Weather Modification: The Economic Context

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ABSTRACT

There are two types of agricultural production technology—mechanical (labor-saving) and biological-chemical (land-saving). Weather modification belongs to the second type. The emphasis on research and development for each type depends on the relative scarcity of land and labor. Present trends indicate an increasing relative economic scarcity of land, thus a greater need for land-saving technology relative to labor-saving technology. This situation favors the development of weather modification. However, there are many competitors in the area of biological and chemical innovations that are generally judged to promise a higher potential than weather modification for increasing crop yields. One of the reasons for such a judgment is the complex nature of the variability of the performance of weather modification. Placing the various sources of risk into a more comprehensive system might improve the understanding and thus the support for weather modification.

1. Introduction

What does weather modification need? We approach this question from two related viewpoints. First, we examine the economic forces which affect research and development in a technology such as weather modification when its principal intended use is to enhance agricultural production. Second, we indicate the importance of risk evaluation in improving the information base for adoption of weather modification for commercial purposes.

2. Two types of technology

Agricultural technology is adopted by farmers because it saves resources, in particular, the two basic resources of land and labor. If the cost of producing a bushel of grain is not decreased by adopting the technology, it is not likely to be adopted. Mechanical technology has the primary effect of replacing labor. It includes improvements in the sources and types of power and in machinery capacity and performance. Although mechanical innovations have their primary effect on reducing the amount of labor required to produce a given amount of crop, they may also increase crop yields through improved timeliness of operations, provided that farm size does not increase to the point that these potential gains are offset.

Biological-chemical technology has the primary objective of increasing the efficiency of the crop production system through which solar energy is captured and transformed into crops. Land is the resource which is saved by this type of technology. Improved crop varieties, fertilizer, pesticides, irrigation and successful weather modification are examples of innovations in this class. Although biological-chemical technologies are land-saving, they are also apt to be moderately labor-using because the additional inputs as well as higher yields will tend, in and of themselves, to increase labor requirements per acre of land.

Of course, both types of technology require particular skills and management capabilities, and these are necessary conditions, along with economic feasibility, for the continued use of a technology. Both types of technology require higher levels of management sophistication as farming becomes more complex. Not only is the successful operation of a technology such as weather modification becoming more demanding, but the complexity of determining whether it is worth integrating into the farm business in the first instance is also increasing. For example, a decision to adopt weather modification should, at the minimum, consider alternative sources of water (e.g., ground water), water storage facilities and the drainage system. The role of risk is discussed later in this paper.

We may summarize the effects of the two types of technology by thinking in terms of the following ratios. Mechanical technology increases the land/man ratio while biological-chemical technology increases the crop production per acre of land, the output/land ratio. The combined influence of the two kinds of technology is reflected in crop production per man, which is found by multiplying the land/man ratio by the output/land ratio.

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a. The relative importance

In order to assess the relative importance of the two types of technology on the productivity of labor in farming, we need to examine data on the relationships among land, labor and crop production.

Our principal interest lies in the productivity of the human resource—labor. How much did labor productivity in crop production increase in the Corn Belt in the last 35 years? Data in Table 1 indicate that crop production per unit of labor in the Corn Belt is now nearly 6½ times as high as it was in 1939.

Breaking this increase into its two technological components, we find that the index for the land/man ratio or acres per unit of labor (a measure of the effect of mechanical technology) is 3.4 times higher than in 1939 and that the index of yield per acre is 1.9 times higher than in 1939. Multiplying these two components by each other we get the increase in labor productivity ($3.4 \times 1.9 = 6.5$). Our conclusion is that over this entire period mechanical innovations have played a more important role in increasing labor productivity than have biological–chemical innovations. It should be noted that the increase in the biological–chemical technology's influence was greater than that of mechanical technology in going from the 1950's to the 1960's, a period of rapid increase in the use of fertilizer.

b. Resource scarcity

To explain the past emphasis on mechanical technology we choose the doctrine of "induced innovations" (Hayami and Ruttan, 1970). In brief, the process of research and development of new technology is guided by the relative scarcity of the inputs for which the technology is intended to substitute. Thus if land is scarce relative to labor, we would find the research and development in the private sector emphasizing biological and chemical research which would eventually lead to adoption of a land-saving technology. If labor is scarce relative to land, the emphasis would be on mechanical technology. It has been asserted that public institutions respond in the same way, partly because of their close linkages to industry and also their sensitivity to responses of the needs of farmers.

