Book Reviews

Rainmaking: Claims and Questions

Weather Modification: Science and Public Policy. Natural Resources Public Policy Seminar, Seattle, Wash., 1966–67. ROBERT G. FLEAGLE, Ed. University of Washington Press, Seattle, 1969. x + 150 pp., illus. $7.95.

There is clearly a need for a thorough and dispassionate review of "science and public policy" with respect to weather modification, and particularly that aspect of it popularly called "rainmaking."

This need is evidenced by the difference in response elicited by the conclusion of the National Academy of Sciences-National Research Council Panel on Weather and Climate Modification (NAS-NRC Publication No. 1350, 1966) that "there is increasing but still somewhat ambiguous statistical evidence that precipitation from some types of cloud and storm systems can be modestly increased or redistributed by seeding techniques," and by, for instance, the results of an analysis by Neyman, Scott, and Smith [*Science* **163**, 1445–49 (1969)] of one carefully conducted experiment which indicates that "the average seeding effect in the entire region [comprising 100,000 square miles] is a 21-percent loss of rain." The NAS report has been represented as substantiating the claims of the commercial operators and as justifying a large expansion of operational attempts to augment precipitation, including the multiplication by a large factor of the Bureau of Reclamation's program for inducing additional precipitation in the Colorado River Basin. A letter to *Science* by Assistant Secretary of Commerce Myron Tribus [**164**, 1341 (1969)] is an example of the reaction the negative indications of Neyman's analysis produced. Tribus writes, "The important issue facing us is whether we have enough information on hand to attempt to schedule operational weather modification activities. I believe we are much closer to this state of knowledge than Neyman indicates."

In effect, ambiguous evidence of modest increases is met with enthusiastic decisions to expand operational efforts to augment precipitation; strong statistical evidence of a substantial decrease over a large area is met with skepticism [see also L. J. Battan, *Science* **165**, 618 (1969)] and rejection by persons in responsible policy positions, such as Tribus.

It should be noted that the two results quoted are not contradictory. It has been recognized by many investigators that precipitation from some types of cloud and storm systems under some circumstances in some areas can be increased by seeding but that with other types of cloud and storm systems, or under other circumstances, or in other areas, seeding produces decreases in precipitation. To make more specific the issue voiced by Tribus, the question is whether we have enough information on hand to determine a priori whether in any set of existing circumstances seeding will produce an increase or a decrease (or, perhaps, no effect). Insofar as this question is faced in the book under review, the answer that emerges is in the negative.

The volume is an attempt to meet the need suggested by its title. It is comprised of lectures presented during the 1966–67 academic year to a Seminar on Natural Resources Public Policy at the University of Washington. As is usual when several authors contribute to such a lecture series, the nature of the presentations is quite varied. Some of the chapters, such as the one on "Weather modification and the law" by Robert S. Hunt, are well documented and thorough, in spite of being concise. Others are more general and polemical.

One chapter having the latter character is that by James E. McDonald on "Evaluation of weather modification field tests." Since Fleagle, in the introductory chapter on "Background and present status," indicates that McDonald's analysis of commercial cloud seeding records was responsible for the National Academy of Science Panel's reaching the conclusion quoted above, one might have expected McDonald to present a review of his analysis of the commercial operations, as well as the results of evaluation of various other experiments. Instead he confines himself to discussing what might be called the philosophy of weather modification evaluation, arguing against the "antistatisticians" who, failing to allow adequately for the variability of the weather and our inability to predict precisely what would have happened in the absence of treatment, claim to be able to "see" the consequences of their seeding activity without controls or statistical analysis.

In view of the suggestion that McDonald's analysis was largely responsible for the "cautious optimism" of the conclusion of the NAS Panel's report, it is interesting to note that his own emphasis is on caution rather than optimism. He says, "The actual response, especially in Congress [to the Panel's report], was rather overwhelming to some panel members, including myself, for the proposed levels of spending in the area of cloud seeding alone ran to many tens of millions of dollars per year in some of the bills. Speaking only for myself, I would have to emphasize that I cannot see how we can beneficially spend such funds in the immediate future, nor do I feel that the panel's findings warrant such expenditures."

The statistical aspects of weather modification receive more specific treatment in a chapter by Douglas G. Chapman. He examines in some detail the various possible sources of bias in the target-control area regression procedure of evaluation of rainmaking operations. His treatment of randomized experiments is much briefer; although he points out that randomization eliminates many of the sources of bias, he, unlike most other statisticians, does not appear to favor randomization to the exclusion of other procedures, but rather implies that with adequate reporting of commercial operations these can answer most of the questions regarding the efficacy of cloud seeding in augmenting precipitation.

