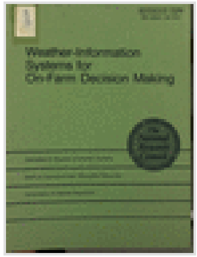


Weather-Information Systems for On-Farm Decision Making (1980)

Pages
97

Size
8.5 x 10

ISBN
0309332206

Committee on Weather-Information Systems; Board on Agriculture and Renewable Resources; Commission on Natural Resources; National Research Council

Weather-Information Systems for On-Farm Decision Making

A report of the
Committee on Weather-Information Systems
Board on Agriculture and Renewable Resources
Commission on Natural Resources
National Research Council

NATIONAL ACADEMY OF SCIENCES
Washington, D.C. 1980

NOTICE

The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the Committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

This study was supported by the National Oceanic and Atmospheric Administration of the U.S. Department of Commerce and the Economics, Statistics and Cooperatives Service of the U.S. Department of Agriculture.

BOARD ON AGRICULTURE AND RENEWABLE RESOURCES

Chester O. McCorkle, Jr., *Chairman*, University of California, Davis

George K. Davis, *Vice Chairman*, Gainesville, Florida

John D. Axtell, Purdue University

Thadis W. Box, Utah State University

*Robert E. Buckman, USDA Forest Service

Neville P. Clarke, Texas A&M University

Ellis B. Cowling, North Carolina State University

Sally K. Fairfax, University of California, Berkeley

John E. Halver, University of Washington

Helen M. Ingram, University of Arizona

*Ralph J. McCracken, USDA/SEA

Bernard S. Schweigert, University of California, Davis

George R. Staebler, Weyerhaeuser Company

Philip Ross, *Executive Secretary*

*Liaison Member

COMMITTEE ON WEATHER-INFORMATION SYSTEMS

Robert H. Shaw, *Chairman*, Iowa State University

William C. Burrows, Deere and Company

Harold C. Cochrane, Jr., Colorado State University

Robert F. Dale, Purdue University

John F. Gerber, University of Florida

Bryant E. Kearl, University of Wisconsin

Marshall Pile, Albany, Missouri

William Ramsey, Salinas, California

Thomas F. Saarinen, University of Arizona

Donald J. Schrickel, Quaker Oats Company

STAFF

Philip Ross, *Executive Secretary*

Selma P. Baron, *Staff Associate*

WORKSHOP PARTICIPANTS

William C. Burrows, Deere and Company

Harold C. Cochrane, Jr., Colorado State University

Kenneth Comba, National Weather Service

Robert F. Dale, Purdue University

Robroy D. Fisher, Glen Allan, Mississippi

John F. Gerber, University of Florida

Martin Gossett, Dumas, Texas

Roger T. Huber, University of Arizona

Ray E. Jensen, National Weather Service

Robert Josephy, Bethel, Connecticut

Bryant E. Kearl, University of Wisconsin

Arthur F. Mathias, Haines City, Florida

James A. Mull, Denver, Indiana

Allan H. Murphy, Oregon State University

F. Earl Nay, Purdue University

Gaylord M. Northrop, The Center for the Environment and Man, Incorporated

Marshall Pile, Albany, Missouri

William Ramsey, Salinas, California

Thomas F. Saarinen, University of Arizona

Wilbur Schlect, Enderlin, North Dakota

Donald J. Schrickel, Quaker Oats Company

Robert H. Shaw, Iowa State University

Richard Smith, Soledad, California

CONTENTS

PREFACE

A recent study of climatic fluctuation and U.S. agricultural production (NRC 1976) concluded that the "major cause of season-to-season variation in food production is the fluctuation of weather and climate." Weather is recognized as a major element of uncertainty and risk in agriculture. Better information about expected weather events and climate should reduce the fluctuation in agricultural production by identifying the most profitable on-farm alternatives, strategies and tactics for both favorable and adverse weather.

The Board on Agriculture and Renewable Resources (BARR) established a Committee on Weather-Information Systems to assist the U.S. Department of Commerce and the U.S. Department of Agriculture (USDA) in the design of agricultural weather- and climate-information systems. The objectives of the study were as follows:

1. Assess the rationale of farm managers for using or not using weather information in their operations.

2. Determine the effects of weather factors and their variability on farm management. Identify avoidable losses due to weather and increased operational costs resulting from inadequate, incorrect, or misapplied weather information.

3. Develop criteria for the credibility, timeliness, format, and accessibility of information for systematic use in farm operations.

4. Provide: (a) recommendations for appropriate weather- and climate-information systems, (b) guidelines on research and development needs relating to the recommended systems, and (c) rough estimates of the cost of implementing such systems.

The Committee held a three-day workshop in Kansas City, Missouri, on June 20 through 22, 1979. The participants included managers of farms producing corn, wheat, cotton, soybeans, vegetable crops, fruit crops, grapes, citrus crops, livestock, and swine, and specialists in agrometeorology, agribusiness, pest management, information dissemination, systems analysis, systems technology, and sociology. Advice and guidance were provided by members of the National Weather Service (NWS) of the National Oceanic and Atmospheric Administration (NOAA). This report was prepared from reports and discussions at the workshop and further communication among Committee members.

The Committee is indebted to Charles Roberts of USDA and Norman Canfield of NOAA for their interest in and support of the project. The Committee is also indebted to Philip Ross and Selma P. Baron of the BARR staff for their help and guidance.

ACRONYMS

AAM	Advisory Agricultural Meteorologist
AFOS	Automation of Field Operations and Services
AGRISTARS	Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing
BARR	Board on Agriculture and Renewable Resources
CASSL	Consortium for Atmospheric Sciences Specialization
CEAS	Center for Environmental Assessment Services
CWIS	Committee on Weather Information Systems
DIFAX	Digital Facsimile Network
EDIS	Environmental Data and Information Service
ESSC	Environmental Study Service Center
FACTS	Fast Agricultural Communications Terminal System
FOFAX	Forecast Office Facsimile Network
FONFACS	a part of the Integrated Pest Management Program at Iowa State University
FWIS	Forestry Weather Interpretations System
GOES	Geostationary Operational Environmental Satellite
GREEN THUMB	a cooperative program testing the feasibility of computer-disseminated weather and weather-related information
LACIE	Large Area Crop Inventory Experiment
LAMP	Local AFOS MOS Program
MICROS	Meteorological Information Computer Remote Operating System
MOS	Model Output Statistics
NACOA	National Advisory Committee on Oceans and Atmosphere
NAFAX	National Facsimile Network
NAMFAX	National and Aviation Meteorological Facsimile Network
NASA	National Aeronautics and Space Administration
NCC	National Climatic Center
NIMBUS 7	type of satellite
NOAA	National Oceanic and Atmospheric Administration
NOWCAST	experimental system for providing weather information in nearly real time
NWS	National Weather Service
NWWS	NOAA Weather Wire Service

RAWARC	Radar Reporting and Warning Coordination Teletypewriter System
SDSD	Satellite Data Services Division
SEASAT	type of satellite
TIROS N	type of satellite
USDA	U.S. Department of Agriculture
WSFO	Weather Service State Forecasting Offices

SUMMARY

Previous studies have concluded that the major cause of season-to-season variation in food production is fluctuation in weather and climate. These studies raise questions about the types of weather information needed by agriculturists and foresters, about who should be responsible for providing this information, and about how it should be disseminated. The Committee on Weather-Information Systems was established to assist the USDA and the U.S. Department of Commerce in answering those questions.

As the result of meetings and a workshop attended by people involved in representative farm areas and activities, this report has been prepared making ten recommendations relative to weather-information services (see Recommendations section).

A review of previous surveys that included questions about weather information shows that most of them had consistent results. Most of the surveys indicate that radio and television stations are the major sources of weather information for farmers, with a high percentage of farmers favoring early morning broadcasts. The surveys also indicate that many farmers are unaware of the variety of weather information available to them. Generally, farmers believe that weather information needs to be tailored more toward agricultural operations in their area and that more accurate forecasts are needed, but they do not generally feel that they should pay for additional or improved services. One survey showed weather information as the third most important type of information needed by farmers (see Chapter 2).

In determining the value of weather information, a distinction needs to be made between weather-sensitive events on a farm (e.g., crops being damaged by a hail storm) and weather-information-sensitive events (i.e., events about which weather information enables farmers to make beneficial decisions). Determining the value of weather information is difficult. The tendency is to account for all gains resulting from the information but not to discount for losses (see Chapter 3).

Weather and climate information may be classified into three types: (1) weather forecasts, (2) current (now-time) weather descriptions, and (3) climatological analysis. These types of information are currently presented through information services available to the general public and through special information services. New weather information services are being tested for their potential. These new services need to be examined to determine how the information they provide differs from that provided by current information services (see Chapter 4).

Mini-surveys made by the Committee in California, Indiana, and Iowa showed results similar to those of the surveys reviewed in Chapter 2. Practically all respondents receive weather information daily, with radio and television being used about equally. Radio often becomes the more important source of weather information when farms are in full operation, however, because farmers often take radios into the fields. Most farmers were generally satisfied with the information they received. The most frequently made suggestions for improvement were: (1) greater accuracy, (2) more-localized forecasts, and (3) better long-range forecasts (see Chapter 5).

Most farmers at the workshop gave weather-information services a rating of 80 on a 0 to 100 scale, but one farmer rated them as low as 30 to 40. Radio and television were again cited as the principal sources of weather information. The opinions of individual farmers about the accuracy, availability, and additional information needed vary widely with the geographic location and type of farm operation (see Chapter 6).

Avoidable agricultural losses caused by the weather and reported by farmers attending the workshop occurred over a wide range of farming operations and geographical areas. All workshop participants reported losses that could have been avoided had the proper weather information been available. The most frequently mentioned needs were more accurate and more-localized forecasts (see Chapter 7).

Evaluation of existing and future needs for an agricultural weather-information program must consider the benefits of adding to current programs or beginning new programs. Current and future weather-information systems (including the Green Thumb program) are discussed, and recommendations for new information systems are made (see Chapter 8). Guidelines for research and development of new weather-forecasting services and techniques are presented in Chapter 9.

RECOMMENDATIONS

The Committee has based its report and recommendations on the following four premises:

1. Because food, feed, and fiber production are national and international resources and weather forecasting requires global information, the provision of basic weather data and related information services for agriculture should be primarily a federal responsibility. If this responsibility is not specifically mandated, it should be accepted as if it were.

2. The weather information and related services of concern to the Committee are in addition to those now available to the general public.

3. Established special services (e.g., the Fruit-Frost Forecast) should be continued and improved as new technology permits.

4. Weather information and services for specialized research purposes were outside the scope of the Committee's work.

The Committee from information provided at the workshop, from information obtained from surveys, and from information from the published literature makes the following ten recommendations:

- The appropriate agencies of NOAA and USDA should jointly and formally accept a continuing responsibility for maintaining a nationwide weather service, available to farmers everywhere, that provides information designed to serve agriculture and forestry.

- Additional efforts should be made to inform farmers and others about what weather information is available to them. Responsibility for this must be shared by NOAA, USDA, private meteorologists, commercial radio and television stations, agriculturists, and agriculture-related organizations.

- Forecasts of importance to agriculture and forestry should be updated more frequently and be disseminated on schedule.

- Because this study revealed that farmers receive most of their weather information from commercial radio and television, a mechanism should be devised to encourage those stations to maintain and improve their weather information services. This mechanism should apply particularly to low-wattage, local stations.

- NOAA Weather Radio transmission should be improved in quality, area coverage, agricultural weather content, and accessibility to farmers.

- Efforts to use new technological developments to improve the accuracy, applicability, and site-specific timeliness of all forecasts should be continued.

- Observation and dissemination systems should become more sensitive to possible new observations required as the agriculture and its related technologies change.

- The climatological network should be maintained at least at its present level, and additional special observations should be added at selected locations. The observation times should be standardized, e.g., 8:00 A.M.

- Current pilot interactive-demand information systems in which farmers aggressively seek information by telephoning computerized services, as well as alternate systems, must be evaluated to determine their effectiveness in disseminating agricultural weather information.

- Whatever reporting system is used, the format of agricultural forecasts and advisories should be developed through advisory committees that include representatives from NWS, USDA, and organized user groups within each state, management, or commodity region so that the information will best satisfy users' requirements.

CHAPTER 1

INTRODUCTION

> For as long as people have cultivated the land to raise food, the most important factor that has determined whether the harvest is good or bad has been the weather, or, in long-range terms, the climate, which is weather writ large--the summation of weather conditions over a period of time . . . . Thus climate imposes a mandate on us--a compelling pressure to deal with the problem of too many people and not enough food as soon as possible and as effectively as possible.
>
> The Climate Mandate,
> Roberts and Lansford (1979)

The world food problem is intertwined with the food and economic problems of the United States because the United States is a major exporter of food, feed, and fiber. Exports of these products are a significant factor in the world food supply and in the U.S. balance of payments.

This Committee was charged with studying how to make better information about weather and climate available to all agricultural and forestry interests to help them in their decision making. Determining what information is most important is not simple, because there are both weather-sensitive events and weather-information-sensitive activities. Farming is sensitive to certain weather events--hail, for instance--but it is only weather-information-sensitive if a forecast of a weather event--frost, for instance--allows farmers to take some action--say, prepare orchard heating equipment (see Chapter 6). The operations of all farms are weather-information-sensitive in varying degrees. It has been estimated by Thompson (1972) that, nationwide, weather-caused agricultural losses are about 3.6 billion dollars annually. These losses could be reduced by an unknown amount if appropriate weather information reached individual farmers in sufficient time for them to take appropriate action.

For uniformity, weather and climate are defined in this report as they were in earlier NRC (1975, 1976) reports. In general, "weather" refers to meteorological events occurring within a two-week period. "Climate" refers to events occurring over longer time spans--a month, a year, or longer.

The current century has seen unparalleled developments both in the capacity to produce food particularly in the United States, and in the ability to observe and understand the atmosphere. Yet, in 1976, authorities disagreed on whether there was enough food in the world to adequately feed everyone if it were properly distributed.

Few nations are major exporters of food, but all are consumers. The United States has moved from being one of many exporters to being the largest exporter of food. Food, feed, and fiber are recognized as major natural resources of the United States; and climate is the major factor causing variability in both the supply of and demand for these resources. Information gained from improved understanding and forecasts of the weather and climate, if made readily available to the user in a form that he can understand, can provide the basis for better planning to cope with climatic events.

CHAPTER 2

REVIEW OF SELECTED PREVIOUS WORK AND SURVEYS

Several surveys in recent years have included an evaluation of the use of weather information.

Rench and Makosky (1978) summarized the results of a survey made in Arkansas on the utility of agricultural weather services in the mid-South. The following points have been taken from their summary:

1. Different farm enterprises are affected by weather in widely different ways.

2. The importance of weather varies widely with the season.

3. A high percentage of farm users of weather information favor early morning (5:00 A.M. to 8:30 A.M.) broadcast times. Second choice was the 11:00 A.M. to 1:30 P.M. time period.

4. Farmers and agribusinessmen stated that 51 percent of their weather information came from television, 40 percent from radio, and 5 percent from newspapers.

5. A high percentage of farmers made their own weather observations. About 70 percent of those interviewed knew there were special weather information services available to them.

Getz (1978) reported on three surveys conducted in 1972 and 1973 in which the availability and use of agricultural weather information were examined in southern New Jersey. Farmers, representatives of the agricultural industry, and radio stations were surveyed. The surveys indicated that much information was gathered but that dissemination of the information was inadequate. Most of the individuals surveyed (including 80 percent of the farmers) were unaware of the many information services available to them. Selecting from the choices "very accurate," "average," "little accuracy," "no accuracy," about two thirds of those surveyed indicated that the accuracy of temperature, precipitation, and frost forecasts was "average."

Temperature forecasts were considered "very accurate" by 20 percent of the respondents, but only 5 percent felt rainfall forecasts were "very accurate." Radio was the primary source of weather information for these respondents.

Brown and Collins (1978) reported on a survey of large commercial family farms ($40,000 or more in sales) made as part of a Cooperative Extension Service program. Several questions related to weather information were asked of 1,639 randomly selected farms across the United States. In response to the question, "What kinds of information are of the greatest value to you in operating your farm and in planning for the future?", weather information was ranked first or second by 15 percent of the respondents. Only marketing and production technology rated higher. The most important sources of weather information were radio (41 percent) and television (37 percent). When asked about the preferred way of receiving weather information, 53 percent preferred television and radio, while 34 percent preferred newspapers and magazines. Only 7 percent preferred consultation with experts. Thirty-nine percent said that the Federal Government should pay for providing weather information, 32 percent said that state and local governments should pay for it, and 13 percent thought that other tax-supported institutions should provide it. Only 10 percent said farmers themselves should pay for weather information.

In 1977 a seminar was held in Canada which involved both farmers and weather forecasters. (Joint Report of a Seminar on Agricultural Weather Forecasting and Advisory Service, 1979. Sponsored by the Canadian Federation of Agriculture and the Agrometeorological Section of Agriculture Canada.) One of the principal objectives was to obtain a more exact understanding of farmers' weather forecast needs. The goal was to improve the content and dissemination of agricultural weather forecasts.

Several important points are made in the report on that seminar:

1. There is a need to approach improving farm weather service on both a national and regional basis (by enterprise).

2. There is need for an ongoing dialogue between farmers and meteorologists, primarily forecasters. This should include education of farmers on the understanding of technical terms.

3. There is need to identify farm-weather information service requirements by enterprise.

4. There is a question of responsibility for providing a total service of both weather forecasts and related advice to agriculture.

5. Farmers would like the 3-day forecast to be extended to the fourth, fifth, and beyond to the sixth and seventh day, with a reasonable degree of accuracy. They also desire advance warnings of violent weather changes.

6. The accuracy of forecasts is of utmost importance. Forecasters should give the probabilities or risks involved. In an unstable or uncertain situation the second most probable weather scenario should also be given. If the forecaster is uncertain about the forecast, it would be helpful if he would say so.

7. Farmers need more-localized forecasts.

8. Farmers need longer range seasonal forecasts.

9. A better system of dissemination of agricultural weather forecasts is needed.

Krawitz and Newhouse (1978) surveyed users of the Automation of Field Operations and Services (AFOS), an extensive modification of several primary data services now provided by NWS. (A more detailed account of these services is presented in a later chapter.) AFOS has little direct influence on agriculture since few users are found in agricultural areas. AFOS indirectly affects them, however, through television, radio, and universities, all of which are important sources of weather and related information for agriculture. Of the 921 questionnaires Krawitz and Newhouse sent out, 84 percent were returned. For various reasons, however, only 71 percent were used. Analysis of the results indicated that a significant fraction of the potential external user community (non-NWS) cannot or will not spend any additional resources to obtain NWS weather data. At best, they are very reluctant to incur additional expense. With relatively few exceptions, all of the data disseminated by the various NWS circuits are used by external users, and NWS must continue to make these data available. A new data dissemination system such as AFOS would be used by a significant portion of external users only if using it would not require user capital investments of more than $1,000 or increases in monthly lease costs of not more than $100.

In recent years interest in the effects of climatic variability has increased. McKay (1979) reported that:

> The farmers, like everyone else, requested more accurate forecasts; but a shrewd appraisal of their demands indicates that they can benefit enormously from timely and well-tailored climatic information.

It should also be recognized that the farmer often utilizes his own extensive climatic information, which is based on past personal experience. As McKay notes, he may often use this information unconsciously in making decisions:

> Interestingly at that time an evaluation of how a credible, reliable climatic forecast would have altered cereal production operations in Saskatchewan, 1974, was being examined by Glantz (unpublished). An early appraisal of the effects were--no change. Despite the unusually delayed spring, the wet fields, subsequent drought and early frosts, the basic agricultural strategies that were employed were correct, taking into account the market circumstances of the time. The benefits in that year would be difficult to prove! The successful strategies were based on climatic experience. As noted by one farmer, "Almost all production decisions are dependent on the farmer's knowledge of the climate." Education and communication would appear to be vitally important for further use of climatic information.