TABLE 1. Indexes of crop production per unit of labor, acres of land used for crops per unit of labor, and crop production per acre. Corn Belt 1939–75, by decades (U.S. Department of Agriculture, 1976).

	(1939=100) Crop production per unit of labor	Acres of land used for crops per unit of labor	Crop production per acre
1939	100	100	100
1940–49	130	124	105
1950–59	244	207	117
1960–69	479	287	166
1970–75	646	339	191

TABLE 2. Farm land values, farm wage rates and months of labor required to purchase one acre in Illinois, 1910–76. [Illinois Cooperative Crop Reporting Service (1949, 1950–76); Pressly and Scofield (1965)].

Year	Average value of farm land and buildings ($ per acre)	Farm wage rate ($ per month with board)	Farm labor required to purchase one acre (months)
1910	108	24.50	4.41
1920	188	52.50	3.55
1925	137	41.90	3.27
1930	109	38.90	2.80
1935	70	24.20	2.89
1940	82	32.70	2.51
1945	116	79.00	1.47
1950	174	99.00	1.76
1954	230	120.00	1.92
1959	320	144.00	2.22
1964	357	162.00	2.20
1969	490	234.00	2.09
1974	857	334.00	2.57
1975	952	341.00	2.79
1976	1,184	369.00	3.21

In a market economy, price indicates relative scarcity. Land prices are influenced by expectations about future needs for land and its supply. Farm wage rates are an indicator of the current productivity of this resource in farming and the incomes from alternative employment, which reflect the state of the general economy. A comparison of the changes in these two market-determined values, land prices and wage rates, provides the collective judgment concerning relative scarcity of land and labor.

In Table 2, data are presented on the average Illinois land values and farm wage rates. In the last column we present the number of months of work necessary to purchase one acre of land. This is the land-price/wage-rate ratio. In 1910 this value was 4.41 months, followed by a steady decline until the end of World War II. During this period land was becoming less scarce relative to labor. Thus the economic environment was one in which development and adoption of mechanical technology would appear to be more rational, following the objective of replacing the more extensive input, labor. However, an increase has occurred in the land-price/wage-rate ratio since World War II. This increase has been especially sharp in the 1970's and appears to be continuing.

A rational economic response to the expected continuation of the increase in this ratio would be a greater emphasis on yield-increasing research and development. Estimates of the length of the time lag between investments in research and the adoption by farmers are approximately 7–10 years in the case of applied research and longer with more basic research. Consequently, it is likely that this shift to emphasis on biological-chemical research is already occurring.

Just because weather modification is a biological-chemical or land-saving technology does not mean that it will automatically share in the predicted increase in biochemical research designed to augment agricultural production. It must compete against a number of candidates. One, for example, is the possibility, through genetic modification, of developing cereal crops that would manufacture their own nitrogen as legumes now do. Such a development would be energy-saving because of the reduced need for nitrogen fertilizer. Energy efficiency will be an important factor as potential technologies are selected for further research and development. How well weather modification fares in this competition for research and development funds will depend, to a large extent, on demonstrating that it has a high-energy efficiency potential in terms of increasing agricultural production.

In the final report of the steering committee of the National Research Council Study on World Food and Nutrition (National Academy of Sciences, 1977), areas of research expressly designed to cope with the world food problem are identified. Twenty-two high-priority research areas are identified in this report. Thirteen deal rather directly with agricultural production. Among these there is strong emphasis on expansion of research in the biological-chemical or land-saving types of technology. Thus, it appears that the public sector is responding to the relative scarcity of land as shown in our price-ratio analysis. The research areas identified include weather and climate, but not weather modification. The report recommends research on improvement of techniques for predicting weather and climate.

Delegates to a recent conference on agricultural research (ARPAC, 1975), were asked to judge 49 research area needs according to the criterion:

> "The importance of the research need area or subarea to the United States as a means of increasing and improving domestic and world food supplies."

