substantial "science based" input in their development;

(iii) A third issue is that of the analyst neglecting excessively those emerging technologies for which no "hard" data are available for assessment. This problem can, however, be at least partially overcome by use of a flexible

framework which permits the combination of a variety of analytical procedures including those of a "Delphi-type" to evaluate those emerging technologies for which hard data do not exist.

#### Advantages and Disadvantages of the Technology Assessment Framework

The following listing of advantages and disadvantages of the TA framework is not a comprehensive one but probably includes most of the important considerations.

##### Advantages

(i) the multiple-criterion framework permits the identification of economic, environmental, social and other trade-offs;

(ii) flexibility of the technique -- it utilizes a broad range of methods -- from complex analytical tools to subjective determinations of potential impacts. There is no single "technology assessment methodology". Thus, if certain types of data are not available the assessment framework does not "break down";

(iii) TA permits consideration of "nonmarket" as well as "market related" criteria (e.g., environmental impacts can be included even though they are not priced in the market);

(iv) TA permits the evaluation of the "whole" production system and the "linkages" in the system as well as the "individual" components;

(v) the use of the TA framework does not preclude the use of other specific analytical and/or evaluative techniques. It can, in fact, utilize information generated by a broad range of methods;

(vi) each TA can be focused on the important dimensions of technology suggested by the objectives of the assessment.

### Disadvantages

(i) TA may not generate unique answers to the questions under consideration;

(ii) the analytical procedures are necessarily somewhat ad hoc (e.g., particularly those used in evaluating the social, and institutional impacts);

(iii) the framework does not, in itself, provide a weighting procedure for each of the multiple assessment criteria;

(iv) if the TA is a partial analysis of one agricultural commodity, changes in other segments of the system which influence the segment in question, will have impacts which will not be accounted for (e.g., price changes in other crops due to technological advances in the production technology of these other crops);

(v) the interaction of price and technology. Some technologies will cease to be feasible under certain price regimes. This is true since the price of a commodity is not independent of the production technology and at the same time technology employed is dependent on price. This interaction between prices/technologies may require an interactive framework. But, such a framework is feasible in TA.

(vi) there is a trade-off between the narrower "single criterion" evaluative frameworks and the broader TA framework. The scope of the single criterion evaluative framework is narrow, however, its strength (and appeal) is that numbers can be calculated -- the results are tangible.

### In Conclusion

Technology policies, including those related to public sector R & D, often require information from multiple-criterion evaluation procedures.

We conclude that a "technology assessment" framework can be effectively utilized to generate such multiple - dimension evaluations. But, for effective utilization, the objectives for a TA need to be well specified in advance of the analysis. And, a systematic analytical framework should be developed. This is, of course, true for almost any other evaluative procedure, as well.



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