The Committee's workshop was closely related to a meeting sponsored by the Agricultural Research Institute in cooperation with the Board on Agriculture and Renewable Resources (BARR) and held at the University of Maryland on September 28 and 29, 1978. The report of that meeting on "Methods of Improving the Dissemination of Weather Information to Agricultural and Forest Producers" makes the following six recommendations:

> 1. That there be one compatible, unified system for delivery of weather information to agriculture and forestry; that it contain or have access to all needed information for agriculture and forestry; that it be readily accessible at low cost, and that it be cost effective.
>
> 2. That a method for the continuing evaluation of existing and prototype delivery systems be devised by the United States Department of Commerce and United States Department of Agriculture. The evaluation should be performed by a team consisting of representatives of the service agencies in USDA and USDC not directly responsible for the system, Cooperative State Extension Service, the State Agricultural Experiment Stations, and producers of food, feed, fiber, and forest products.

3. That current and future needs of farm and forest producers for weather information be carefully defined before the further specification or implementation of a system for delivery of weather information; however, research and development on both collection, retrieval, and dissemination systems must continue.

4. The delivery systems should include the capability to collect and retrieve weather information to provide for the preparation of special advisories, analysis and interpretation based upon operational models for crop growth, integrated pest management, water management, etc. Of necessity, this system must include observational data pertinent to agriculture and forestry and insure that this information is made available in a timely manner.

5. That an extension specialist in agricultural meteorology be established by the Cooperative State Extension Service in every state participating with and utilizing the weather delivery systems.

6. That special attention be given to dissemination of weather forecasts, information, warnings, and advisories in real or near real time. This information should be made available in visual, graphical, and other innovative formats and displays which are easily comprehended by the user and which utilize the best technology in both the private and public sectors.

CHAPTER 3

EVALUATION PROBLEMS FOR WEATHER-INFORMATION SYSTEMS FOR ON-FARM DECISION MAKING

From an economic standpoint, a weather forecast can only have value if the cost of using it is less than the amount of money it saves by reducing weather-related losses. A weather forecast, however, may have indirect effects which affect the producer's efficiency. Weather-related losses are often difficult to measure, and the total annual loss due to weather is a poor gauge of the potential value of better weather forecasts. Certain activities are sensitive to the weather itself, while other activities are sensitive to the information farmers receive about the weather. Losses of wheat due to hail in the Great Plains are substantial, i.e., the wheat crop is weather-sensitive. Yet if a 24-hour forecast of hail is made, what can a farmer do? He can work around the clock to harvest his crop if it is at the proper stage of development, or he may be in an area where an attempt is made to overseed the clouds to decrease hail. Overall, however, his operation is relatively insensitive to weather information. Yet the same knowledge may be weather-information-sensitive for the hail insurance adjuster. For instance, a freeze situation in a citrus orchard in Florida is a weather-information sensitive event, while the actions taken to protect the crop from the freeze are also weather-information sensitive for marketing.

It is, therefore, only in circumstances where feasible protective measures are available that weather data or forecasts are potentially valuable to the farmer. If frost is predicted, each orchardist must evaluate the forecast and utilize any other information available (such as site situation, labor and fuel costs, or value of crop), to decide what he should do. Establishing values is not simple. In most instances a National Weather Service warning only alerts the orchardist to potential damage; the decision on whether to activate heaters is the orchardist's. Many orchards have an alarm system that is triggered by near freezing temperatures, and only when the system is activated are protective actions implemented. Even then, the orchardist has to decide what protective measures to take. When he should activate heaters, and how many, depends upon the minimum temperature predicted and the expected duration of low temperatures. The reduction in loss attributable to the National Weather Service's forecast, the reduction attributable to the alarm system, and the reduction attributable to other management actions are not clearly distinguishable.

Another problem encountered in evaluating weather forecasts is that the evaluator may overemphasize successes while ignoring diseconomies. The difference between the cost of protection and the rewards of loss reduction must be adjusted by the cost of mistakes. Since forecasts are often imperfect, the actions taken will often leave the farmer either over- or under-protected. To the extent that this occurs, the actions taken are an additional cost of using weather data.

Most, if not all, of the approaches used to evaluate weather information are rooted in the cost/loss benefit tradeoff illustrated above. There are often a number of options open to the decision maker. In a freeze situation, for example, a tomato grower may force harvest, irrigate, hire helicopters to circulate air, plan a salvage operation, contract for tomatoes from other areas, buy replants before the freeze, or do nothing. It is also possible to conceive of dual options, the first chosen as a result of the forecast, the second in response to climatological information. In the case of citrus growers, for example, the activation of heaters is a realistic short-term option. Over the long haul, though, growers might decide to relocate their orchards to a warmer location, thereby diminishing the need for heaters.

Because the farmer has various options, the cost/loss framework is vulnerable on several points. It does not address the issue of risk, it assumes that the decision maker can rationally process probabilistic information, and it assumes that individual actions do not have an impact on the market.

RISK AND VALUE

The previous discussion assumed that the objective of the decision maker is to maximize profits or returns, or minimize losses. But it may well be that degree of risk is just as important, if not more so. Very little research has been undertaken to determine the amount of profit a decision maker is willing to trade off in order to reduce risk. It is clear that such a tradeoff will depend upon the nature of the enterprise and the existence of risk-spreading mechanisms, such as crop insurance. There is risk involved in using imperfect forecasts. The user must balance the cost of reducing risk against the possible reduced return. As the risk of using the forecast becomes higher--that is, as the possible loss due to a wrong forecast increases--the user must have a greater expected return. But the risk attached to non-meteorological decisions, such as decisions to use fertilizer or insecticides, may be even greater.

Practically all weather forecasts now include some probability values. The occurrence or nonoccurrence of an event, such as rain, and the amount of rain expected, can affect the user's decisions. A small amount of rain, for example, may not impair the effectiveness of a pesticide whose effect would be nullified by a very heavy rainfall. Both the probability of rain and its expected amount are what is needed. In the case of an orchardist, a forecast of freezing weather will set in motion preliminary frost-protection procedures, but the orchardist's final actions will depend upon the intensity of the freeze. The forecast should therefore be that which best fits the local situation.

VALUE TO WHOM?

It is possible that a more accurate weather-information service would benefit one sector of the economy at the expense of another. This is especially true with respect to agriculture, where large harvests leading to depressed farm prices have been a periodic problem.

If improved weather information increased the supply of potatoes, for example, farm revenue would decline because a 1-percent increase in the quantity of potatoes may induce a 2-percent drop in price. In the tomato market, however, only a slight reduction in price would be observed because a 1-percent increase in quantity induces only about a 0.2-percent drop in price. Thus, better weather information would mean a loss to the potato grower but not to the economy as a whole.

Improved weather information might also cut farm operating costs. If that occurred, farm profits might increase without any effect on the price of agricultural products. (See Greenberg 1977 for a more detailed explanation of these potential effects.)

PERCEPTION OF PROFIT AND LOSS

The decision to undertake protective action because of a forecast of adverse weather depends heavily upon the decision maker's perception of profit or loss. The loss sustained by any one farmer depends upon the actions taken by other farmers as well as the impact of the weather event upon prices. This is clearly illustrated by the frost warnings provided for citrus growers. Each grower must decide whether to procure labor and activate heaters or do nothing and accept the consequences. The results of any decision depend upon the reaction and condition of other citrus growers, and several outcomes are possible.

If the harm to most growers is great, the decision on protection made by the individual farmer will determine his loss. It is therefore the individual's perception of his plight relative to others and his actions that determine the payoff.

1. If the decision was to protect but the crop sustained great damage, the grower will incur a large loss (namely, the funds invested up to that point plus the funds expended for protection).

2. If the decision was to protect and the crop sustained only minor damage, a very large gain will be realized.

3. If the decision was not to protect and the crop sustained great damage, a loss smaller than that illustrated in 1 will be incurred.

4. If nothing was done and only minor damage ensued, only a small loss in potential revenue will occur.

The value of weather information will also depend heavily upon the cost of energy and the cost of meeting environmental standards. Prior to the onset of the so-called energy crisis, energy was relatively abundant and inexpensive. As a result, energy was used liberally while other, more expensive factors, such as labor, were used more sparingly. It is probably safe to say that cheap energy was substituted for information in much the way it was used in place of capital or labor. For example, it may have been cheaper to apply pesticides several times than to take the chance that a forecast of rain would prove to be inaccurate. Rapid growth in the price of energy will eventually force decision makers to reevaluate their use of weather information. It is highly likely that the above-mentioned concerns will induce a shift away from expensive energy toward the use of relatively inexpensive information. This trend can only be accentuated by growing environmental protection costs.

POTENTIAL AND ACTUAL VALUE

The value of weather information under the cost/loss approach can only be of potential value. If farmers indicate that they would not use new weather data, its actual value (at least temporarily) is zero. Seldom do the response to surveys and the results of independently conducted value studies point in the same direction. Most often, value studies of weather information claim substantial net benefits while users indicate that weather-information services are merely "helpful." This difference of opinion should not induce despair. Instead, it should be viewed as an opportunity to better understand users' needs. If a potentially valuable information service is ignored, it is important to determine why. It may be that the method used to evaluate the forecast has omitted an important cost or that potential users have not fully recognized their options.

WHY FARMERS USE OR DO NOT USE WEATHER INFORMATION

A commonly held assumption is that information provided to people will automatically be assimilated and incorporated into behavior. Nor would it be surprising to find this true with respect to weather information for farmers. The strong relationship between crop yields and weather underlines the importance of weather for farming. Furthermore, since farmers avidly seek any and all information about the weather and constantly talk about it, we might suppose that they routinely incorporate information on weather variations into their daily, weekly, or monthly decision making. The only problem would seem to be in determining how much new information is being used, since farmers may be using knowledge about the weather based on their own past experiences along with direct forecast information.

There is increasing skepticism, however, that more information by itself is effective in changing behavior. In the first place we have very little evidence that this is so, since information campaigns rarely include follow-up studies to assess their effectiveness in changing behavior. Although it may make sense to assume a relationship between increased information and behavioral changes, we have too little information to confirm or reject this assumption. Furthermore, in the few instances where information campaigns have been evaluated--such as those discussed later relative to the Committee survey--the results have been discouraging. Why this may be so in the case of providing weather information for farmers needs to be considered in terms of five possible types of reasons. These are: (1) the issue of weather-sensitive versus weather-information-sensitive which has already been discussed, (2) the scale on which the information is gathered and used, (3) the methods of communicating the information, (4) the nature of human decision making, and (5) the constraints that affect the final decision to act on specific types of weather information.

A fundamental problem associated with the use of much weather information is its broad scope. Weather data are gathered and analyzed at the national level, but farmers use it at the local level. Generalized weather analysis masks tremendous variations within smaller regions that may be crucial for agricultural decision making. These may be variations in such physical factors as altitude, slope, exposure, or type of soil, or to special factors dependent on type of operation. Farming operations that are weather-information-sensitive require very timely inputs of weather information. Weather events are critical for specific crops at specific locations and at vulnerable points in the crop or livestock cycle. Both farmers and forecasters must be aware of these relations. Generalized weather reports based on national-level data are not designed to provide the necessary precise information. To be maximally effective, in other words, weather information should be tailored to the needs of the individual user.

The effect of the manner of communication of weather information on its use by farmers has rarely been measured directly, but it is clear that effectiveness requires close attention to all phases of the communication process. It is not sufficient simply to print or broadcast information and expect it to reach users. There must be an initial assessment of potential user groups and of ways to reach them. This may mean placing the information in formats suitable for different groups. We know very little, for example, about whether the use of probabilities in weather forecasting is effective, yet such knowledge would seem to be basic to determining whether that type of information is or will be properly used. Determining the most effective medium for the presentation of different types of information is also an important consideration. Excellent visual presentation of satellite data may overcome to some degree the entertainment approach to weather presentation, the need for timeliness may best be fulfilled by broadcasting updates of weather information to farmers with radios in their tractors, and in-depth analyses and discussions are probably best suited to a printed format. Or the question may not be which individual medium to use but how to reinforce weather messages with the most effective combination of media. Another question in communication of information is the credibility of the source. Does television presentation of the weather forecast as entertainment lessen its credibility? Would occasional explanations of the reasons for forecast failures raise the level of credibility? Failure to consider communication questions like these can lessen the likelihood that weather information will make a difference by altering farmers' actions.

The nature of human decision making also helps to explain why farmers might not use better weather information. It is clear that people do not have perfect information, and it seems apparent that they are often more likely to engage in some form of satisfying activity than in optimizing economic gain. There appear to be definite limits to human capabilities of understanding risk and uncertainty, the situation which frequently prevails in agriculture. It is the rare, extreme events that provide the greatest opportunity or risk, but in such circumstances people tend to try to make complex information more understandable by simplifying it. People also tend to overestimate their knowledge and to underestimate risks. Furthermore, people tend to become more resistant to change as habits are established. Their habitual opinions may therefore distort their interpretation of new evidence. All of these factors may prevent prompt use of new information.

Finally, it is evident that weather information is only one input into the decision making of farmers. Like other people, farmers are beset by many factors and faced with a whole series of constraints such as those arising from external technological or management decisions, income, stage of life, knowledge, or previous decisions. Weather may be of little importance in making a final decision. One could argue that economic or marketing conditions are often more important factors than weather, and in fact in many cases they are. For a midwestern farmer the status of the Brazilian soybean crop may be a more salient point of reference for planting decisions than current moisture conditions.

ADOPTION TIME, DISCOUNTING, AND VALUE

If there were a discrepancy between the potential and actual value of improved weather information, it is possible that a considerable amount of time would pass before potential users could be persuaded to avail themselves of it. Since program and equipment costs would be incurred right away while benefits might accrue slowly, the benefits may have to be significantly positive to ensure lasting success. This is because of discounting. The value of the benefit stream will depend upon (1) the magnitude of benefits per potential user, and (2) the time at which the service is actually used. It is too early to speculate about the rate of diffusion; the question, however, deserves careful thought.

CHAPTER 4

CURRENT DISSEMINATION SYSTEMS

BACKGROUND

The weather and climate information currently used by farmers and other agricultural decision makers can be divided into four general types: (1) weather forecasts, (2) current weather descriptions, (3) climatological analysis, and (4) agricultural advisories. Farmers can receive weather and climate information passively through radio, television, automatic phone-answering services, and newspapers and other publications, or they can actively seek answers to specific questions by telephoning weather services or gaining access to computerized weather information. The types and quantities of information available and the efficiency of its dissemination are highly variable across the United States. Mini-surveys conducted by the Committee show that explicitly prepared weather and climate information is also highly variable and disappointingly little used.

NOAA is essentially an observer of meteorological events and a producer and disseminator of weather forecasts and climatological information. NOAA's basic efforts have been to improve large-scale weather forecasts and severe local-storm warnings, to make them available to the public through the media (including its own NOAA Weather Radio), and to publish climatological data. Notwithstanding cooperative forest-fire weather and air pollution advisories, the efforts of individual meteorologists at NWS field stations, and the establishment of a few NWS agricultural weather service centers, NOAA has expended little effort to apply its weather forecasts and climatological information. Such application is left primarily to private meteorologists and the cooperative USDA-state extension services. Except where state-funded climatologist programs have replaced the federally funded climatologist programs terminated by NOAA in 1973, USDA-state efforts to determine what weather and climate information is useful to farmers and to actually provide it have generally been minimal.

Although some radio and television stations provide excellent weather information, the information needs of most farmers have not been met by the news media. And since private meteorological consulting is available only to paying customers, it is doubtful whether the needs of any but the largest farms will be met in that way. A recent program in Miami County, Indiana, illustrates some of the problems. In 1978 and 1979 the county provided a special agriculture weather-service program through a computer terminal in the county agent's office. But six "representative" farmers from the county said they used the service only occasionally, partly because it required making a toll telephone call. Evidence like this underscores the need to educate both the users and the producers of agricultural weather information.

Less than 15 percent of the farmers surveyed by the Committee used NOAA Weather Radio. This NOAA service is new, however, and the broadcast network was not scheduled for completion until late 1979. Even when the network is finished, however, there will be some areas outside its range. The usefulness of this NOAA effort to supply reliable, continuous weather forecasts remains to be evaluated and compared with improved public media weather forecasts. Furthermore, the establishment of the NOAA Center for Environmental Assessment Services (CEAS), the reporting of current weather and climate conditions throughout the world in the National Weekly Weather and Crop Bulletin, and the establishment of the NASA-USDA-NOAA Large Area Crop Inventory Experiment (LACIE) and its successor, the Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing (AGRISTARS), were prompted by the need of the Federal Government to assess world food supplies. These programs were not designed to increase efficiency in agricultural production or marketing but to help stabilize the market and help producers make marketing decisions by providing estimates of export demand.

The weather and climate information available to most farmers is basically the same as that available to all private citizens of the United States. Generally, only people who use aviation weather services receive different information. The forecasts disseminated by the news media are prepared by NWS for a broad audience. The user has no control over specific content or availability; the forecast or other information is provided as a public service at scheduled times on radio and television and in the printed media. The media receive the information via press wire news services, the NOAA Weather Wire Service, direct telephone links, and, in some cases, by private links to NWS satellite or radar data. The media are permitted to edit and schedule the forecasts as they deem appropriate. Some commercial television stations employ professional meteorologists who present weather shows incorporating graphic weather information, surface weather charts, satellite cloud maps, radar rainfall and cloud echoes, prognostic charts, jet stream locations, and more. Just about all of this basic information originates at NWS, although the radar information may come from private sources. All of the information, of course, is valuable for agriculturists. The NWS weather forecast, providing precipitation probabilities and maximum and minimum temperatures for "today, tonight, and tomorrow," generally is relayed faithfully by the public media. A sample public forecast for the Indiana zones is given in Figure 4.1.

Special agricultural forecasts, warnings, and advisories are prepared by NWS for immediate dissemination by the news media, and media located in agricultural areas broadcast or print this information, with broadcasts usually being sponsored by businesses related to agriculture. Specialized agricultural forecasts and weather information are usually broadcast early in the morning or at noon, partly because it is assumed that the farm audience is listening at those times. Normally, neither the media nor NWS directly measure the effectiveness of forecasts for agricultural users.

Longer-range (3- to 5-day and 6- to 10-day) weather forecasts also are made available occasionally by most public media. Where the NOAA Weather Radio service is available, listeners owning special receivers can obtain undistorted weather forecasts directly from a local transmitter. Newspapers publish forecasts and some current climatological information, and professional farm magazines and some federal-state cooperative extension information services distribute news releases and circulars containing a few special articles describing research on the use of weather information in farm management.

CURRENT ONE-WAY SYSTEMS

National Weather Service User Policy

In the past, NWS has transmitted much of its information through a series of teletype and facsimile services. A new system--Automation of Field Operations and Services (AFOS)--is now being installed to replace many of the current services.