Although the research area "Weather and Climate" was ranked in the upper one-half of the 49 research area needs, weather modification was ranked 17th among the 20 important problems identified within this research area. Perhaps one of the reasons for the low priority is that weather modification does not fall within the traditional and familiar subject-matter areas of colleges of agriculture and the U.S. Department of Agriculture. Although judgments from other scientists may differ, it appears that the current appraisal from the agricultural research community is one which does not give weather modification research a high priority in terms of increasing agricultural production.

3. Risk analysis

In this section we examine the risk component of the economic incentives for adoption. It is believed that our inability to evaluate risk is a substantially greater deterrent to adoption than the lack of institutional arrangements necessary for a collective decision to be made. In fact, we have a number of examples of collective decision-making units acting to adopt an agricultural practice when its performance is clearly demonstrated. Irrigation districts, mosquito abatement units and other cooperative arrangements come easily to mind. However, it is recognized that many of these situations lack the counterpart of the potential damage to non-participants that we find in the case of weather modification.

It is useful to view risk analysis from two perspectives. First, there is the question of information needed to formulate expectations of outcomes of weather modification. One "need" for an improved economic analysis of weather modification is a description of the relationships in the system in such a way that risk may be evaluated. Classical experimental methods usually emphasize only the *average* results. Thus, a weather modification program may increase crop yields an average of, say, X percent. With a technology such as weather modification it is at least of equal importance to have estimates of some of the other parameters of the crop yield increase distribution.

Because of the uncertainty of 1) the performance capability of weather modification technology in terms of intermediate effects (precipitation, wind, hail, lightning, etc.) and 2) the more ultimate effects on such economically important activities as crop production, there is a need for information on the physical and biological relationships in a weather modification system to be collected (whether from experimental or non-experimental sources) in such a way that synthesis into a decision-making framework can be facilitated. The estimation procedures should especially take into account the different sources of risk, preferably in a rather formal decision framework. This would permit organization of available information in a structure that would improve the economic base for adoption decisions. Earlier work has ignored the risk arising from performance of the technology, and taken into account only that from the weather itself as it affects year-to-year yield variability (Sonka and Potter, 1977; Swanson *et al.*, 1972).

A second aspect of risk analysis deals with the attitudes toward risk taking. Even if good estimates of the mean of the crop yield increase and its variance, including all sources of variance, are available for formulating expectations, we know very little about the risk preferences of producers. In the case of weather modification, collective decision-making is involved and thus the pooling of individual risk preferences is an important part of the needed analysis. Nevertheless, the risk preferences of individual producers are the initial building blocks from which the collective decisions for adoption are made. If these building blocks indicate adequate incentive to adopt weather modification, institutions for collective action will follow naturally.

The cost of estimating the individual risk preferences is very high and other methods need to be explored. Estimation of individual risk preferences requires long interviews with carefully constructed questionnaires and experienced interviewers. The ordering of risky prospects according to stochastic dominance has been suggested as a practical guide to technology adoption when risk is an important element (Anderson, 1974). By using this method there is more focus on the lower tails of the distribution of yield increases. Thus, it is important to design the experiment so that observations will be made and reported under unfavorable, as well as average and favorable, conditions. In terms of extension programs, it should be recognized that recommendations based on average results, which do not take into account risk, may be inadequate and thus misleading. In summary, I view inclusion of risk considerations as the most needed improvement in providing a base for economically rational decisions regarding the adoption of weather modification. This need is a major challenge to both researchers and practitioners dealing with weather modification.

4. Concluding comment

It is clear that widespread public support has not developed for substantial research and development efforts for weather modification. The initiative for additional research and development for land-saving and hence cost-reducing technology might, in principle, be expected to come from the public acting in the role of consumers. However, because of government agricultural price-support programs much of the gain accruing from output-increasing technology is retained by farmers (Swanson, 1977). Further, weather modification could offer, at best, only small reductions in the cost of a food bill that, at present, comprises only 17% of total family income. Given that the support of agricultural producers is crucial in both publicly sponsored research and the development and adoption process, the present inadequate description and analysis of the sources of uncertainty in the performance of weather modification keep it low on the economic-need priority lists.

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