In his chapter on "Economic evalu-

ation of weather modification" James A. Crutchfield points out that the benefits to agriculture of an artificial increase in precipitation must be weighed against the benefits resulting from alternative adjustments to precipitation shortages, such as shifts to drought-resistant crops or water-conserving cultivation techniques. He states, "Despite the general lay opinion, it is not at all clear that the marginal net economic benefit from expanded application of water to land is as great—in total, or by specific area and type of agriculture—as could be achieved by investment in increased quantities or improved quality of other agricultural inputs." In this situation research into the cost-benefit relationship of potential effects of artificial increases in precipitation should be given priority even over theoretical, laboratory, and field studies to determine the circumstances under which seeding can produce consistent increases.

For other applications of weather modification, such as fog dispersal, lightning suppression to prevent forest fires, and hail prevention, the economic benefits are more definite, but only for dissipation of supercooled fog (liquid drops below 0°C) are techniques of proven effectiveness available.

The impact of weather modification, in addition to economic aspects, on human activities and the ecological balance of nature is considered in chapters by W. R. D. Sewell and W. T. Edmondson. Their conclusion is that investigation of the ecological and social consequences should precede or be concurrent with the development of any program to modify the weather, to insure that undesirable "side effects" do not outweigh the expected benefits.

Gordon J. F. MacDonald, in his chapter on "Federal government programs in weather modification" (as well as in his article based on it in the *Bulletin of the Atomic Scientists*, Oct. 1968), advocates "a major reorganization of federal programs, in which a new agency, preferably an independent one, is given primary responsibility for promoting research in environmental prediction and modification." He would leave weather modification operations to the various mission-oriented agencies, and "support for fundamental studies through grants and fellowships" to the National Science Foundation.

If establishment of a new independent agency would attract appropriations for research adequate to the magnitude of the problems involved in fully understanding atmospheric processes on all scales, one can heartily endorse the proposal. MacDonald points out that eight federal agencies participated in weather modification activities in 1966. A new agency might represent a ninth hand competing for a share of federal funds, with the result being further fractionation of resources instead of the development of a program large enough to exceed the "critical mass" required.

A further concern is whether it would be possible to find enough well-qualified personnel to man such a new agency. At present most of the experts in atmospheric sciences in the country are employed by the Environmental Science Services Administration. ESSA's predecessor (now one of its components), the Weather Bureau, has been criticized as having been unduly conservative and having failed to exercise leadership in the field of weather modification. However, the justice of these criticisms may be questioned in the light of the uncertainties which still remain concerning the efficacy of rainmaking and the inadequacy of the appropriations with which the Bureau has had to carry out its extensive observational, informational, and forecasting activities, even without the undertaking of extensive investigations of weather modification. Perhaps it would be best to take full advantage of the expertise resident in ESSA, rather than to attempt to build a competent staff from scratch in a new agency.

Extensive hearings have been conducted by Congress in the attempt to resolve the conflicts of viewpoint among scientists, commercial operators, consumers, and governmental agencies. The need for a well-defined policy is recognized by all groups, and particularly by Congress. Regrettably, the foundations for such a policy in terms of the economic, social, and ecological objectives, the legal constraints, and the scientific and technical potentials and limitations are shown by this book to be not yet available. The intelligent interim policy would be to foster and adequately support research to find answers to these questions. Also regrettably, it is easier to get support for a premature program to augment precipitation or prevent hail than for the basic research which will render these objectives possible.

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Processing the Future

Technological Forecasting and Long-Range Planning. ROBERT U. AYRES. McGraw-Hill, New York, 1969. xviii + 238 pp., illus. $12.50.

In the last few years, because of the needs of the present a new breed of professionals called "futurists" has come into being. This breed contains a strange mixture of sociologists, technologists, physicists, and others, some charlatans, some poets, some meticulous workers, and others even geniuses. Most of them have considerable imagination. Many of their customers or semi-allies, however, belong to the penumbral areas of corporate or military management; and imagination there is often lacking. If it can be said of the teaching profession that "those who can, do; those who can't, teach," it can be said of the planning profession in U.S. corporations and military, "Those who can, run the show; those who can't, run the planning department."

This is a useful book for those of us who teach or run planning departments. The references and the introductory history are handy and cannot be found in any other single source that I am aware of. It is a book which will be of considerable use in many corporations, government agencies, and the type of consulting firm that is known as an "also-RAND." Given the scope of the book—it attempts to cover all technological forecasting and long-range planning methods—it is well organized and manages to go over a great deal of terrain. I do, however, get the feeling that it plays down and somewhat underestimates behavioral and organizational problems and is light on the dynamics of planning. There is also a lack of attention to the interrelation of planning, responsibility, and decision-making.

I am glad I read the book, it is useful, but it is not exciting. And I happened to be handicapped in my reading of it by knowing a great deal about some of the particulars in it. That is always dangerous to a book. For example, in reading Toynbee, if one happens to have a deep knowledge of any particular culture the charm of seeing the world as a whole soon disappears. It is to some extent unfair to fix on specifics when a man is trying to paint the broad picture. However, if nothing else the examination of specifics helps us form some criteria for judging the whole. So, let us look at some of these in this book.

To an economist, it was rather comforting to learn on page 3 that "as