Impacts that Proposed Changes Will Have on Users

The effects that AFOS will have on those who use the NWS services listed below have been summarized by Cressman (1979) as follows:

a. NOAA Weather Wire Service (NWWS)--None where the current service equals 75 wpm, otherwise, teletype will need to be changed to 75 wpm.

```
NNNN##
ZCZC INDZFPIN
FPUS5 KIND 140300 AMD
-INDZFPIN

UPDATED INDIANA ZONE FORECASTS
NATIONAL WEATHER SERVICE INDIANAPOLIS IN
10PM EST THU SEP 13 1979
...NOT TO BE USED AFTER 5AM EST FRI...


IN 06
IN 09
10PM EST THU SEP 13 1979

......FLASH FLOOD WATCH REMAINDER TONIGHT AND FRIDAY MORNING......

RAIN...LOCALLY HEAVY AT TIMES TONIGHT AND EARLY FRIDAY...MAY CAUSE FLASH
FLOODING.  RAIN TAPERING OFF AND ENDING FRIDAY.  LOWS TONIGHT IN THE UPPER
50S TO MID 60S.  HIGHS FRIDAY IN THE LOW TO MID 70S.  CLEARING AND COOLER
FRIDAY NIGHT.  LOWS IN THE UPPER 40S AND LOW 50S  SATURDAY...SUNNY WITH
HIGHS IN THE LOW 70S.  WINDS NORTHERLY 10 TO 20 MILES AN HOUR TONIGHT AND
FRIDAY.

PROBABILITY OF RAIN 100 PERCENT TONIGHT AND 50 PERCENT FRIDAY.
$$

IN 11
......FLASH FLOOD WATCH REMAINDER TONIGHT AND FRIDAY MORNING......

RAIN...LOCALLY HEAVY TONIGHT ENDING FRIDAY MORNING.  HEAVY RAINS MAY CAUSE
FLASH FLOODING.  LOWS TONIGHT AROUND 60.  BECOMING PARTLY CLOUDY FRIDAY
AFTERNOON.  HIGH IN THE MID AND UPPER 70S.  FRIDAY NIGHT CLEARING AND
COOLER.  LOW IN THE UPPER 40S AND LOW 50S.  SATURDAY MOSTLY SUNNY AND COOL
WITH HIGHS IN THE LOW AND MID 70S.

NORTHERLY WINDS 10 TO 20 MILES AND HOUR TONIGHT AND FRIDAY.

PROBABILITY OF RAIN 90 PERCENT TONIGHT DECREASING TO 30 PERCENT FRIDAY.
$$
IN 11 250

IN 08
IN 10
10PM EST THU SEP 13 1979

......FLASH FLOOD WATCH THE REMAINDER OF TONIGHT AND FRIDAY MORNING.....

RAIN LOCALLY HEAVY AT TIMES TONIGHT ENDING FRIDAY MORNING.  HEAVY RAINS
MAY CAUSE FLASH FLOODING.  LOWS TONIGHT AROUND 60.  BECOMING PARTLY SUNNY
FRIDAY AFTERNOON.  HIGHS IN THE MID 70S.  CLEARING AND COOLER FRIDAY NIGHT.
LOW IN THE UPPER 40S AND LOW 50S.  SATURDAY MOSTLY SUNNY AND COOL WITH HIGHS
IN THE LOW AND MID 70S.
```

FIGURE 4.1 Public forecast for the Indiana zones.

b. Long-line teletypewriter meteorological network Services A, C, and O. May have to pay charges for a longer line to access at a more distant primary drop in order to receive the same set of observations. These services are expected to be phased out at all NWS sites in early 1981. Services A, C, and O are controlled and operated by FAA.

c. National Facsimile Network (NAFAX)--will be discontinued in January 1983 and later reevaluated.

d. National and Aviation Meteorological Facsimile Network (NAMFAX)--will be discontinued by January 1980.

e. Forecast Office Facsimile Network (FOFAX)--will be discontinued in January 1980.

f. Digital Facsimile Network (DIFAX)--depends on current combinations of services. (Equipment costs will be significantly higher than NAMFAX, FOFAX, or NAFAX alone, significantly higher for a satellite picture option, and there may be added charges for a longer line to a more distant primary drop. DIFAX is a new facsimile service initiated in 1979.)

g. Radar Reporting and Warning Coordination Teletypewriter System (RAWARC)--Terminal equipment and extension drops will be phased out at each NWS site as AFOS becomes operational, and each circuit will be dropped when all NWS sites on the circuit are operational with AFOS.

News media contemplating using the AFOS system should take into account certain considerations, summarized by Cressman as follows:

> Interfacing with AFOS will be cost effective to some users of weather information. It is most likely to be cost effective for users who (a) now have a large number of services (circuits), (b) now expend significant manual or processing resources to use current services, or (c) plan to expand their own operations and services.

Users of current NWS services who provide weather information to the agricultural community include radio and television stations with and without special meteorological services, agribusinesses that offer special services to their customers, private meteorological consulting firms, state and local government agencies, and universities with meteorological and agricultural curricula. The services used by individual agriculturists vary widely. How changes in these services, particularly in cost, will affect their use has not been determined. Current plans include giving a limited number of groups free access to the AFOS. These will then supply information, at a cost not yet determined, to all other users. Many of these outside users are concerned that increased costs could preclude their obtaining maps and the other special data now transmitted by facsimile and teletype at nominal cost. A recent joint UCAR/AMS committee report (1979) states, "Costs to the user of real-time data may greatly exceed present day costs, increased costs that cannot be easily borne by the universities." The present interpretive information provided by NWS over the state weather wire, however, will not be affected by AFOS.

Services of Particular Importance to Agriculture

NOAA Weather Wire Service

This service disseminates large amounts of information, such as current weather conditions, maximum and minimum temperature, and precipitation for major cities in the United States, forecasts of sky conditions and temperature, the national weather summary, major map features, national and local forecasts, foreign temperatures and current weather for 1200 Greenwich Mean Time, precipitation reports for selected stations, soil temperature data, radar summaries, and special-event information. The agricultural weather forecast is usually distributed three days per week. The NOAA Weather Wire is an important source of information for the news media and is rarely received directly by farmers.

The fees charged by the telephone company for use of the long-distance line that transmits the Weather Wire are paid by NOAA. Newspapers, and radio and television stations, pay only a fee for local connections and line charges for the teletype machine (typically, $10 to 20 per month for the connection plus $115 per month for the teletype). Even so, many small radio stations cannot afford the NOAA Weather Wire. (In Iowa, for example, about one-third of the stations fall into this category.) This means that many small, local radio stations whose audience includes a significant number of farmers do not have access to the Weather Wire. Their only weather information is supplied by news service wires. If individuals or agricultural organizations subscribed to the Weather Wire, they would be required to pay all line, connection, and teletype charges.

The current service policy of NWS (Cressman 1979) is to operate NOAA Weather Wire circuits at a standard speed of 75 words per minute and, subject to budget approval, make this service available in all 48 conterminous states.

NOAA Weather Radio

NOAA Weather Radio currently covers about a 40-mile radius from each transmitter. It operates on one of three high-band FM frequencies: 162.40, 162.475, or 162.55 MHz. The network now has 300 stations and will eventually include more than 350 stations (USDC 1979). As an example, in Iowa there will be 6 stations, with 2 out-of-state locations also serving parts of Iowa. NOAA Weather Radio will then cover about 70 of the state's 99 counties, or about 70 percent of its farms. Nationwide, about 90 percent of the population will be within listening range, but the percentage of farmers will be considerably smaller. The number of NOAA Weather Radio stations depends upon the amount of federal and state money available in each state. A designated amount of federal money was made available to each state for the stations, and the states have supplied differing amounts of additional funds. Hardware and installation costs per station are approximately $50,000. Operation and maintenance cost up to $10,000 per year.

The following information is broadcast by NOAA Weather Radio:

a. Radar summaries (every half hour),

b. Traveler's forecasts for a 36-hour period covering the area within 400 miles of major cities,

c. State weather conditions, general pattern,

d. General state forecasts,

e. Public zone-localized forecasts, and

f. Five-day forecasts.

NOAA Weather Radio is flexible in its coverage and could include agriculturally related information. In the areas served by the NWS Environmental Study Service Centers (ESSCs) and in some other areas, a one-minute agricultural forecast is generally included at certain periods of the day. NOAA Weather Radio may eventually be more helpful to individual agricultural users of weather information, since a January 1975 White House policy statement designated it as the Federal Government's way of providing private homes with direct warnings of both natural disasters and nuclear attacks.

Radios manufactured specifically for monitoring the three Weather Radio channels are now available at a cost of less than $100, and some AM-FM radios also include these channels. Most standard radios, however, are not capable of receiving the channels. Committee members questioned the selection of channels not available to most radio users.

Radar

Essentially 100 percent of the area east of the Rocky Mountains is covered by weather radar. Much of the Rockies and the Far West also are covered, but because of topographical variation the coverage is not complete. A long-range, 10-cm radar network provides most of the coverage, with additional local coverage provided by short-range, 3-cm radars.

The radar network routinely provides data from which an hourly summary of precipitation is prepared, which includes where the precipitation is falling, the type and intensity of precipitation, the area covered, the direction and speed of movement, and the trend of intensity. If precipitation is present over a large area, locations of heavy precipitation are emphasized. The hourly reports are disseminated over the NOAA Weather Wire and NOAA Weather Radio. During periods of severe weather radar information is available from both the long-range radar network and the short-range radars. Scope pictures can be shown at any time by commercial or cable television stations with suitable equipment.

Satellites

The Satellite Data Services Division (SDSD) of the Environmental Data and Information Service (EDIS) of the National Climatic Center is the U.S. repository for environmental data obtained by satellite. While primarily intended to provide data for meteorologists, the sensors also provide data of value to other user groups.

Potential users of satellite data may be divided into two categories: real time and retrospective. Real time users are concerned primarily with evaluating current meteorological conditions or forecasting near-term conditions. These are generally government organizations, consulting meteorologists, and radio and television stations. Agricultural users find televised satellite pictures helpful in decision making and operational management.

Retrospective users include a wide cross-section of the population, and satellite data are applied both to climatological and hydrological problems as well as directly to agricultural problems.

Two types of satellites, polar orbiting and geostationary, routinely produce the environmental data kept at SDSD. Polar orbiting satellites are in relatively low orbits (approximately 500 to 900 miles above the earth). The satellites circle the globe 12 to 14 times per day and obtain data along a path on the surface up to 1,550 miles in width. Data from these satellites are either transmitted in real time when the satellite is within reception distance of a ground receiving station or are stored on onboard tape recorders for later transmission. Sites on earth are viewed by this type of satellite twice daily.

Geostationary Operational Environmental Satellites (GOES) are "parked" in orbits about 22,000 miles above the earth. That is, their movement is such that they remain continuously above the same point on earth. The sensors on board acquire data and imagery of the complete earth disc (about one-fourth of the earth's surface) every 30 minutes, 24 hours per day. Ground resolution is 4 to 8 kilometers.

The United States now has five functional geostationary satellites in space--three active and two standby. Recently, geostationary satellites with sensors designed to gather information especially for oceanographers (SEASAT, NIMBUS 7) were launched. SEASAT, however, is nonfunctional.

NWS Agricultural Weather Service

The existing NWS Agricultural Weather Service program provides additional weather observation and forecast services, both for more-localized agricultural areas and for weather elements generally not observed or described in the public weather forecast. The forerunner of the NWS Agricultural Weather Service was the Fruit-Frost Forecast Service, which cooperated with citrus grower organizations in California (1915) and the State Agricultural Experiment Station in Florida. An experimental Advisory Agricultural Meteorologist (AAM) program was initiated by NWS in the Mississippi Delta in the early 1950s. Through political pressure, it was expanded into several other states. The AAM program was essentially a one-man, one agricultural area (or state) concept. In some states, such as Indiana, Michigan, and Kentucky, the AAM and the NOAA State Climatologist were both located at the land grant university and worked with federal and state agricultural researchers, teachers, and extension agents in encouraging wider use of weather forecasts and climatological information. NOAA economy moves led to termination of the state climatologist program in 1973 and the pooling of several AAMs from adjacent states into centrally located Environmental Study

Service Centers (ESSCs) intended to provide agricultural forecasting services for a larger area with greater efficiency. The first ESSC was established at Auburn, Alabama, in 1974; the second at Stoneville, Mississippi; the third at College Station, Texas; and the fourth at West Lafayette, Indiana (Purdue University), in 1977. The existing offices of the NWS Agricultural Weather Service program are shown in Figure 4.2. It should be noted that even in the Agricultural Weather Service area official responsibility for state weather forecasts rests with the Weather Service State Forecasting Offices (WSFO). A sample forecast from the Illinois WSFO in Chicago is shown in Figure 4.3. Each ESSC adapts and interprets official WSFO forecasts in its advisories, samples of which are shown in Figures 4.4 and 4.5.

The functions of the ESSC at Purdue University listed below are representative of those at the other ESSC locations:

- Arrange for and coordinate the issuance of agricultural weather forecasts by forecast centers in the six-state area (Illinois, Indiana, Kentucky, Ohio, Michigan and southeastern Missouri).

- Provide advisories on how the weather may affect agriculture.

- Establish, manage, collect and process information from a 20- to 30-station-per-state agricultural weather network.

- Provide or arrange to provide multiple releases of agricultural weather information.

- Cooperate with state, federal, and local levels of the extension service.

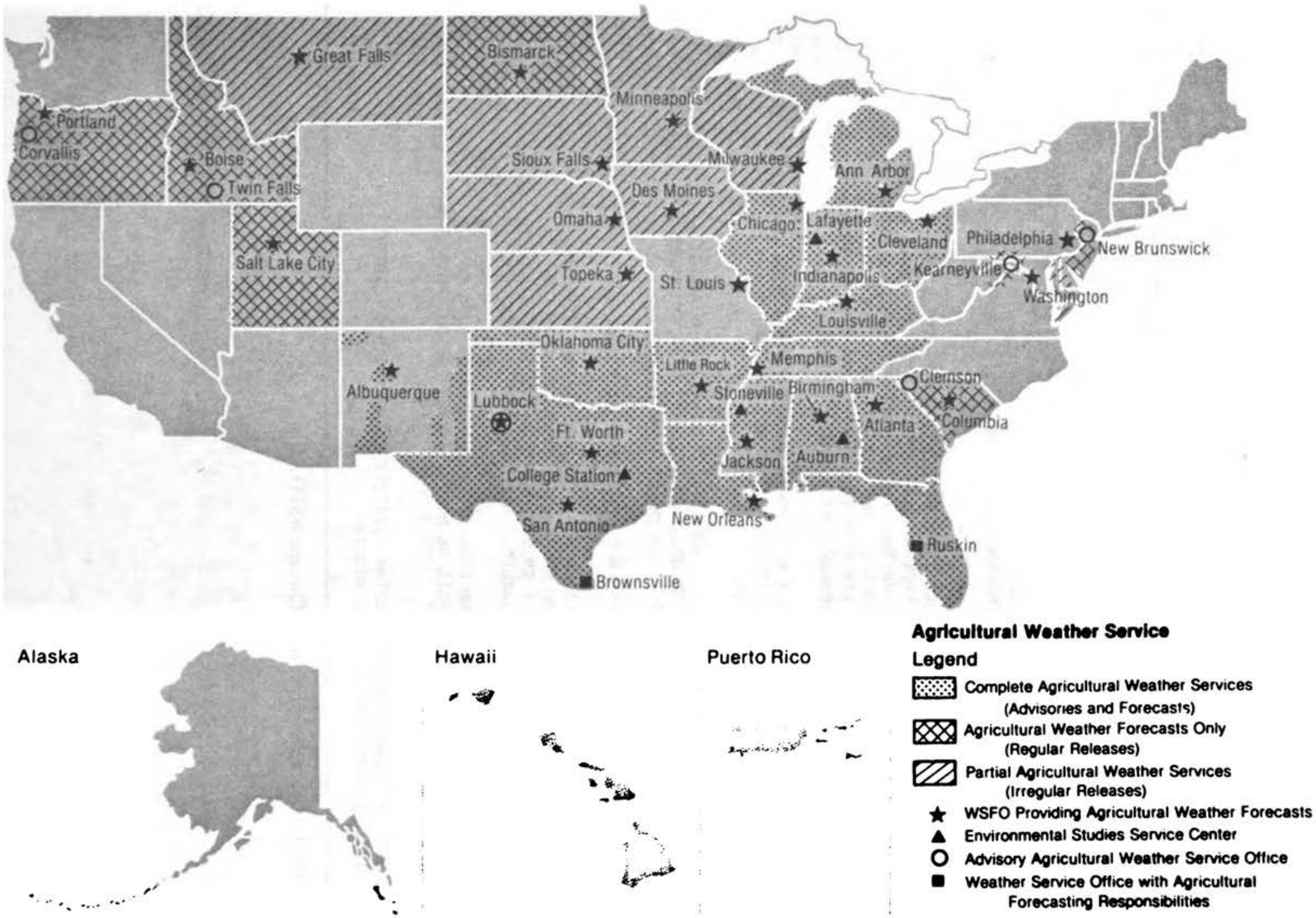
- Make public the results of research on agricultural weather.

The ESSC-Purdue Agriculture Weather Center provides the following services:

- Agricultural advisories twice daily (Monday through Saturday) to Indiana, Illinois, Ohio, and Kentucky, and once daily to Michigan and southeastern Missouri.

- Serves as backup for late-morning advisories to the Michigan State University agricultural meteorologist.

- Disseminates advisories and observations to state weather wire circuits, NOAA Weather Radio, and news wire services through relays to forecast centers.



SOURCE: Weather Operations Manual, NWS, 1978.

FIGURE 4.2 Existing NWS Agricultural Weather Service Program offices.

```
NNNN##

ZCZC
FXUS8 KCHI  142300

ILLINOIS AGRICULTURAL FORECAST
NATIONAL WEATHER SERVICE CHICAGO IL
6PM CDT THU SEP 14 1978

SYNOPSIS...THE WEATHER FRONT WHICH WAS OVER THE PLAINS STATES
YESTERDAY HAS ACCELERATED EASTWARD AND HAS BROUGHT AN
END TO THE GENERAL SHOWER AND THUNDERSTORM ACTIVITY WHICH COVERED
THE STATE.  THE FRONT IS FOLLOWED BY FAIR AND DRIER WEATHER
AND THESE FAIR CONDITIONS ARE EXPECTED TO LAST THE REST OF THIS
WEEK...THE WEEKEND AND PROBABLY INTO EARLY NEXT WEEK.

WINDS...WINDS WILL BE FROM A WEST TO NORTHWEST DIRECTION
THROUGH SATURDAY WITH 5 TO 10 MPH SPEEDS AT NIGHT AND
10 TO 15 MPH DURING THE DAYS.

PRECIPITATION...THE GENERAL SHOWER AND THUNDERSTORM ACTIVITY
WHICH COVERED THE STATE LAST NIGHT AND THIS MORNING HAS ENDED.
NO FURTHER PRECIPITATION IS EXPECTED THROUGH SATURDAY.

SUNSHINE...80 TO 100 PERCENT BOTH FRIDAY AND SATURDAY.

RELATIVE HUMIDITY...MUCH DRIER AIR OVER THE STATE.  HIGHEST
HUMIDITIES BOTH TONIGHT AND FRIDAY NIGHT WILL BE 70 TO 80
PERCENT BUT SOME DEW LIKELY IN THE MORNINGS.  LOWEST
READINGS BOTH FRIDAY AND SATURDAY WILL BE 30 TO 40 PERCENT.

TEMPERATURE...WARM DAYS AND COOL NIGHTS WITH DAILY LOWS MOSTLY
IN THE 50S.  DAILY HIGHS WILL BE MOSTLY IN THE 70S BUT WITH SOME
80S SOUTH.

OUTLOOK SUNDAY THROUGH TUESDAY...LITTLE CHANGE WITH CONTINUED
DRY AND WARM DAYS AND COOL NIGHTS.
```

FIGURE 4.3 Sample format from Chicago WSFO.

```
ZCZC INDAORLAF
ABUS50 KLAF 131615
-INDAORLAF
AGRICULTURAL ADVISORY FOR INDIANA
NATIONAL WEATHER SERVICE ESSC
AGRICULTURAL WEATHER CENTER WEST LAFAYETTE INDIANA
1115 AM EST THU SEP 13 1979

ABUNDANT MOISTURE AND SHOWERS ARE PROGRESSING NORTHWARD FROM THE GULF STORM
SYSTEM AND SHOWERS ARE ALREADY UNDERWAY AS FAR NORTH AS KENTUCKY.  A COLD
FRONT HAS ALSO ENTERED THE NORTHWEST PORTION OF INDIANA AND APPEARS TO BE
CONVERGING WITH THE SOUTHERN STORM SYSTEM AS A PRECIPITATION PRODUCER.
WETTING WILL BE UNDERWAY IN ALL THE STATE TODAY VARYING FROM JUST SCATTERED
SHOWERS NORTH TO AN ALL RAIN SITUATION SOUTH.  THUNDERSTORMS WILL ACCOMPANY
THE ACTIVITY STATE WIDE AND MOST NUMEROUS IN SOUTH.  PRECIPITATION IS
EXPECTED TO END IN SOUTHWEST FRIDAY AND GRADUALLY IN REMAINDER OF STATE BY
FRIDAY EVENING.  A COOL AND DRIER PERIOD IS EXPECTED TO FOLLOW FOR WEEKEND.

FIELD OPERATIONS WILL BE DELAYED BY NEW WETTING FOR A COUPLE DAYS IN ALL
BUT NORTHERN AREAS OF THE STATE.  HARVEST OF SILAGE AND TOBACCO COULD
RECEIVE SOME EXTENDED DELAYS IN SOUTH THIRD OF STATE FROM TONIGHTS RAINFALL.
ELSEWHERE FIELD WORK WILL STAND A GOOD CHANCE TO RESUME ON WEEKEND.  DRY-
ING WILL BE SLOW ON FRIDAY AND ONLY SMALL IMPROVEMENT ON WEEKEND BECAUSE
OF SOME CLOUDS AND COOLNESS.

TOBACCO GROWERS IN SOUTHERN INDIANA MAY HAVE A FEW HOURS YET THIS AFTERNOON
TO MOVE TOBACCO DRYING IN FIELDS INTO BARNS.  WETTING WILL BE SUFFICIENT
HEAVILY BLEACH OUT ANY CUT TOBACCO STILL REMAINING IN FIELD.  BRISK NORTH-
EAST WINDS WILL TEND TO PRODUCE SOME WETTING INTO TOBACCO BARNS ON EAST AND
NORTHEAST EXPOSURES.  HIGH HUMIDITY CONDITIONS CAN ALSO BE EXPECTED FOR
NEXT 48 TO 72 HOURS AND RATHER POOR VENTILATING CONDITIONS FOR AT LEAST
FIRST PART OF WEEKEND.

FRUIT OPERATIONS IN SOUTHERN INDIANA CAN EXPECT SOME FRUIT DROP FROM TREES
WITH THE INCREASING WIND SITUATION FOR TONIGHT.  THE NEXT GOOD SPRAY OPPOR-
TUNITY IS NOT LIKELY UNTIL LATTER HALF OF WEEKEND.

THE NEW INFLUX OF COOL AIR FRIDAY WILL LOWER NIGHTTIME MINIMUMS INTO 40S
BY EARLY SATURDAY IN NORTHERN HALF OF STATE.  AT THIS TIME NO FROST THREAT
IS INDICATED.

END/WLS


NNNNZZZZ
```

FIGURE 4.4 Sample of ESSC Agricultural Advisory Forecast for Indiana.

```
NNNN#AEVADVAWVAFVARVACV
ZCZC
ABUSS50 KJAN STNM6 151600

-JANAOAMS

MISSISSIPPI AGRICULTURAL WEATHER ADVISORY
NATIONAL WEATHER SERVICE STONEVILLE MS
1000 AM CDT FRI JUN 8 1979

FARM WEATHER THROUGH TUESDAY...THE MISSISSIPPI WEATHER PICTURE WILL REMAIN ABOUT
THE SAME THROUGH TUESDAY EXCEPT FOR A FEW ISOLATED AFTERNOON SHOWERS SUNDAY AND
WARMER OVERNIGHT TEMPERATURES ON THE WEEKEND.

NORTH MISSISSIPPI...ZONES 1 - 7...

NORTH MISSISSIPPI FARMERS WILL BE ABLE TO CULTIVATE CROPS AND PLANT REMAINING
BEANS THROUGH TUESDAY WITH LITTLE, IF ANY, INTERFERENCE FROM THE WEATHER.
CHANCES FOR RAIN LOOK A LITTLE BETTER NEXT WEEK, AND THIS WILL HELP RELIEVE
MOISTURE SHORTAGES STARTING TO SHOW UP IN SOME AREAS.

AERIAL APPLICATION  OF CHEMICALS WILL BE HAMPERED BY MODERATE EAST AND SOUTHEAST
WINDS THIS AFTERNOON.  BEST TIMES FOR SPRAYING WILL BE THIS EVENING AND SATURDAY
UNTIL ABOUT 8 AM.  SPRAYING FROM GROUNDRIGS WILL CONTINUE WITH FEW PROBLEMS
TODAY OR SATURDAY.

THE DEGREE DAY 50 ACCUMULATIONS FOR DELTA RICE GROWERS ARE TUNICA 1181
STONEVILLE 1312 AND ROLLING FORK 1377.  ABOUT 28 DD50S WILL ACCUMULATE EACH DAY
THROUGH THE WEEKEND.

NO SIGNIFICANT THREAT TO HAYING AND SMALL GRAIN HARVESTING IS FORESEEN THROUGH
TUESDAY.  OPERATIONS WILL BE STARTING BY MID MORNING OVER THE WEEKEND.  PASTURE
PRODUCTION WILL BE DECLINING THROUGH TUESDAY AS MOISTURE GIVES OUT.  SOME HOPE
FOR RELIEF IS IN SIGHT NEXT WEEK.

TUPELO AREA POULTRY GROWERS ARE ADVISED THAT MOSTLY EAST WINDS OF - TO 14 MILES
AN HOUR SHOULD PROVIDE SUFFICIENT VENTILATION TO KEEP FLOCKS COMFORTABLE AS HIGHS
REACH THE MID TO UPPER 80S.  WINDS WILL DECREASE TO NEAR CALM TONIGHT, AND LOWS
NEAR 60 ARE FORECAST.

SOUTH MISSISSIPPI...ZONES 8 - 13...

SOUTH MISSISSIPPI POULTRY GROWERS ARE ADVISED THAT MOSTLY EAST WINDS OF 7 TO 14
MILES AN HOUR SHOULD PROVIDE SUFFICIENT VENTILATION TO KEEP FLOCKS COMFORTABLE
AS HIGHS REACH THE MID TO UPPER 80S.  WINDS WILL DECREASE TO NEAR CALM TONIGHT,
AND LOWS NEAR 60 ARE FORECAST.

FARMERS WILL BE ABLE TO CULTIVATE CROPS AND PLANT REMAINING BEANS THROUGH TUESDAY
WITH LITTLE, IF ANY, INTERFERENCE FROM THE WEATHER.  CHANCES FOR RAIN CONTINUE
SLIM THROUGH NEXT WEEK.

AERIAL APPLICATION OF CHEMICALS WILL BE HAMPERED BY MODERATE EASTERLY WINDS THIS
AFTERNOON.  BEST TIMES FOR SPRAYING WILL BE THIS EVENING AND SATURDAY UNTIL
ABOUT 8 AM.  SPRAYING FROM GROUNDRIGS WILL CONTINUE WITH FEW PROBLEMS TODAY OR
SATURDAY.

NO SIGNIFICANT THREAT TO HAYING OR SMALL GRAIN HARVESTING IS FORESEEN THROUGH
TUESDAY.  OPERATIONS WILL BE STARTING BY MID MORNING OVER THE WEEKEND.  PASTURE
PRODUCTION WILL BE DECLINING THROUGH TUESDAY AS MOISTURE GIVES OUT.  LITTLE HOPE
FOR RELIEF IS IN SIGHT NEXT WEEK.
```

FIGURE 4.5 Sample of ESSC Agricultural Advisory Forecast for Mississippi.

- Disseminates advisories, observations, and some forecasts directly to computer systems at Michigan State University, Purdue University, Ohio State University, the University of Illinois, and the University of Kentucky.

- Provides automatic answering or code-a-phone devices for direct user calls to the Agricultural Weather Service offices in Michigan and Indiana.

- Provides live radio advisories each weekday for 55 locations in Ohio to the Agriculture Broadcast Network, for 41 locations in Illinois to the Brownsfield Farm Network, and for 8 locations in Missouri to the Delta Farm Network.

- Collects and stores regular and agricultural weather data for 25 locations in Indiana, 20 in Illinois, 21 in Kentucky, 14 in Michigan, 25 in Ohio, and 11 in Missouri.

- Maintains Purdue's computerized agricultural weather data base for crop and pest management users in Ohio, Illinois, Indiana, and Kentucky, and for the Fast Agricultural Communications Terminal System (FACTS) in Indiana.

- Automatically collects, processes, and stores hourly data from four Meteorological Information Computer Remote Operating System (MICROS) weather stations in Indiana.

- Prepares and relays via computer once-weekly weather summaries from the agricultural network data base to state climatologists or crop reporting services in Kentucky, Ohio, and Indiana.

- Provides agricultural weather coordination services to focal points at the forecast centers in each of the six states.

- Provides agricultural weather coordination to 5 to 10 designated extension specialists in each of the six states served.

- Provides weather briefing services via direct incoming calls to users in all six states.

- Participates in weekly weather briefings of 44 extension service offices on the Illinois TEL NET conference call system.

- Establishes, services, supplies, and documents agricultural observation station networks in the six-state area.

• Provides weekly or biweekly weather information about horticulture, entomology, and crop areas to newsletters in Ohio, Illinois, and Indiana.

• Maintains real time status reports via computer for growing-degree days, soil moisture, precipitation, evaporation, and soil temperature information for the six-state area.

• Provides direct agricultural weather information to newspapers, magazines, and farm publications (e.g., Illinois Farm Bureau Weekly, with a circulation of 100,000).

• Assists in the development, application, and dissemination of agricultural weather research for public use.

OTHER TYPES OF SYSTEMS

Several other systems for disseminating agricultural weather information are in operation or are being tested. The U.S. Forest Service established a Forestry Weather Interpretations System (FWIS) at the request of southern foresters. It is now undergoing a 2-year pilot test to determine whether a combination of observational and weather forecast data stored in a computer can be used in making various forestry management decisions. It is intended to meet the critical needs of foresters for localized and specialized weather information. The Consortium for Atmospheric Sciences Specialization (CASSL) is a special package developed as an expansion of the Forestry Weather Interpretations Systems to attempt to fit the national needs of all agriculture and forestry.

NOWCAST

NOWCAST is an experimental system for providing weather information to farmers in nearly real time. Developed by Colorado State University with support from NASA, NOWCAST is designed to use public service television stations to broadcast printed, graphic, and oral weather information. The information would be made available continually or almost continually and could be viewed on regular television channels. Since public service television stations in some states already broadcast nearly complete weather coverage, the cost of instituting NOWCAST should not be great. NOWCAST, however, requires specialized communication between NWS offices and public service television stations as well as careful scheduling to make it available frequently without interfering with other programs. NOWCAST offers good possibilities for showing graphic displays and has the advantage of not requiring the user to purchase specialized equipment. It places particular importance on the following:

- providing current and short-range weather information to the farm community,

- disseminating this information hourly over public television stations,

- tailoring weather information for the agricultural community, and

- providing to the public pertinent weather information usually available only to NWS meteorologists.

NOWCAST would combine satellite imagery of clouds, radar, weather maps and surface weather data, mini-computers, specially trained agricultural weather interpreters, and public television to produce hourly weather briefings for agriculturists.

The Satellite Freeze Forecast System

The Satellite Freeze Forecast System was developed by the University of Florida in conjunction with NWS and NASA. Using thermal data from GOES, the system offers a nearly real time thermal display on cold, clear nights approximately 30 minutes after satellite observations. Resolution is approximately 1° C. Each pixel represents an 8-km square surface area (64 km). Clouds which obscure the earth's surface do not cause operational problems because they preclude freezing temperatures. The thermal image is portrayed in false color so that ranges of temperature are shown. On the basis of current temperatures as well as current weather conditions, a computer model is used to generate a predicted thermal map on an hourly basis for the remainder of the night. The thermal image could be broadcast by commercial television stations, but doing so would require either specialized communication links to transmit the signal to the stations or the development of specialized microcomputer communication techniques to supply commercial television with a commercially compatible color signal.

Green Thumb

Green Thumb is a program to test the feasibility of a computerized system for disseminating weather, market, and other agricultural production and management information on a day-to-day basis. The test is to be conducted under an agreement among the Cooperative Extension Service of the University of Kentucky, USDA, and NWS.

A network of computers will form a path for data flow. NWS, NOAA, the Chicago Board of Trade, and other sources will feed data through subscription wire services to a computer in Kentucky. Kentucky's computer will sort the data according to county and provide each county with appropriate data over a dedicated telephone link. The counties' computers will periodically receive updates from the state's computer and will disseminate those data to farmers' homes upon demand. Farmers will use a "Green Thumb Box," or computer-based terminal, to interrogate the county's computer over telephone lines. Answers to their questions will be displayed on home television sets.

FONFACS

An Integrated Pest Management Program (called FONFACS in Iowa) is or soon will be available in a few states. This program is usually operated by the state extension service. Information is placed on a telephone system and can be obtained by dialing the FONFACS number. Local radio stations can record the FONFACS message for rebroadcast. The message is also recorded by many extension service offices at the county level. Individuals can obtain the information by dialing the FONFACS central location or the county extension office, or by listening to it on the radio. The message is updated at 9:00 A.M. each weekday. A typical message follows:

> This is FONFACS, a part of the Integrated Pest Management Program at Iowa State University. This information is valid Monday, May 21.
>
> Soil drying conditions will be good today and fair Tuesday. Evaporation will be nearly 1/3 inch of water today and 1/5 inch tomorrow. There is a chance of rain Tuesday night, ending Wednesday, mainly in eastern Iowa. Thursday and Friday will be mostly fair with seasonable temperatures. The outlook for Saturday through Wednesday of next week indicates seasonable temperatures. Rainfall may exceed the normal of 1/5 inch during the 5-day period. Average soil temperature at the 4-inch depth is 65° in central Iowa.
>
> The field work outlook is fair this week in eastern Iowa and mostly favorable in the rest of the state. At present soil temperature, corn emergence will require 10 days. Emergence of soybeans will require 2 weeks.

Alfalfa weevil is increasing in the south and northeast. Fields should be checked for weevil damage levels once per week. Treatment or harvesting will be required to prevent economic loss in some areas during the next 10 days.

The hay-drying outlook is fair this week. Corn stands are good to excellent in fields where corn has emerged. Dingy cutworm problems are being reported in some corn-following-soybeans fields. Weather conditions will encourage moderate development of this pest during the next 5 days. Black cutworm damage will begin to become a problem by next week.

Sutan application is of diminished effectiveness when temperatures are too cool. Temperatures will remain a little on the cool side for effectiveness this week.

If you need any technical advice or information, contact your local County Extension Director. This is Elwynn Taylor, Extension Climatologist. This information will be updated Tuesday at 9 A.M.

The message lasts 2 minutes, with approximately 45 seconds for weather and 1 minute for pest management information. The message form is flexible, and additional items can be included. As an example, either tables or a TI-59 computer program (cost $400.00) can be used to determine when to treat for green clover worms. Degree days for the next 5 days are needed in this calculation, and they could be supplied as part of the FONFACS message. The steps the individual farmer would take to develop the necessary inputs are given in Figure 4.6. The advantage of such systems is that they are directed toward a particular problem and enable farmers to make decisions according to their own particular circumstances.

Other Systems

Michigan State University receives weather information from communications networks utilized by the Federal Aviation Administration. This information, loaded into a computer file accessible through a dial-up terminal, is used primarily by farmers for the operation of integrated pest management programs. The computer file also includes special advisory information.

In some areas of the country, FM radio channels are used to transmit weather information during regular programs. In Georgia, FM radio is used to transmit information to the main agricultural area of the state (about one-third of the

1 - Count the worms.
2 - Look at the damage and status of the soybeans.
3 - Get the weather forecast.

1

Shake the larvae onto a plastic sheet from two feet of row in each of 5 locations in the field. Count the larvae.

More than 160 larvae in the 10 feet of row sampled	Treat
Less than 40	Don't treat
Between 40 and 160	Check weather & bean stage

How long are the worms: all sizes, mainly less than 1/2 inch, mainly bigger?

2

What is the stage of the plants? If they have developed to seven (7) nodes (V7 stage), they have reached the point where insect damage causes economic loss. Most sensitive stages are: V7 - 7 nodes with full leaves, some bloomed,
R2 - full bloom,
R4 - expanding pods.

3

Get the forecast for temperatures for the next 5 days (or get the 5-day expected "Degree Day 52" values from your county extension director or IPM office.

4

Determine which is the best bet: to treat or not to treat. Use the IPM programs green cloverworm-treat. Then to assess damage potential if left untreated, use green cloverworm damage program. Available for TI-59 calculators with printers or tables furnished from which it can be calculated.

FIGURE 4.6 Steps to take in determining when to treat for green cloverworms.

state) at a cost of $14 per message. Each county taking part has a receiving terminal, which costs approximately $2,000. FM radio offers a way to transmit messages at a cost considerably below that of a telephone network.

This is by no means a complete review of all the systems available. It is intended only to show the wide range of systems now in operation or being tested. Omission of a description of the Fruit-Frost Forecast Service does not mean the Committee felt it unimportant.

CHAPTER 5

SUMMARY OF MINI-SURVEYS MADE BY THE COMMITTEE

In April and May of 1979 the Committee interviewed 11 farmers in California, 33 in Indiana, and 32 in Iowa to learn about their use of, and need for, weather information. The questionnaire used, prepared by Committee member Thomas F. Saarinen, is shown in the Appendix.

Although the samples for each state were small, the consistency of the answers strongly suggests that the surveys represent the consensus of farmers' feelings toward weather information. Iowa and Indiana are major producers of corn and soybeans, and also produce similar animal products. Iowa has had no specialized agricultural weather service, but it has a long record of close cooperation between agricultural and weather-service organizations. Indiana has had a special advisory agricultural weather service since 1966. California has a completely different type of agriculture and, except for the Fruit-Frost Forecast Service, has no special agricultural weather service.

The scheduling of Committee meetings allowed only limited time to develop the questionnaire, and lack of both funds and time limited the size of the samples that could be taken. Interviews were conducted by Committee members and extension personnel. Those interviewed ranged from operators of small farms (120 acres) to managers of large operations (50,000 acres). Most of those interviewed had been in farming more than ten years, and several had farmed all their lives.

The questionnaire was designed so that categorical "yes" or "no" answers were generally required, and this must be remembered in reading the following material. One question, for example, was, "Will you save money in your operation if you know more about the weather?" The answer is "yes" or "no." But if the question "how?" had then been asked the respondents would often have found it difficult to answer in a single word.

Overall, there was little difference among the replies from farmers in the three states.

The responses to the question, "Do you currently get weather information on a regular basis?" were:

California		Indiana		Iowa	
Yes	11	Yes	32	Yes	31
No	0	No	1	No	1

The farmers' sources of information were similar for all three states. Radio and television were the principal sources and were used equally. "Own observations" was a distant third. Most respondents received information several times each day.

When asked if they were satisfied with the weather information they received, farmers from the three states gave more "yes" (51) than "no" (26) answers. The most frequently made suggestions for improvement were (a) greater accuracy, (b) more-localized forecasts, and (c) better long-range forecasting. A desire to receive many different special observations and forecasts was mentioned by several farmers.

The response to whether additional information was desired was not clear. "Yes" predominated, but only by 24 to 19.

Many types of additional information were mentioned as being needed, the predominant ones being soil temperatures in the spring, more accurate medium- to long-range forecasts, and humidity forecasts. The operations most affected by this weather information were planting, spraying, and haying, followed by general operations.

Questions relating to the usefulness of summaries of past weather events (climatology) were predominantly answered "yes" in all three states (48 "yes," 18 "no"), but farmers were often vague about how such information would be useful to them. Generally, they thought it would be useful in making plans for planting, timing their operations, making harvest decisions, and deciding when to conserve water. More climatological information might be useful if the users were educated about its value.

The response to questions about the accuracy of weather forecasts showed that farmers consider only short-term forecasts to be very reliable. The longer the forecast, the less reliable it was perceived to be.

		Very Reliable	Somewhat Reliable	Not Reliable
a. Short-term	(1-3 days)	32	42	2
b. Medium	(4-10 days)	6	54	16
c. Monthly	(30 day)	1	35	40
d. Seasonal	(> 30 day)	1	26	46

Answers to question nine, which asked respondents to rank weather forecasts for various periods of time on the assumption that the forecasts were totally reliable, may have been biased. Most of the respondents ranked the forecasts in the same order in which they were listed in the question. Several farmers, however, listed the seasonal forecast first because little flexibility remains after seed is purchased in winter for use during the following year.

Farmers in all three states were unanimous in thinking that there were times of the year when current weather forecasts would be likely to affect their farming decisions, but only 60 percent believed that past weather information would affect their decisions.

When asked about the flexibility of their operation, most farmers (59) perceived their operation as having some flexibility. Eleven perceived their operation as having great flexibility, while five (dairy farmers) felt their operation had none.

It is difficult to perceive any particular trend from the answers, other than that almost all farmers are interested in the weather and that it is one of several factors they use in making decisions. Many watch televised forecasts because they like to see what the weather looks like on the screen and then interpret it for themselves. When farm operations are in full swing during the day, however, radio is a more accessible source of weather information.

CHAPTER 6

FARMER PARTICIPANTS' RATINGS AND COMMENTS

RATINGS OF CURRENT SERVICES

Both the members of the Committee who are farmers and the farmers invited to the workshop used all the information they could obtain for making management decisions. Yet many were not aware of certain sources of available weather information. Each farm operator was asked to rate current weather services on a scale of 0 to 100. Their evaluations are presented below:

Rating	Farm Operator
80-90	Citrus producer, general manager, Florida
80	Cotton producer, Mississippi
80	Livestock, corn, sorghum producer, Missouri
80	Vegetable grower, packer and processor, California
80	Wheat producer, North Dakota
80	Wine grape grower, California
70-80	Corn and pork producer, Indiana
40-50	Fruit producer, Connecticut
30-40	Livestock operator, Texas

The differences probably reflect differences in the weather information services in their areas and the type of farm operation. All of the farmers expressed a desire for additional and timely weather information.

COMMENTS ON CURRENT AND NEEDED SERVICES

The farmers at the workshop received their weather information from the sources shown in Table 6.1. Commercial radio and television were the predominant sources, but NOAA Weather Radio was also a significant source. One participant used the NOAA Weather Wire, primarily for such specialized information as the Fruit-Frost Forecast. All of the farmers at the workshop said they watched commercial television channels that present graphic weather information, e.g., surface weather charts, satellite cloud maps, radar echoes, prognostic charts, and jet stream

TABLE 6.1 Source of Weather Information for Farmer Workshop Participants

Participant	Operation	Source of Information							Comments
		Radio	TV	Graphics *	NOAA Radio **	NOAA Weather Wire	Long Range	Private Meteorologist	
1	Soybeans Cotton	1	2	2	1		Newspaper	3	Would like dedicated Ag weather
2	Corn Soybeans	2	1	2			Newspaper	no	Wants seasonal trends
3	Hogs, Corn Soybeans	1	2	2				no	Livestock most important needs temp. change warnings
4	Wheat	1	2	2				no	
5	Livestock	1	2	2			Newspapers Magazines	yes	Not enough info needs good long range (yearly) forecast
6	Citrus		2	2	2	1		no	Gets long range forecast from trade assn. uses Fruit Frost Forecas
7	Grapes	2	2	2	1			no	
8	Lettuce Broccoli	1	2	2	2		Newspaper		
9	Apples	2	2						Not enough of accurate weather information

* Graphics used on TV includes surface maps, radar and satellite data and images.

** NOAA Weather Radio was not available to all members.

1 = Principal Source 2 = Secondary Source 3 = Some Use

locations. All indicated that radar echoes and satellite cloud maps were more useful than verbal or printed weather information. It was apparent that these farmer participants understand the precipitation probabilities used in NWS forecasts, and it was also clear that farmers valued graphic information and would use it more than other types if it were more available. In addition, they understand the local movement of weather systems to the extent that they can judge when weather events such as rainfall and low temperatures are imminent and when they are developing in such a pattern as not to present serious problems.

All the farmer participants indicated a desire for reliable long-range forecasts ranging from seasonal to annual, and they felt there were many advantages to dissemination of information by the news media or NOAA Weather Radio. Some, however, were not aware of NOAA Weather Radio or were outside the broadcast range. They saw the primary advantages of passive, or one-way, methods of dissemination as being their low cost and their ready availability through commercial media links. They felt that forecasts and advisories usually were reliable but that dissemination may be haphazard during certain periods of the year. The main disadvantages of passive methods were that farmers have no way to obtain additional information or evaluations of the accuracy and reliability of forecasts. Additionally, if a forecast is out of date, or is not broadcasted or received by the media, the farmer is without weather information tailored to his needs.

Active, or interactive, methods of disseminating weather information are new in concept, design, and implementation. Therefore the farmers had no direct experience with them, but they did express opinions about how the information should be made available and what specialized information should be supplied.

The following comments made by the farmer participants express their opinions about farmers' needs for weather information services and about methods for distributing that information:

- "Farmers need forecasts even if the chances of being right are low, because they must make daily decisions."

- "One of the basic reasons that we are interested in television is so that we can get access to satellite and radar data. What we really need are long-range forecasts for one year in advance or at least a season in advance. There is really a strong interest in seasonal forecasts."

- "It seems to us that private meteorologists do a better job of forecasting than the NWS even though they get their information from the NWS. Is this because the private meteorologists tailor their forecasts more closely to local needs?"

- "The reason that we need a long-range forecast is because we can not always anticipate what some of the secondary weather effects will be. Dry weather in north Missouri brought on a cutworm epidemic that wiped out acres and acres of corn. If we had known that it was likely to be dry, we would have been prepared with proper control measures and pesticides, we might have planted deeper or waited longer before planting since we had had wet weather."

- "Our main appeal is for more information. Farmers may need to define their needs in advance so that they can get a more specific response. Violent storms are always broadcast by the news media, but there is little attention given to rainfall, etc., which is of more importance to agriculture. We understand that the farther away an event is in time the less reliable predictions about it will be, but we still need the best information we can get to make decisions."

- "One of my observations is that weather information is not presented in a way in which farmers can use it."

- "A lot of weather information sources which are presented as raw data are not really usable or interpreted for the user."

- "As a farmer, I would rather have the basic weather information and do my own interpretation."

- "Even if a long-range forecast was only 51 percent accurate, I would use it to assist me in deciding when to buy cattle and plant crops."

- "Integrated pest management is highly weather-dependent. There is need for more accuracy, but it is difficult to estimate the value. It is not a black and white issue, and there are no definite answers."

- "Farmers need more agricultural weather reports. Farmers using the information for decision making would like to have it made available to them as a public service."

- "The 5-day forecasts for rain, frost, and high temperatures are important in viticulture. The low temperature forecast is the most important in California.

Agricultural weather advisories must be localized and tailored to local needs."

- "What we need in a rainfall forecast is an estimate of the amount of rain. The forecast of precipitation without an estimate of amount is not very useful. I have a need for weather information enroute to markets. I can not get this information unless I have the NOAA Weather Wire or a private consultant."

- "In considering the value of weather information, it is only fair to consider those losses due to weather which can be avoided and not the other losses."

- "In my business of hog raising, weather is very important. Rapid changes in temperature in the farrowing house cause losses. I have experienced rapid changes in temperature from 85 to 65°F and have not been alerted by the forecast. I do not know if it is a forecast problem or if it is a dissemination problem."

- "The forecasts for the [Texas] Panhandle are not very good. I call my friends upstream to find out about the weather. Wind and snow are one of my primary concerns because these conditions cause cattle to drift away from the area and they have to be recovered. I have experienced losses from cattle that have been frozen and also from cattle that have lost from 100 to 200 lbs as a result of the storms."

- "I have a need for local weather information and local forecasts that are of special importance. For example, soil temperature information is important in the harvest and production of maple syrup. I have missed the best sap run because I did not know the soil temperature and it was not in the forecast. Forecasts are also important to me in apple production. There are usually not any forecasts about inversions on cold nights, and I have been forced to use helicopters to prevent frost damage when, unfortunately, there was an inversion. In fact, I usually cannot get forecasts and have very poor access to them. There is usually not any forecast of wind, which is an important factor in estimating the presence of an inversion."

- "I don't know how adequate the present weather information is, but I would judge it to be about 80 percent. One thing I am sure of, I want and need more weather information. There are some problems with all horticultural crops. I plant 285 days of the year and harvest 285 days of the year; weather information and weather are very important in integrated pest management. I would agree that weather information, especially the forecasts, is about 80-percent adequate. Television has had a dramatic impact on this value."

- "We have taken 400 to 500 minimum-temperature readings and compiled them and kept them with the minimum-temperature forecasts over the years. There has not been any significant improvement or any really significant losses. If one is going to do flooding for frost protection, one needs at least 24 hours of lead time. There is a need to increase the reliability of the forecasts."

- "I believe the reason that we do not get the quality and kinds of forecasts which we need in agriculture is because agriculture is specialized like aviation and other special groups in which there are only small numbers of people served by the forecasts. What farmers should do is prevail upon private radio and television stations for better agricultural forecasts. We should make sure that we make better use of the mass media."

- "I do not really use the forecasts very much, but it is important in the way in which we harvest grain. I do not have the capability to receive weather information from NOAA Weather Radio."

- "Every morning I have a management briefing with people who work for me. This briefing depends upon weather information, and if there is any possibility of improving agricultural weather services, it will certainly assist me in the decisions that I make."

- "The best possibility for improving agricultural weather services seems to lie in close cooperation between the agricultural services (extension and research) and the NWS personnel. This effort should be made in close cooperation with the farm user, the NWS, the farm service representatives, the integrated pest management scouts and advisors, and the Cooperative Extension Service."

- "The best chance for improving the quality of the forecast may be for close liaison between the meteorologists, the growers, the people in the universities, and those involved in dissemination. Dissemination and access methods should be both convenient and inexpensive."

- "Radar displays and satellite information are the real reason that we have an interest in television. If television radar displays were available, it would be a hands-down choice as a method of obtaining weather information. NOAA Weather Radio, which is established by the NWS, serves some of our needs; but all the agricultural areas should be covered and should have an agricultural weather forecast. When I compare a passive system with an active system, I am pretty happy with the passive system."

- "It is important that you evaluate the Green Thumb Pilot Program. Since it is so important and has a different approach, I would recommend that the interactive Green Thumb approach be carefully evaluated for effectiveness as a mechanism for dissemination of weather information and that careful evaluation of the pilot project be undertaken and conducted by an independent group."

- "It should be possible for us to make better use of the present FM channels for NOAA Weather Radio and not require special frequencies."

- "The USDA and NOAA should jointly undertake the dissemination of weather information with local input and advice because at the local level there must also be participation in the preparation and dissemination of agricultural weather information."

* * * *

It is evident from these statements that farmers receive and use weather information and want additional information. Graphic portrayals (radar, satellite clouds, weather maps) were perceived as being particularly useful. Most of the farmer participants felt that the forecasts were good but could be improved. Some farmers have a strong need and desire for long-range forecasts. All felt that more weather information is needed.

Farmers obtain weather information from commercial television and radio stations, NOAA Weather Radio, and the NOAA Weather Wire, in that order. General forecasts and their adaptation by private meteorologists on commercial television staffs are apparently serving many of the needs of farmers, but the farmers felt they needed greater access to graphic information, including radar displays, satellite images, and weather charts. Some felt that interpretation of data for special needs and applications, such as integrated pest management, also was important.

Although there is much information available from NWS, not all of it is accessible. Most of the farmer participants felt they should try to prevail upon local radio and television stations to make information more available as a public service. The farmers also felt that NWS should continue to provide basic information and forecasts and that the USDA should ensure that they are disseminated to farmers.

Most farmer members of the Committee felt they should not have to pay for services directly, although if certain special services (e.g., imminent rainfall in large cattle feedlots prior to feeding, accurate snow warnings for stockmen) were available, the larger specialized farmers with good management skills would purchase these services. Several reasons were given for not charging farmers for agricultural weather information services, including the high cost of creating and maintaining a limited-access system, denial of access to some users, and uncertainty that a fee system would represent a significant improvement over the present system. Many felt that a charge for access to public information to permit better adaptation to weather conditions would constitute a double charge (tax plus fee) and that farmers had more legitimate needs for public weather information than other users with free access.

There was much discussion of NOAA Weather Radio, and several Committee members and workshop participants said they made good use of it. Some did not realize that it was an NWS product and felt that the voice and transmission quality were not very good. They wondered why regular FM frequencies were not used, since regular FM frequencies do not require special receivers and their fidelity if often good. There was also much interest in public television, since farmers in many states could receive better farm coverage from public television stations than they can from NOAA Weather Radio.

Most of the farmer participants expressed interest in the Green Thumb concept and in computer-assisted and computer-generated forecasts. Some of the farmers were more optimistic about the future usefulness of these technical innovations than the scientists and technicians on the Committee. Most farmers have seen vast improvements in farm management and operations from the use of computers and felt that there was an excellent potential for improvement in the general weather forecast, agricultural weather information, and dissemination of both. Although interactive systems like Green Thumb have certain advantages, some preferred the free access of the one-way systems like NOAA Weather Radio and commercial radio and television. The Committee's farmer members indicated a strong desire to monitor the development and evaluation of new technology applicable to the dissemination of weather information. One farmer participant who lives in a highly urbanized area and has poor access to agricultural weather information commented that the only prospect for improvement in weather services for agriculture in his area depended on better use of computer technology and improved dissemination.

CHAPTER 7

AVOIDABLE AGRICULTURAL LOSSES CAUSED BY WEATHER

There are many estimates of agricultural losses due to the weather, but avoidable losses are seldom distinguished from unavoidable ones. This chapter lists specific incidents in which farmers attending the workshop were directly involved or which occurred in their area and for which some action could have been--and sometimes was--taken. The general literature was not surveyed.

RAISIN CROP HURT BY UNEXPECTED RAINS

Heavy losses in the 1978 California raisin crop were caused by unexpected rainfall that occurred after the grapes were placed in trays on the ground for drying. Farm producers could have delayed picking or covered the trays if the rainfall had been predicted. As with most weather-induced losses, some producers lost 100 percent of their crop. Overall losses were approximately 50 percent, showing that individual farms are affected by weather in different ways.

The California raisin season is, at most, 6 weeks long. An accurate one-week forecast would have prevented much of the loss; part (perhaps, 20 percent) of the loss could have been prevented by a good three-day forecast; only a small part of the loss could have been prevented by better one-day forecasts.

"Residual" losses often do not include losses caused by the weather, even though weather is often an factor. The California Raisin Advisory Board had been working to develop both the domestic and export markets, but the crop loss in 1978 virtually brought exports to a halt and led to domestic price hikes that nullified domestic market-development efforts. Unemployment and lost revenue in the processing and transportation industries were also residual losses arising from the failure to predict the rains.

IRRIGATION PROTECTS GRAPES AGAINST FROST

In California, a frost protection irrigation system with a projected life of 20 to 30 years costs $1,000 to $1,500 per acre to install. Since the average value of a wine grape crop is between $1,500 and $2,000 per acre, an irrigation system used only once essentially pays for itself if it saves 50 percent of the crop from frost damage ($1,000 saving per acre). Most of the frosts that occur in the grape-growing area of California are radiation frosts during which a cloud cover originally predicted to persist suddenly disappears. This has happened twice in 5 years, but in both instances most of the crop was saved by irrigation.

LABOR COSTS LOST DUE TO WEATHER

Laborers in the Salinas Valley fields of California cost $5 per hour per person. If enough rain falls to drive them from the fields there is a direct loss to the grower. In some cases, work already accomplished must be done again. More often, work hours that must be paid for are lost because employees are at the job site but are unable to work.

SEED EMERGENCE

There was a report of a 60 to 70 percent reduction in the emergence of lima beans in California due to excessive rainfall. If the rainfall had been properly forecast planting could have been delayed until after the precipitation. Replanting is expensive, requiring additional expenditures for labor, seed, machine time, and fuel ($30 to 40 additional per acre).

WHEAT SPROUTS IN SWATH IN NORTH DAKOTA

To guard against shattering the heads on wheat and to allow for different maturity rates, wheat in the northern Great Plains is swathed (a process whereby the crop is mowed by a machine that also rakes the mowed plants into windrows). Several days of rainy weather can result in the wheat's sprouting in the swath, resulting in losses on the order of 20 percent. In contrast, losses from shattering amount to only about 5 percent. While different varieties of wheat respond in different ways, a good 3- to 5-day forecast allows growers to decide whether to swath the crop or let it stand.

WEATHER INFORMATION PREVENTS FLORIDA CITRUS LOSSES

In Florida every winter the weather information system for agriculture saves money for citrus fruit growers. After receiving frost warnings, orchardists start up wind machines and orchard heaters to avoid fruit losses. Some growers without frost protection equipment have suffered severe losses. One grower, for example, unable to respond to the forecast, picked 500 boxes of frost-damaged fruit per acre and received $1.50 per box. A nearby producer with frost protection equipment picked an equal number of boxes per acre and received $7.25 per box. Since protection costs $100 to $150 per acre per year and is used on an average of once per year, the savings to the grower who owned the proper equipment were about $2,700 per acre.

WEATHER WARNINGS TO STOCKMEN INADEQUATE

In Worth County, Missouri, on March 23, 1979, a livestock operator lost 19 calves and 6 cows because of a winter storm. There was no advance storm warning. The 19 calves were valued at $600 to $700 each. Most counties in northwest Missouri reported losses of 300 to 400 calves from this storm. On April 9, 1973, a similar, unforecast storm also resulted in high livestock losses.

Improperly forecast winter storms have also caused heavy livestock losses in the Texas Panhandle. Snowfall or wind alone do not cause heavy losses, but a light snow with high winds causes livestock to drift across the pastures. In 1977 a combination of snow and wind caused the loss of 156 light yearling cattle, which froze to death after drifting up against a fence in an unprotected area. With an adequate forecast the cattle would have been moved to a protected and penned area. One indication of the potential magnitude of this type of loss is that within a 50-mile radius of Dumas, Texas, there are between 80,000 and 100,000 cattle exposed to weather events on pasture land each year.

CONNECTICUT LACKING GOOD AGRICULTURAL WEATHER SERVICES

Fruit growers in Connecticut must depend almost entirely on the weather forecasts developed for the general public, and frost protection systems are minimal. In one case an orchard operator anticipating a freeze was able to avoid losses by hiring a helicopter whose rotating blades mixed warmer air above the orchard with cold air at the surface. Other growers in the area irrigate strawberries or flood cranberry bogs to avoid frost damage. Proper protective action requires advance warning.

WEATHER INFORMATION SERVES "KING COTTON" WELL

Precipitation is the critical meteorological element in the Mississippi Delta. If it rains heavily shortly after an insecticide is applied to cotton the insecticide is washed off and must be reapplied at a cost of $12 per acre. A rainfall of less than half an inch, however, will not wash off the insecticide. Good forecasts, which cotton producers in the Delta are now receiving, include the amount of precipitation. Such predictions also have considerable value in soybean production. When the topsoil is dry, soybeans are planted approximately 3 inches deep in moist soil. If a 2-inch rainfall follows, replanting becomes necessary at a cost of $20 per acre.

CURRENT BENEFIT OF AGRICULTURAL WEATHER INFORMATION IS CONSIDERABLE

Overall, comments from the producers who attended the workshop suggest that forecasts need to be more localized and should include rainfall amounts as well as probabilities. Current weather and forecast information are important. In areas where crop value per acre is high it appears that weather information systems have evolved which serve many producers fairly well. In areas where more general agriculture is practiced and where crop value per acre is lower, much more detailed weather information is needed than is now received.

CHAPTER 8

WEATHER INFORMATION NECESSARY FOR ON-FARM DECISION MAKING

In evaluating existing and future needs for an agricultural weather information program, the added value of such a program over the benefits gained from using regular public forecasts and climatic information has to be calculated. Both climatological networks and current forecasting services need to be considered.

CLIMATIC INFORMATION

A farmer's need for, and ability to use, explicit climatological information depends upon his experience and his management skills. Climatological information can replace expensive trial-and-error experience in making decisions on the following questions. Is the climate of the site appropriate? What crops should be grown? Should the farmer invest in irrigation equipment? Freeze protection? Grain drying equipment?

In short, if a farmer decides to introduce a new crop variety or management practice, explicit climatic information is essential. Abandoned orchards in freeze-prone areas, deserted farms in areas prone to drought, and failing hydroponic tomato businesses in locations that receive too little winter solar radiation bear witness that too much agricultural planning is done by trial and error rather than by using quantitative climatological information.

An experience described by a grape grower in California's Salinas Valley excellently illustrates the importance of thorough and complete climatological information. Recognizing a growing demand for Cabernet Sauvignon grapes, the grower knew from experience that summers in the Salinas Valley were cooler than in areas where this variety of grape is normally grown. He therefore obtained from the University of California at Davis the number of accumulated growing-degree days (GDD), sometimes called growing-degree units, required to bring Cabernet Sauvignon grapes to maturity. The experimental work to determine the GDD had been carried out in the Napa Valley.

Using information obtained from nearby climatological stations, the grower then calculated the accumulated GDD for a number of years and concluded that a particular area of the Salinas Valley was climatically suited for Cabernet Sauvignon.

Armed with this information, he obtained a bank loan and planted 1,000 acres of grapes. After a few years, however, he found that the grapes did not mature or produce quality fruit. The grapes had to be regrafted or replanted with another variety. On searching for the reason the climatological planning failed, the grower found that GDD had been estimated for both Napa Valley and Salinas Valley on the basis of maximum and minimum temperatures, i.e., GDD = (max + min)/2-50°F. This was satisfactory for the Napa area, whose normal diurnal temperature pattern shows about the same number of hours above the mean temperature as below it. In the Salinas Valley, however, the temperature rises rapidly until about noon, when the sea breeze sets in and keeps afternoon temperatures much lower than the noon maximum. As a result of this quirk in Salinas Valley temperatures, the grower had overestimated the mean temperature and the derived GDD totals.

Even with the usual diurnal temperature pattern, of course, the same mistake could have been made if information from an unrepresentative weather station had been used in making the planning decision. By far the more common practice, however, is for farmers to make plans with no use of explicit climatological information. The outcome of such plans thus depends upon the farmers' subjective and limited experience.

The format for presenting climatological information is highly variable. The climatological summary for Salinas is shown in Figure 8.1. The general information that this summary gives to a farmer moving from one area to another should serve as a red flag to indicate the need for more specific agricultural climatic information.

Climatological data may be analyzed to provide answers to specific questions. Figure 8.2 shows the average number of growing-degree units between the average spring planting date and the average frost date in the fall. It also provides information useful in selecting the proper maturity class of corn hybrids. These two examples are from a passive climatological system. A system is needed to provide, on request, a catalog of pertinent climatic analyses for the crop and the area of interest. The present climatological network is assumed to provide the minimum essential data.

LATITUDE 36° 40'N
LONGITUDE 121° 36'W
ELEV. (GROUND) 85 feet

U. S. DEPARTMENT OF COMMERCE, NATIONAL WEATHER SERVICE
IN COOPERATION WITH SALINAS CHAMBER OF COMMERCE
CLIMATOGRAPHY OF THE UNITED STATES NO. 20-04

CLIMATOLOGICAL SUMMARY

STATION Salinas, California

MEANS AND EXTREMES FOR PERIOD 1941-1970

Month	Temperature (°F) Means: Daily maximum	Means: Daily minimum	Means: Monthly	Extremes: Record highest	Extremes: Year	Extremes: Record lowest	Extremes: Year	Mean degree days **	Precipitation Totals (Inches): Mean	Greatest daily	Year	Snow, Sleet: Mean	Snow, Sleet: Maximum monthly	Snow, Sleet: Year	Snow, Sleet: Greatest daily	Snow, Sleet: Year	Mean number of days: Precip. 10 inch or more	Temperatures Max.: 90° and above	Temperatures Max.: 32° and below	Temperatures Min.: 32° and below	Temperatures Min.: 0° and below	Month
(a)	30	30	30	30		30		30	30	30		30	30		30		30	30	30	30	30	
Jan.	61.3	38.4	49.9	83	1962	20	1949	474	2.87	1.75	1970	T	1.0	1962	1.0	1962	6	0	0	7	0	Jan.
Feb.	63.2	40.6	51.9	85	1954	25	1962+	372	2.30	1.87	1941	T	T	1951	T	1951	6	0	0	3	0	Feb.
Mar.	64.8	41.4	53.1	88	1969	27	1953+	353	1.97	1.70	1950	0	0		0		5	0	0	1	0	Mar.
Apr.	66.4	44.2	55.3	95	1947	30	1964	279	1.37	1.42	1941	0	0		0		3	*	0	*	0	Apr.
May	68.5	48.1	58.3	99	1970+	35	1962	208	0.32	0.98	1957	0	0		0		1	1	0	0	0	May
Jun.	70.5	50.9	60.7	99	1943	41	1958+	141	0.09	0.46	1967	0	0		0		*	*	0	0	0	Jun.
Jul.	71.1	52.7	61.9	100	1959	42	1970	105	0.02	0.23	1966	0	0		0		*	*	0	0	0	Jul.
Aug.	72.0	53.0	62.5	102	1968	42	1963	90	0.04	0.32	1965	0	0		0		*	*	0	0	0	Aug.
Sep.	75.5	51.9	63.7	103	1949	36	1950	75	0.20	2.60	1959	0	0		0		*	2	0	0	0	Sep.
Oct.	74.2	48.1	61.2	102	1961	32	1946	133	0.53	1.16	1944	0	0		0		1	2	0	0	0	Oct.
Nov.	68.9	43.5	56.2	94	1966	28	1941	267	1.63	1.29	1965	0	0		0		3	*	0	1	0	Nov.
Dec.	62.5	40.1	51.3	92	1958	23	1954	415	2.80	2.34	1955	0	0		0		6	*	0	4	0	Dec.
Year	68.2	46.1	57.2	103	Sept. 1949	20	Jan. 1949	2912	14.14	2.60	Sept. 1959	T	1.0	Jan. 1962	1.0	Jan. 1962	31	5	0	16	0	Year

(a) Average length of record, years.

T Trace, an amount too small to measure.

** Base 65°F

\+ Also on earlier dates, months, or years.

* Less than one half.

SOURCE: The Salinas Chamber of Commerce, 119 E. Alisal St., P.O. Box 1170, Salinas, California 93901.

FIGURE 8.1 Climatological Summary for Salinas, California.

Salinas is located near the mouth of the Salinas Valley, a rich, flat agricultural valley averaging about 10 miles in width and 100 miles in length, widening in the Salinas area and opening directly on Monterey Bay about 10 miles west of Salinas. The valley is oriented northwest-southeast parallel to the Pacific Coast, but with the exception of the extreme lower valley, it is largely protected from the coastal weather by the Santa Lucia Mountains which rise to elevations of 3,000 to 5,000 feet. The Gabilan Mountain Range borders the eastern side of the valley, with peaks rising to 3,000 to 4,000 feet.

The proximity of the ocean to the open valley mouth, along with the prevailing northwesterly winds, tends to give Salinas a moderate year-around climate. There is only about 14 degrees difference between the mean temperatures of the warmest month, September, and the coldest month, January. The lowest temperature recorded in the past 30 years was 20° on January 10 and 11, 1949, and the highest was 103° on September 22, 1949. Such extremes are very rare, however, since there are an average of only 5 days per year with maximum temperatures of 90° or higher and only 16 days per year with minimum temperatures of 32° or below. The probability of observing specific extreme readings is set forth in Table 1.

Summers are dry, over 90% of the annual rainfall occurring between November 1 and April 30. Approximately 70% of the precipitation occurs between the first of December and the end of March. Even during this rainy season there are many sunny days since, on the average, there are only 31 days per year with 0.10 inch or more of precipitation. Rainfall varies from year to year, with annual totals exceeding 22.7 inches one year in 20 and falling below 7.3 inches with the same frequency. One-half of the time the yearly precipitation will be found within the limits of 10.7 and 17.0 inches. See Table 2 for monthly probabilities.

Fog and low stratus clouds moving inland from the ocean are fairly frequent, especially on summer mornings. As a general rule, these summer fogs or stratus dissipate before noon. The prevalence of this morning fog and stratus with northwesterly on-shore winds during the summer months contribute to the cool summers and help to account for the highest average maximum temperatures of the year occurring not in the summer, but in September and October. With occasional stagnant air during the winter there are some days of heavy fog, but this condition is infrequent and the periods are of short duration. Relative humidity is fairly high, generally averaging between 85% and 95% at 4:30 a.m. and 65% to 75% at 4:30 p.m.

Thunderstorms are relatively rare in Salinas, averaging less than two per year. Many years no thunderstorms whatever are recorded, and hail is equally infrequent. Snowfall is practically unknown, an inch being the greatest amount ever recorded. In most years none at all is recorded, and when snow does occur it melts soon after falling. Precipitation intensities of about 0.8 inch in one hour and 2.6 inches in 24 hours can be expected to occur about once each two years, increasing to 1.6 inches per hour and 5.8 inches in 24 hours as often as once in 100 years. See Table 3 for additional intensity-frequency relationships.

From March through October the prevailing wind is predominantly from the northwest with speeds averaging between 7 and 8 miles per hour. In late fall the frequency of northwesterly winds decreases, and during December and January the prevailing winds are southeasterly with slightly higher average speeds. Although calms are rare, high winds are also infrequent. In a sample 4 year period no winds over 38 mph were recorded; speeds over 31 mph were recorded in only 7 hours and speeds from 25 to 31 mph in only 64 hours. These strong winds were nearly all associated with winter storms. The rather steady northwest winds of summer rarely exceed 20 mph.

The average date of the last 32° reading in the spring is March 13, and the average date of the first 32° reading in the fall is November 30, giving an average growing season of 262 days. Additional freeze data are shown in Table 4.

The mild year-round weather and the deep alluvial flood plain soils in the Salinas area provide optimum growing conditions for lettuce, carrots, artichokes, strawberries, and broccoli, which has given cause for the title, "Salad Bowl of the World." Table 5 shows evapotranspiration figures for irrigated and dry-farming conditions. Further up the valley sugar beets, beans, and tomatoes are grown. Including its livestock, agriculture in the Salinas Valley is the primary industry, providing a total annual agricultural income of more than $225,000,000.

C. Robert Elford
Climatologist for California

Table 4. Probability of receiving freezing temperature after given dates in spring or before given dates in fall.

T°	P	90%	80%	70%	60%	50%	40%	30%	20%	10%	GS	10%	20%	30%	40%	50%	60%	70%	80%	90%	P
32	97	1/31	2/19	3/1	3/7	3/13	3/19	3/26	4/2	4/12	262	11/6	11/14	11/20	11/25	11/30	12/5	12/11	12/19	12/31	90
28	50	a	a	a	a	1/1	1/7	1/26	2/6	2/22	364	11/23	12/5	12/17	12/28	b	b	b	b	b	43
24	13	a	a	a	a	a	a	a	a	1/12	365	b	b	b	b	b	b	b	b	b	3
20	10	a	a	a	a	a	a	a	a	1/1	365	b	b	b	b	b	b	b	b	b	0

a: Date falls earlier than January 1st.
b: Date falls later than December 31st.

FIGURE 8.1, continued

Average Temperature (°F)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l
1941	52.1	54.4	55.4	54.6	61.5	60.6	62.8	63.0	62.7	58.0	57.4	52.2	57.9
1942	52.2	50.0	52.1	55.0	56.9	58.8	62.2	61.0	61.5	59.0	54.6	50.8	56.2
1943	50.0	53.8	54.6	55.2	58.4	58.8	61.4	61.2	63.2	59.4	57.1	50.6	57.0
1944	50.2	49.1	53.0	51.9	58.2	60.0	61.2	60.8	60.7	61.8	53.9	53.2	56.2
1945	50.6	51.8	51.6	53.1	57.2	61.2	63.2	61.4	63.4	62.0	55.9	53.4	57.1
1946	50.2	49.0	51.0	55.2	59.0	-	-	61.2	64.8	59.3	51.9	51.0	-
1947	48.4	54.1	57.4	59.0	60.0	63.0	62.2	64.6	63.8	62.0	52.6	50.2	58.2
1948	54.4	49.3	51.6	55.3	57.1	62.0	62.1	62.9	62.0	60.9	55.0	46.6	56.6
1949	42.2	48.2	53.0	57.4	58.1	60.9	60.9	62.3	64.6	58.2	61.1	49.0	56.3
1950	45.9	52.1	53.4	56.1	56.7	59.5	62.2	63.7	64.5	62.2	61.3	54.4	57.7
1951	49.6	51.3	53.1	54.1	58.7	60.1	60.7	62.2	64.1	61.8	56.2	48.5	56.7
1952	48.0	52.2	50.4	56.4	59.2	59.0	64.0	62.1	65.1	60.6	54.3	51.2	56.9
1953	53.7	51.5	53.0	54.4	57.3	59.6	62.4	63.1	65.4	61.5	57.1	52.5	57.6
1954	49.6	56.5	51.4	57.7	58.6	60.6	63.3	62.3	63.6	60.7	57.8	51.4	57.8
1955	46.9	50.0	53.7	52.2	57.4	60.1	59.9	61.0	62.[illegible]	60.5	54.5	52.8	55.9
1956	50.2	49.0	53.0	55.5	59.5	61.0	61.3	61.9	65.0	59.7	59.6	53.7	57.5
1957	47.3	55.2	54.4	57.0	59.7	63.8	62.6	61.9	65.6	63.5	57.8	54.8	58.7
1958	-	-	-	-	60.6	63.0	62.4	65.4	67.9	63.5	57.2	56.4	-
1959	53.2	51.1	56.1	58.5	58.2	60.5	63.1	64.4	62.5	63.7	58.3	52.8	58.5
1960	47.9	51.7	55.5	56.6	58.0	62.0	61.8	61.2	62.2	59.5	53.8	50.2	56.7
1961	53.8	52.7	52.1	56.0	57.1	62.8	63.3	64.0	63.9	61.1	54.7	49.8	57.6
1962	50.3	51.0	50.5	57.3	56.8	59.5	59.1	63.8	60.6	62.1	56.7	53.2	56.7
1963	48.0	57.1	51.6	53.7	58.2	59.9	61.9	62.4	65.4	62.2	54.9	51.6	57.2
1964	48.8	51.3	51.0	53.3	55.2	60.2	61.9	62.9	61.9	62.6	52.7	52.0	56.4
1965	51.4	50.6	53.0	56.3	56.9	59.2	61.5	65.0	62.5	64.1	55.9	47.4	57.0
1966	48.7	49.3	53.3	58.5	58.0	61.2	61.4	62.8	64.3	62.4	56.8	51.7	57.4
1967	51.3	53.2	52.8	50.5	59.4	58.7	62.6	62.7	66.3	64.3	58.0	48.3	57.3
1968	49.9	57.0	55.2	55.5	58.1	60.9	60.8	63.6	64.0	59.4	53.8	47.8	57.2
1969	50.2	49.1	52.6	53.7	58.4	61.7	61.5	61.1	63.0	59.3	57.9	52.3	56.7
1970	52.0	54.2	54.8	53.6	60.3	60.9	61.4	60.6	65.0	59.9	57.6	50.5	57.6

STATION HISTORY

Weather observations in Salinas were first made in 1872, and they have continued throughout most of the time since then. Some of the early observers were Dr. E. K. Abbott and Miss Bertha Abbott, the Southern Pacific Company, Dr. E. D. Eddy, and Charles Melander. The period from 1941 to the present was used in the preparation of this summary, using data from the following observers.

From 1938 to 1946 Mr. F. A. Trigeiro provided data from Griffin and Abbott Streets. From 1958 to 1970 the readings were made by the Fire Department at 1380 East Alisal St., and from 1970 to date the USDA Agricultural Research Station at 1636 East Alisal St. has been the observer. Additional data have also been available from the airport during the period from 1946 to the present time.

It has been necessary to combine data from these locations in order to provide a reasonably complete record for the last 30 years. The present summary is possible because of the voluntary contribution of time and effort of these observers.

Table 3. Precipitation Intensity-Duration-Frequency Combinations. (Rainfall Amounts)

	Interval (Hours)						Interval (Days)								
	1	2	3	6	12	24	2	3	4	5	6	7	8	9	10
1 Yr in 2	.8	1.0	1.2	1.7	2.1	2.6	3.1	3.5	3.8	4.1	4.3	4.5	4.8	5.0	5.2
1 Yr in 5	.9	1.2	1.5	2.1	2.7	3.3	4.1	4.7	5.2	5.5	5.9	6.2	6.6	6.9	7.2
1 Yr in 10	1.1	1.4	1.7	2.4	3.1	3.9	4.8	5.6	6.1	6.6	7.1	7.5	7.9	8.3	8.7
1 Yr in 25	1.3	1.7	2.0	2.9	3.7	4.6	5.8	6.7	7.5	8.1	8.6	9.2	9.8	10.3	10.7
1 Yr in 50	1.4	1.9	2.3	3.3	4.2	5.2	6.6	7.7	8.5	9.2	9.9	10.5	11.2	11.8	12.3
1 Yr in 100	1.6	2.1	2.5	3.6	4.7	5.8	7.4	8.6	9.6	10.4	11.2	11.9	12.7	13.3	14.0

Table 5. Computed potential evapotranspiration, computed actual evapotranspiration, and related figures.

Precipitation (inches)		PET (inches)		4Ea (inches)		
Year	GS	Year	GS_{32}	Year	GS_{32}	Dry Date
14.14	5.03	27.48	22.95	14.14	9.62	June 15

FIGURE 8.1, continued

Total Precipitation (Inches)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l
1941	4.16	7.05	4.44	3.96	0.33	0.04	T	T	0	1.20	0.26	6.66	28.10
1942	2.25	1.87	2.12	2.63	1.02	0	0	0.01	0.02	0.94	1.52	2.21	14.59
1943	3.12	1.93	3.63	1.22	T	0.03	0	0	0	0.36	0.24	2.49	13.02
1944	2.51	5.89	0.19	1.31	0.52	0.15	0.05	T	0	1.17	3.78	1.81	17.38
1945	0.40	2.70	2.72	0.34	0.10	T	0	0.28	0.05	0.60	1.76	4.06	13.01
1946	1.05	2.84	2.40	0	0.45	0	0	0	0	0.09	3.86	1.73	12.42
1947	0.45	1.28	1.25	0.60	0.31	0.12	0	T	T	1.68	0.70	1.20	7.59
1948	0.10	1.62	3.82	3.14	0.45	0.02	0.07	T	T	0.88	0.40	3.28	13.78
1949	1.25	1.83	3.15	T	0.22	T	0.15	0.03	0.01	0.10	0.74	1.11	8.59
1950	6.57	1.26	2.21	1.34	0.25	0.05	T	0.03	T	1.77	2.92	2.46	18.86
1951	1.43	1.84	0.57	0.93	0.15	0.04	T	T	T	0.65	2.68	6.15	14.44
1952	5.54	1.86	2.49	0.85	0.04	T	T	0.01	0.01	0.02	1.36	4.72	16.50
1953	0.99	0.01	0.77	1.63	0.18	0.06	T	0.02	0.01	0.43	1.34	0.30	5.74
1954	2.51	1.13	3.67	0.65	0.06	0.19	T	T	0.04	T	0.82	2.12	11.19
1955	5.66	1.34	0.10	2.38	0.67	T	T	T	T	T	1.61	8.96	20.72
1956	4.58	1.37	0.14	0.74	0.41	T	T	T	0.09	0.65	T	0.83	8.81
1957	2.75	2.30	0.96	0.84	2.32	0.11	T	T	0.12	0.98	0.46	2.97	13.81
1958	2.87	3.18	4.73	3.85	0.49	0.07	0	0	0.51	0.01	0.19	0.20	16.10
1959	3.15	4.21	0.28	0.18	0.05	0	0	T	4.52	0.01	0	0.45	12.85
1960	2.85	3.49	0.43	0.95	0.14	0	0	0	0.01	0	2.19	0.56	10.62
1961	1.50	0.95	1.67	0.69	0.24	0.18	0	0	T	0.03	1.44	0.61	7.31
1962	2.68	5.90	1.55	0.10	0.05	0.09	0	0.02	T	0.61	0.38	1.78	13.16
1963	2.95	2.20	3.25	3.17	0.17	0	0	0.02	0.36	1.46	2.42	0.26	16.26
1964	2.29	0.10	2.46	0.31	0.75	0.36	0	0.20	T	0.85	2.72	5.48	15.52
1965	1.14	0.39	1.79	1.31	T	T	0	0.42	0.02	0.13	4.20	4.25	13.65
1966	1.26	1.17	0.10	0.14	0.01	0.01	0.23	0	0.18	0	2.23	3.73	9.06
1967	4.40	0.33	2.93	5.69	0.09	0.58	0	0	0.16	0.08	1.35	1.87	17.48
1968	1.93	0.97	2.05	0.32	0.09	0	0	0.06	0	0.29	1.96	3.28	10.95
1969	8.53	6.24	1.21	1.76	0	0.03	0	0	0	0.70	0.90	3.98	23.35
1970	5.34	1.68	1.90	T	0	0.47	T	0	T	0.35	4.56	4.44	18.74

Table 1. Extreme Temperature and Precipitation Values Occur with the Frequency Indicated in the Following Table.

Data	Avg.	Mode	1 Yr in 2	1 Yr in 5	1 Yr in 10	1 Yr in 25	1 Yr in 50	1 Yr in 100
Annual Max. Temp.	96	94	95	98	100	103	105	107
Annual Min. Temp.	26	27	26	24	23	21	19	18
Annual 24-Hr Pcpn.	1.3	1.0	1.2	1.6	1.9	2.3	2.7	2.9
Monthly Pcpn.	4.4	3.4	3.9	5.6	6.7	8.1	9.2	10.2

Table 2. Probability of Receiving Monthly Total Amounts of Precipitation.

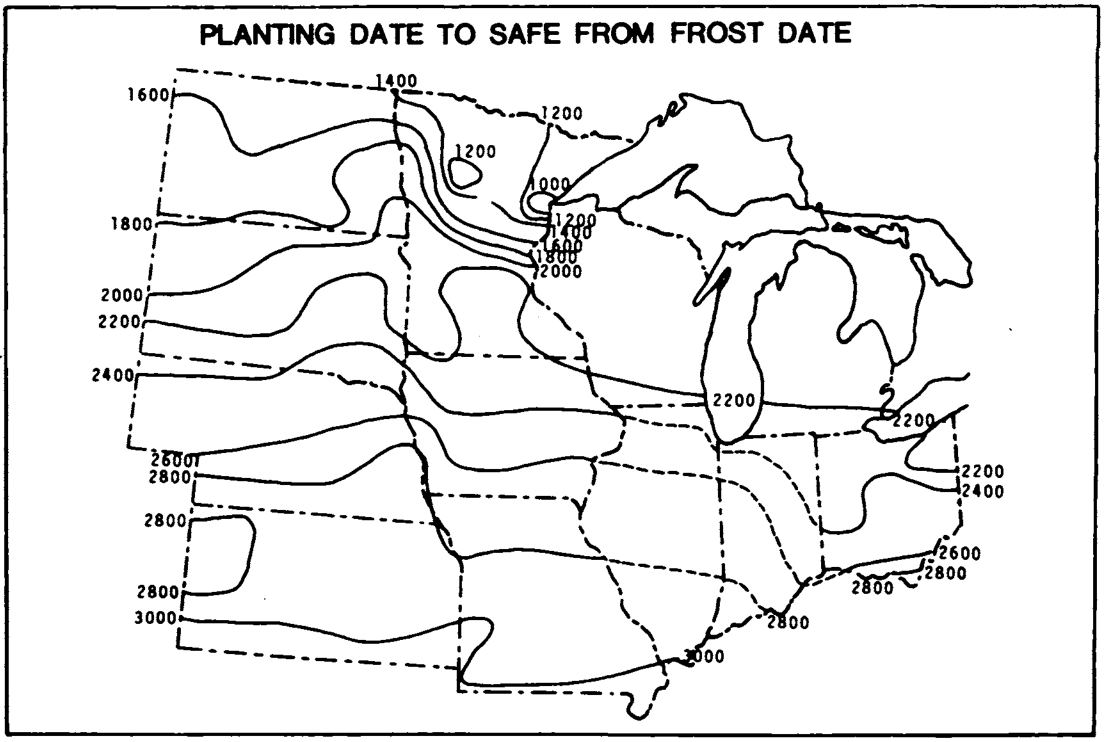
Monthly Total (inches)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Trace or less	0	0	0	10	13	40	87	63	50	13	7	0
.05 or more	a	98	a	87	76	43	12	23	44	80	93	a
.10 or more	a	96	a	84	66	31	8	14	39	74	93	a
.25 or more	99	90	97	76	44	11	1	3	27	58	90	99
.50 or more	95	80	91	65	23	2			15	39	83	95
1.00 or more	85	65	73	47	6				4	17	64	84
2.00 or more	60	42	40	24						3	31	58
3.00 or more	38	27	19	13						1	14	37
4.00 or more	23	18	9	7							5	22
6.00 or more	8	7	2	2							1	7
8.00 or more	3	3		1								2
10.00 or more	1	1										1

a: More than 99%.

Annual Precipitation is less than these Values With the Frequency Shown

Frequency	Per cent of years 5%	10%	25%	33%	50%	67%	75%	90%	95%
Total Pcpn. Exceeds	7.3	8.5	10.7	11.6	12.8	15.7	17.0	20.4	22.7

FIGURE 8.1, continued



SOURCE: Shaw (1975).

FIGURE 8.2 Average growing-degree units for period from average planting date to average fall safe-from-frost date. Dashed lines are estimated values.

Climatological Networks

The basic NWS weather forecast and weather advisory services rely on data reported immediately from the synoptic upper-air and surface observation networks. These networks are always undergoing changes because of the development of better instrumentation, automation, and communication facilities. The networks are basic to the NWS national mission, and there is little doubt that they will continue to operate satisfactorily. The synoptic upper-air network is defensible by any meteorologist. What is less obvious, but sometimes of even greater importance, to weather information users--farmers, the general public, Congress, and even NWS meteorologists not involved directly in hydrologic or other specialized programs--is the need for climatological data in specific geographical areas.

Until NOAA terminated the state climatologist program in 1973, state climatologists did much to integrate and coordinate NWS services, state government services, and university research and extension activities, with the needs of private users, mostly agricultural. State climatologists helped farmers define their needs for climatological data, helped create the observational network, and cooperated in the publication of climatological data. They also served as quality-control officers in the NOAA Environmental Data and Information Service (EDIS) system and, with substation network specialists, monitored maintenance needs of the network. Some states have continued funding the position of state climatologist, and personnel at the EDIS National Climatic Center (NCC) at Asheville and substation network specialists have maintained the national climatological program and network even in states which have not. A concise history of the state climatological program has been prepared by the American Association of State Climatologists (Durrenberger et al. 1978).

The networks operated by state climatologists under EDIS and NWS were classified in the 1950s as "a", "b", and "c" networks. The "a" network, designated a "climatological network," consists basically of key temperature and precipitation stations located on about a 25-mile grid in areas of small climate gradient. The "b" network, or "hydrologic network," is made up of those additional stations needed to forecast river flow, floods, and water supply. Stations not in the "a" or "b" networks were identified as either "c" or "x" stations. The "c" stations are those which serve semipublic needs, such as providing weather information to television and radio stations, agribusinesses, and other weather observers not defined by state climatologists or hydrologists as essential for documenting the mesoclimates. The "x" stations are those whose existence cannot be defended and are marked for closure at the first opportunity. Only data from the "a" network and defensible data from the "b" network are published in *Climatological Data* for the state. Data from "c" and "x" stations generally are not published, although the manuscript record is available in state climatologist and NCC offices.

Generally, "a", "b", and "c" stations are manned by cooperative observers who receive no salary or other compensation. If the observer is required to take special observations or make special telephone calls, e.g., from a "b" station for river forecasting purposes, a nominal payment may be made for each report. If an "a" station has to be moved there are general guidelines for determining whether the new data can be considered a continuation of the old record for climatological purposes or whether the station will be considered a new station but still representative of the same network area. These difficult decisions, previously made by state climatologists and substation network specialists, are now made primarily by the specialists alone, especially in states without a state climatologist. Stations labelled "c" may be used to replace those in the "a" or "b" networks when feasible; otherwise, "c" and "x" stations generally are not replaced.

For the convenience of the cooperative observers, observation times for many stations in the "a" network are in the late afternoon or evening. By the time the observations are made, therefore, the maximum and minimum temperatures have occurred and can be published for that calendar day. Observers at stations in the "b" network, especially those reporting to a river district office, usually have early morning observation times. This means that the observed minimum temperature will have occurred the morning of the observation but the maximum will have occurred the previous day, although it will be published along with the minimum temperature on the day of observation. Time of observation may introduce bias into mean temperatures (Schaal and Dale 1978). Precipitation and evaporation from A.M. and P.M. stations have to be treated separately.

There are other special networks for reporting information on evaporation, soil temperature, and solar radiation, but efforts usually are made to include these observations at stations in the existing networks. For example, evaporation stations are "a" or "b" stations, and most solar radiation stations are either "a" or "First Order" stations (a part of the synoptic network). In states with an agricultural weather service the NWS agricultural meteorologist attempts to have the additional observations included in reports from an "a", "b", or "ab" station. If a cooperative observer does not want to assume this additional task and continuation of a valuable climatological record is imperiled, a "c" station can be established for which data are not published.

Generally, NWS demonstrates less interest in the climatological network than in the reporting network needed to gather data for forecasts. In states with rugged topography the general guidelines of one station per 25-mile grid and the criteria for determining the climatological compatibility of data from a station which has been moved (less than 5 miles and elevations of less than 100 feet) are totally inadequate.

This report has tried to delineate the close relationship between climatological and forecasting services in providing the weather information necessary for agriculture. The basic "a" and "b" networks should be maintained at least at their present levels and information from these networks should continue to be published by NCC. Judicious use should also be made of temporary "c" stations to increase knowledge of mesoclimatology and thereby improve localized forecasts.

The standard thermometers and eight-inch rain gauges used at "a", "b", and "c" stations have provided reasonably accurate, long-term climatic records. When equally reliable electronic equipment becomes available the "a" and "b" networks should be reinstrumented so that observations are made automatically and transmitted to the appropriate users on a timely basis. In order to reduce costs while maintaining quality, the same data base should be used for both climatological studies and weather forecasting whenever possible.

FORECAST SYSTEMS

Impressive progress in the development of mathematical models of the atmosphere has occurred during the past several decades. Large, high-speed digital computers are now used to produce numerical forecasts of weather events in the three-dimensional structure of the atmosphere. This information is obviously useful to agricultural and forestry users and, judging from the farmers' evaluation of weather forecasts reported in Chapter 6, is generally perceived as highly reliable. All users, however, perceive a need for better graphic information and for more accurate, timely, and accessible information on local weather.

The numerical forecasting techniques currently being used have several inherent limitations. The first is the problem produced by grid nodal points 2.5° apart. This distance is necessary because computer size and speed limit the number of computations possible to produce a timely forecast and because numerical forecast models require initial data inputs which have inherent definition limitations. In addition, local weather forecasting is dependent to some degree on local surface observations. Curtailing the number of surface stations would decrease the accuracy of local weather forecasts.

Agricultural Forecasting and Services

No system now exists for disseminating weather information or forecasts solely to agricultural users, who are dependent upon existing weather information sources. But there are specialized forecasts, information services, and centers dedicated to agricultural users.

NWS prepares special agricultural forecasts, warnings, and advisories for immediate dissemination by the new media. This information is usually supplied to farm audiences by commercial radio and television stations in areas where a significant segment of the audience is oriented towards agriculture or forestry. Most of this information is prepared by NWS personnel who have special responsibilities, training, and skills. In some cases, however, those who prepare agricultural weather information are assigned that duty on a rotating basis and may have little special training for, or experience in, agricultural weather forecasts. These forecasts are additions to the general forecast and contain some new information, such as dew, precipitation amounts, sunshine, humidity, and additional wind information. Some of these forecasts are disseminated by NOAA Weather Radio, but they are not always adequate for farm users. In most cases, moreover, the agricultural weather forecast, advisory, or warning are not disseminated directly to the farmer. Nor are they prepared or offered for dissemination in all states. They are only made where special services have been instituted and continue to be operated, usually through state cooperation, funding, and political pressure.

Specialized agricultural forecast services such as the Fruit-Frost Forecast Service, arose because general forecasts could not predict cold weather with enough accuracy to be useful to farmers. These specialized services were cooperative efforts, usually between a land grant university and the Weather Bureau when it was an agency of USDA. In most cases political pressures applied by state congressional delegations were instrumental in the establishment of the service, and it was only through their efforts that the services were maintained, expanded, and improved. The commitment of NWS to these services, however, appears to be fading. Since NWS is no longer a part of USDA, USDA has shown little interest in special weather services. The Department of Commerce and NOAA have repeatedly been advised by members of the National Advisory

Committee on Oceans and Atmosphere (NACOA) that special services to agriculture, such as the Fruit-Frost Forecast Service, should not be provided at public expense by NWS but should be provided by private meteorologists. Private meteorologists, however, do not provide this service, and most of them do not think there is a large enough market for forecasts of minimum temperatures to producers of cold-sensitive crops. The premise of this report is that because of the international aspects of food, feed, and fiber production, and of weather itself, the provision of weather data and services for agriculture should continue to be primarily a federal responsibility.

The special services have performed in an excellent manner in forecasting local cold weather and minimum temperatures, not only for citrus fruit growers in Florida, California, and Texas but also for cranberry growers in Wisconsin and, most recently, for deciduous fruit growers in the Pacific Northwest. The special services have also contributed to the development of techniques for forecasting minimum temperatures and the development of methods of protecting plants from frost damage and educating farmers in their use. In addition, they have provided information to both the universities and the manufacturers that has proved useful in the development of wind machines, heaters, sprinkler irrigation systems, flood control devices, and soil compaction mechanisms. They have been instrumental as well in developing methods of providing artificial clouds that mitigate nocturnal radiation losses and influence local temperatures.

The Environmental Study Services Centers (ESSCs) described elsewhere in this report (Chapter 4) now influence the agricultural forecast and information program of NWS so strongly that their activities must be counted as a part of the services to agriculture supplied by NWS.

Although the ESSCs have been successful to some degree, they suffer from severe limitations. Funds and manpower are supplied for only a 5-day-per-week, 8-hour-per-day operation, although the resources have been stretched to 6 days a week from 3:00 A.M. to 5:00 P.M. from April to November at the West Lafayette, Indiana, office. ESSCs are used by NWS to collect data which are funneled to Weather Service and forecast offices. ESSC personnel spend much time providing communication support and adaptive information. They are generally restricted from making forecasts, however, even when there are needs for special services in the immediate area which they are authorized to serve. The centers have little time to become involved in developing methods for making better use of weather information in agriculture and forestry, but they have been drawn into a supporting role for agricultural research within the land grant system. The centers have too little time to work with the extension service to create and disseminate weather forecasts and information to agricultural and forest users. Many of the programs they have conducted have been useful, but many farmers and some university personnel are unaware of the information provided or are not using it.

NWS Forecast and Information Systems that Indirectly Aid Agriculture and Forestry

NWS has an excellent system for organizing synoptic weather observations recorded by NWS personnel. Almost all of these observations are very important for agriculture in some portion of the year or in some geographic area or commodity sector. Wind velocity, relative humidity, evaporation rates, amount of solar radiation, dew formation and intensity, maximum and minimum and hourly temperatures, extent of cloud cover, amount of rainfall, and in some instances even ceiling height and visibility are important to agriculture. Hourly temperatures, especially those below certain thresholds, are important in breaking the dormancy of deciduous fruits. The maintenance of winter hardiness is especially important for horticultural crops. The number of growing-degree days is important in measuring and estimating the maturity of horticultural crops. Dew intensity and duration are especially important in such matters as harvesting cotton and grains, baling hay, controlling insects, and predicting the incidence of disease, and the effectiveness of certain pesticides and growth regulators.

Unfortunately, however, these various observations are usually not available to agricultural users. In many cases, moreover, the instrument locations and exposures are inappropriate for agricultural and forestry purposes. To be of real use, these observations need to be made available in a nearly operational mode.

The major uses of the synoptic weather observations are for numerical forecasts and current weather forecasting. Other information available from the numerical forecasting centers and distributed to NWS offices--e.g., the numerical prognosis of 500 millibar charts--is extremely important in estimating the likelihood of cold weather in most of the fruit-growing areas of the United States. This information is used by individual horticulturalists if it is available in timely fashion. In addition, the location, presence, and forecast position of the jetstream is recognized by many farmers as being important in making operational decisions.

According to present NWS plans, these weather graphics will be available for use within the NWS AFOS system. Verbal descriptions of upper atmospheric conditions and jetstream locations are commonly included in the NOAA

Weather Wire, but in a very generalized format. Commercial television stations commonly receive much of this information through various facsimile and teletype circuits, but the advent of AFOS raises questions about the future availability of these graphic data.

Satellite and radar data are useful to agriculturists, and both were mentioned by farmer participants in the workshop as reasons why they preferred television as a means of obtaining weather information. GOES satellite data could be broadcast to farmers on either an hourly or half-hourly basis by commercial television stations. The data important to agriculturists includes surface temperatures; the development, movement, and location of clouds; the movement and development of fronts; and subjective estimates of rainfall from cloud-top temperatures. These observations are also available from areas with limited surface observations, or where only irregular and erratic observations are available, namely, the Pacific Ocean, the Gulf of Mexico, and the Atlantic Ocean. The resolution of GOES satellite data is not sufficient to pinpoint individual farms, but the information and imagery available from the TIROS and NOAA satellite series is of sufficient resolution (approximately 1 kilometer) to be extremely useful to individual farmers. Furthermore, the thermal radiometer on the satellites is calibrated so that excellent estimates of surface temperature should be available. In addition, high-resolution visible data from the satellites should provide an excellent opportunity to indicate visually the weather in specific geographical locations. Under current plans, however, GOES and TIROS and NOAA series data will not be available to AFOS.

Radar is of special importance to agriculture because it allows farmers to pinpoint the location of precipitation and to estimate both the movement and the rate of local development of rain. In addition, digitized radar produces estimates of precipitation which, when coupled with measurements of rain and climatic probabilities, can be used for operational decisions regarding water conservation and the management of irrigation systems. Yet this excellent system incorporating observation, forecasting, and real time weather observation via satellite and radar is not available to farmers or foresters other than through the casual dissemination methods of commercial television. Even though radar and satellites constitute the only mesoscale and microscale observational system in NWS, no attempt is being made to disseminate the information gained from it to the farm audience except through isolated private cable television systems.

Future Systems and Plans of NOAA that Affect Agricultural Weather Information Services

The NWS is currently implementing the hardware and software for AFOS. AFOS should greatly speed communications and integrate much of the information now present on several different circuits into a single system. Since it is computer-based, it will add computer capabilities to local Weather Service State Forecasting Offices. Although it is not clear to what extent radar data will be included in this system, hourly digital charts are available; current plans do not include satellite imagery. This is now handled by Laser Fax products in each WSFO. The improvement in the quality of forecasts should be evident. Since the available data will be essentially unchanged, and since there is very limited local incorporation of data, weather information services may be inclined to use the AFOS-disseminated forecast exclusively.

The Model Output Statistics (MOS) program is currently developing prototype forecasting updating systems. These systems have been given the acronym LAMP (Local AFOS MOS Program). LAMP will update and improve the MOS system by using objective weather-map analysis techniques, by using derived meteorological variables as forecast predictors, and by employing climatological records to create reliable estimates of predictors. In addition, Markov model statistics will be used to establish probabilistic methods for creating fiduciary limits on local weather occurrences and to enhance extrapolation to specific local sites. The prototype methods do not appear to use satellite and radar data as input. LAMP has potential for improving the quality of forecasts and would be especially valuable in creating machine-generated forecast statements, but there is no indication that it will be used to meet specific agriculture and forestry needs except as they are embedded within the general forecast or may be met by extrapolation of local site forecasts. MOS, however, is developing dew, precipitation, soil temperature, and maximum and minimum air temperature predictions out to 5 days that are already available in Michigan and Indiana out to 48 hours.

Once AFOS and LAMP are implemented, the proposed methods for disseminating NWS data and information will become a major concern. It is clear that NOAA intends to severely limit access to AFOS and LAMP by non-NOAA personnel because of communication and computer resource limitations. Current plans provide for giving access to a few selected private users in return for their commitment to sell the information to other intermediate and end users. Aside from adding to user costs, this will require the creation of a whole new system of information dissemination. Users who currently obtain all their weather information from the NOAA Weather Wire should not be affected. Since most farmers and foresters depend so heavily upon the dissemination of weather information through commercial television and radio, however, the net effect of current plans could be a disastrous loss of graphic weather information in certain local areas. Clearly, much of the media would have to depend more on verbal forecast systems.

Simultaneous with the development of AFOS and LAMP for forecasting and disseminating weather information within NOAA has been the development of two prototype systems discussed in Chapter 7, Green Thumb and the Fire Weather Information System), for disseminating weather information directly to farmers and foresters. Green Thumb uses alphanumeric and graphic presentations. The Fire Weather Information System uses only alphanumeric data displays but supplies products based upon use of MOS techniques. Currently, however, these products are not widely available. The Fire Weather Information System is operational in the southeastern United States on a fee basis to users through a dial-up computer terminal. Green Thumb is not yet operational but will incorporate radar and satellite imagery. Only the Satellite Freeze Forecast System and NOWCAST would disseminate graphic information from satellites and radar directly to farmers and foresters and would make it available for use by commercial television.

Recommendations for Products that Need to be Developed and Information and Data that Need to be Disseminated to Farmers and Foresters

Current trends in NOAA and USDA make it clear that there is no intention to increase the personnel dedicated to forecasting agricultural and forest weather. As mentioned earlier, the National Advisory Committee on Oceans and Atmosphere (NACOA) has advised NOAA to reduce, restrict, or eliminate all specialized services, including services to agriculture. Numerical forecasting, weather satellites, radar, and AFOS have required so many of NWS's resources that the agency has been forced to close some of its local offices.

The grid nodal spacing which is practical for the numerical forecasting system evidently cannot be made more intensive; i.e., closer nodal spacing is not possible. It seems clear, therefore, that the quality of mesoscale and microscale weather observations will not be enhanced except with special efforts. The special services (e.g., Fruit-Frost Forecast Service) have demonstrated that reliable forecasts of specific local weather occurrences can be made, and advances in technology should make them of even more value in the future. These special services should be expanded to include more agricultural and forest users.

Ways in which Weather Information Services to Agriculture and Forest Users Could Be Improved

Almost all of the farmer participants in the workshop expressed a need for better long-range forecasts. The National Climate Program includes experimental long-range forecasts, and evaluation of these forecasts for their usefulness to agriculturalists could be a part of the program. The National Agricultural Meteorological Plan being developed by NOAA and USDA suggests that NWS remain responsible for observing meteorological elements, preparing numerical forecasts, maintaining and operating satellite and radar systems, and making these data available for agricultural purposes. USDA would be responsible for ensuring that these data were made accessible to agriculturists and foresters, either through direct dissemination or through close cooperation with commercial disseminators. The Cooperative Extension Service at the state level should play a key role in the preparation and dissemination of specialized forecasts for agriculture and cooperate with NOAA in preparing forecasts of weather events of special significance to agriculture.

It appears that the only practical way in which weather services provided to agriculture and forestry can be significantly improved is to use satellite, radar, and automated surface observations to generate textural and graphic information of special importance. Additional hardware, software, and personnel will be required to achieve this. At least two additional personnel would be needed in each state, perhaps located at the land grant university. They would have primary responsibility for liaison between NWS and users of agricultural and forest forecasts (commercial radio and television stations, county extension personnel, and forest and farm operators and managers). The functions of these employees would be similar to those of the Advisory Agricultural Meteorologists previously located in some states before the establishment of the ESSCs. All Committee members felt that each state should have a position similar to that of the Advisory Agricultural Meteorologist. Funding for these positions should be supplied by NOAA and USDA, but those hired to fill them should not be NOAA or USDA employees, since they must be responsive to the needs of local agriculturists.

In addition, computer-assisted and computer-generated techniques and models must be developed for making weather observations, handling data, and making forecasts and prognoses of their usefulness to farm and forest managers. The total resources required cannot be estimated by the Committee, but it would seem possible to secure most of the needed hardware for several hundred thousand dollars per state, with an equivalent annual amount for operation and maintenance. Such a system must not be developed in a monolithic manner. Agricultural producers need information that pertains to individual commodities, and demographic, geographic, and physiographic features make it imperative that the system be tailored explicitly to meet local needs. Conceivably, NOAA and USDA could participate in the development of special products or techniques to be used locally for specific purposes, such as forecasts of leaf wetness, chilling hours, growing-degree days, maximum and minimum air temperatures, soil temperatures, evapotranspiration, rainfall and rainfall intensity, and extrapolation of numerical forecasts to local situations.

Since commercial radio and television stations have played such key roles in supplying farmers with weather information, it is mandatory that any special products and adaptations be made available to media meteorologists. Moreover, methods and techniques to encourage and assist television stations in disseminating weather information of special importance to agriculturists and foresters should be explored. The problem with current dissemination is that media meteorologists are free to do as they see fit with weather information. This sometimes precludes the broadcasting of weather information useful to agriculturalists. In addition, some stations are unwilling to provide special services unless they are paid to do so. A public service commitment should be required of the stations by the Federal Communications Commission, and the Department of Commerce and USDA as well as agriculturists should consider ways in which special incentives or credits could be given to media that play key roles in disseminating weather information. The role of personnel responsible for agricultural weather programs within each state should be to provide close liaison and service to commercial radio and television stations that disseminate agricultural forecasts.

In addition, all new programs, products, and dissemination methods developed by NWS or USDA should be evaluated in the pilot phase by farmers, extension specialists, research scientists, and NWS, and USDA personnel. A continuing feedback and evaluation system should be part of the NWS forecast program. Such a system would help to determine the usefulness of current programs, define future needs, and identify forecasts and services that are not perceived as valuable by users.

CHAPTER 9

GUIDELINES FOR RESEARCH AND DEVELOPMENT OF NEW WEATHER INFORMATION PRODUCTS AND TECHNIQUES

The numerical forecasting used by NWS has greatly enhanced the spatial and temporal accuracy (Chapter 8). Spatial resolution, however, is limited by the 2.5° latitudinal and longitudinal grid size. Although optimal for many purposes, the grid has required the development of other techniques to reconcile current local weather with current area forecasts and to extrapolate forecast and current weather conditions to specific local sites. Some extrapolation is being made with methods similar to those used to create Model Output Statistics (MOS) products. The Forestry Weather Interpretations System (FWIS) developed by the Forest Service for the southeastern United States uses MOS products for local weather, but current NWS products are the only sources farmers have for such information. A question posed for the Committee was "Are the present products adequate for farmers needs and, if not, what should be developed?" This question did not get an unequivocal answer, but the general feeling was that more and better types of information are needed.

Guidelines should meet four requirements for the research and development of new information products to ensure that they are needed and will more adequately meet farmers' needs. Chiefly needed are those that can be used to solve weather-information-sensitive problems.

The types of information produced by NWS have evolved from historical experience, agency expediency, and technological and scientific limitations. Few have been designed as the result of a user market survey. Since current types of information are the only ones available, agriculturalists must of necessity rely on them.

The <u>first requirement</u> should be that a survey be made of the present and future needs of the specific clientele before considering the development of a new information product.

The <u>second requirement</u> should be that pilot informaton products be tested against existing ones to determine whether they are actually of increased effectiveness. Farmers, forecasters, and disseminators should all have a voice in determining the product and its effectiveness. This requirement is important because NWS and the farmer have different perspectives. The NWS is forced to develop a hierarchical perspective of weather needs--hemispherical, continental, national, regional, and local. This perspective has influenced the development of past products. Weather-information needs for the farm have an inverted hierarchy--farm, local, and regional (upstream) needs. Much farm weather is nonsynoptic and is controlled by local conditions; thus, it may not be closely tied to the next 6 to 12 hours' numerical forecast. Therefore, local needs should strongly influence the definition of needed products.

The third requirement for new information products should be that they be oriented towards local weather and be designed to interface with emerging needs for integrated pest management, energy conservation, alternative energy use, water conservation, and containment or reduction of production costs. This requirement should include specific determination of the additional information required for current local weather and short-term forecasts. The format should be tailored for the comprehension of farmers. Timeliness is of the utmost importance for daily management decisions.

There has been some preoccupation in the NWS for standardization of products for efficiency and effectiveness. The Committee believes that this standardization in many cases has decreased the usefulness of NWS products for farmers. Simply restructuring the current forecast to make an agricultural forecast has limited value and is seldom disseminated to farmers. The Committee does not believe the Advisory Agricultural Meteorologist concept is out of date. Most farmers receive information from commercial radio and television. Therefore, the forecasts should have great local applicability and should be of interest to the local audience. Forecasts could be computer generated to meet specific local needs. It is important that the weather reports present information from satellites and radar, weather maps, the calendar of past and present farm operations, and climatic events that affect agriculturists. Weather reports should be primarily oriented toward mesoscale and microscale forecasts so that they will be of maximum utility.

The Committee also believes that neither the NWS nor the USDA will have significant additional personnel available to serve agricultural needs. Furthermore, the numerical forecasting techniques are not oriented to local microscale and mesoscale weather. Satellites, radar, automatic surface stations, and computers, however, offer the possibility of localizing both forecasts and current weather information. Therefore, research on products should emphasize the development of local computer-generated forecasts and current reports that use information from radar, satellites, and automatic surface stations to provide local microscale and mesoscale weather reports for dissemination by radio and television to farmers and foresters.

The fourth requirement should be that testing and evaluation be performed either by a qualified, independent group within NWS or, more desirably, by a disinterested third party. The development of new information products should either parallel or, preferably, precede the development of new dissemination systems.

REFERENCES

Agricultural Research Institute (1978) A Report of a Special Meeting on Methods of Improving the Dissemination of Weather Information to Agricultural and Forest Producers. September 28-29, 1978, University of Maryland.

Brown, T.G., and A.J. Collins (1978) Large Commercial Family Farms--Informational Needs and Sources. Report, National Extension Study Committee, September 1, 1978, Agricultural Economics, University of Missouri-Columbia.

Cressman, G.P. (1979) Proposed external user policies, National Weather Service weather and river information. National Weather Digest 4:7-10.

Durrenburger, R.W., A. Eddy, J. Mather, A. Richardson, and P. Waite (1978) A Service-Oriented State Climate Program for the Citizens of the United States. Tempe, Ariz.: Arizona State University.

Getz, R.R. (1978) A survey of New Jersey's Agricultural Weather Service users. Bull. Amer. Meteorol. Soc. 59:1297-1304.

Greenberg, J. (1976) Economic benefits of improved meteorological forecasts. Pages 608-629, Weather Forecasting and Weather Forecasts: Models Systems and Users, Volume II. Boulder, Colo.: National Center for Atmospheric Research.

Joint UCAR/AMS Committee (1979) Joint UCAR/AMS Committee Report on Activities, Findings, and Recommendations. Bull. Amer. Meteorol. Soc. 60:1313-1315.

Krawitz, L. and H. Newhouse (1978) A survey of external users of NWS information. Bull. Amer. Meteorol. Soc. 59:1288-1296.

McKay, G.A. (1979) Perceptions of the Economic Implication of Climatic Variability. Canadian Climate Centre Report #11. Downsview, Ontario, Canada.

National Research Council (1975) Environmental Impact of Stratospheric Flight. Climatic Impact Committee, Washington, D.C.: National Academy of Sciences.

National Research Council (1976) Climate and Food. Climatic Fluctuation and U.S. Agricultural Production. Committee on Climate and Weather Fluctuations and Agricultural Production. Washington, D.C.: National Academy of Sciences.

Rench, W.E. and F. Makosky (1978) Utility of Agricultural Weather Services in the Mid-South. NOAA Tech. Memo, NWS SR-95, Scientific Services Div., Southern Region, Fort Worth, Texas.

Roberts, W.O. and H. Lansford (1979) The Climate Mandate. San Francisco: W.H. Freeman & Co.

Schaal, L.A. and R.F. Dale (1978) Time of observation temperature bias and 'climate change.' J. Appl. Meteor. 16:215-222.

Shaw, R.H. (1975) Growing-Degree Units for Corn in the North Central Region. Research Bulletin No. 581, North Central Regional Research Publication No. 229. Ames, Iowa: Iowa State University of Science and Technology.

Thompson, J. (1972) The potential economic benefits of improvements in weather forecasting. Pages 45-55, Final Report, Department of Meteorology, California State University, San Jose.

U.S. Department of Commerce (1979) NOAA Weather Radio. NOAA/PA/76015. Revised July 1979.

APPENDIX

QUESTIONNAIRE ON FARMERS' PERCEPTIONS OF THE UTILITY OF FURTHER WEATHER INFORMATION

Hello. I am ______________________ from ______________________. We are currently conducting research on farming in this area and I would appreciate it if you would help us by answering a few questions.

1. How long have you been farming (ranching) in this area? ___years ___all my life

   If less than 10 years, where did you farm (ranch) before?

2. What are some of the things you like most about living in this area, things that you think are advantages and that make this a good place to live? (Do not show or read to respondent.)

   Weather or climate related: ___dryness ___wetness ___sunshine

   ___warmth

   Other (record verbatim)

   None

3. What are some of the things you don't like about living in this area, things that you think are disadvantages? (Check list, do not show or read to respondent)

   Weather or climate related: ___too wet ___too dry ___too hot

   Other (record verbatim)

   None

The U.S. Weather Service is currently in the process of modernizing their weather service. I would like to ask you a few questions which could provide information useful for them in maintaining or improving their service.

4. Do you currently get weather information on a regular basis? ___Yes ___No

If yes: What is your main source of information? (Check list only, do not show or read to respondent.)

____Radio ____TV ___NOAA Weather Radio ___Own observations

Other

Also: How often do you listen / watch NOAA Weather radio / the radio / TV for weather information?

___Several times a day ___Daily ___Less frequently

If no: Why not? Isn't it important for your operation? (Probe)

5. Are you satisfied with the weather information you get? ___Yes ___No

If no: Why not? How could it be improved?

If yes: Is there any way in which you think it could be improved? __Yes __No

If yes, in what way?

6. Are there specific types of weather or climate information not currently provided which you would like to have? ___Yes ___No

If yes: What ones?

How would they help you in your operation?

7. With modern computers, it would be feasible to provide considerable information on past weather events such as the probabilities of a continuation or change in the current weather pattern based on information from previous years. Would you like the weather service to provide such information?

_____Yes _____No

Would it be useful for you in making decisions? ___Yes ___No

If yes: How?

8. I would like you to give me your opinion on the reliability of current weather forecasts. Please rate each of the following types of forecasts in terms of whether they are very reliable, somewhat reliable, not reliable.

(a) short-term forecasts (1-3 days).

___very reliable ___somewhat reliable ___not reliable

(b) medium-term forecasts (4-10 days).

___very reliable ___somewhat reliable ___not reliable

(c) monthly forecasts (up to 30 days)

___very reliable ___somewhat reliable ___not reliable

(d) seasonal forecasts (for periods of more than 1 month)

___very reliable ___somewhat reliable ___not reliable

9. If weather forecasts were totally reliable, how would you rank the following types of forecasts in terms of importance to your own operation? (Rank them 1,2,3,4)

	Rank
(a) short-term forecasts (1-3 days)	____
(b) medium-term forecasts (4-10 days)	____
(c) monthly forecasts (up to 30 days)	____
(d) seasonal forecasts (for periods more than one month)	____

Why do you consider _____ (fill in one ranked as most important) forecasts as most important?

10. Are there specific times during the year when weather forecasts would be likely to affect your farming decisions? ___Yes ___No

If yes: What information at what times?

In what way would it affect decisions?

If no: Why not?

11. Are there specific times during the year when information about past weather events would be likely to affect your farming decisions? ___Yes ___No

If yes: What information?

At what times?

Item 11 continued: (Are there specific times during the year when information about past weather events would be likely to affect your farming decisions?)

In what way would it affect decisions?

If no: Why not?

12. Are your farming decisions ever altered by information about marketing your product? ___Yes ___No

If yes: In what way?

If no: Why not?

13. Some farming operations may have very little flexibility with respect to changing decisions on the basis of weather or climatic information while others have a great deal of flexibility in responding. How about you? Would you say your operation has a great deal of flexibility, some or no flexibility in responding to weather information?

___Great flexibility ___Some flexibility ___None

Why do you say so?

14. Can you think of any (or "any other" if some have been mentioned) specific instances in which you changed your mind about doing something on your farm or decided to do something on the basis of a weather forecast received?

____Yes ____No

If yes: Can you give me an example or two?

15. Could you think of any situation in which it would be useful to have good weather information from the past to help make a decision about current farming practices?

____Yes ____No

If yes: In what circumstances?

9a. In your opinion, what accuracy (in percent) would forecasts have to have in order for you to use them in your management decisions?

	Rank
(a) short-term (1-3 days)	____
(b) medium-term (4-10 days)	____
(c) monthly (up to 30 days)	____
(d) seasonal (more than 1 month)	____

Rationale For Each Question

Introduction: Does not reveal exact purpose of questionnaire, thereby allowing the possibility of some open-ended questions which might help place weather in perspective.

1. Experience seems to be a key variable and this is related to number of years farming in area.

2. and 3. These very general questions have been used on other questionnaires and generally yield much information about the area. Of particular interest here is whether weather and climate are seen as among the important factors and how they appear. For example, in the Great Plains farmers tended to mention drought more often than any other advantage or disadvantage.

4. One measure of the perceived usefulness of weather information might be the avidity with which it is absorbed as measured by whether and how often weather reports are attended to.

5. A general measure of satisfaction with current weather information as well as suggestions for improving it.

6. Possibly could reveal raw measures which might be useful.

7. A possible new type of information processing which the weather service could provide. It offers the possibility of substituting good information from past periods for experience.

8. A measure of the credibility or reliability of forecasts of various durations.

9. A ranking of the types of forecasts in terms of importance to their operation.

10. This could possibly be made more explicit by asking a series of questions about the utility of weather information at the time of planting, fertilizing, spraying for pests, or harvesting. It should yield information as to time periods in which weather information is crucial for which types of operations.

11. A parallel question to 10, but focusing on the utility of past weather information, i.e., the probability of ameliorating weather in a cold spring based on past weather.

12. This is just to test responsiveness to information using a different type of information in case farmers are responsive to information but not weather.

13. Try to get at the degree to which farmers are locked into their daily routine once basic decisions are made.

14. and 15. Try to get at question of weather information sensitivity.