Agriculture

AGRICULTURAL METEOROLOGY DEFINED

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1. AGRICULTURAL METEOROLOGY

Agricultural meteorology involves the study of how weather and climate variabilities (spatial and temporal) influence the amount of agricultural production, the profitability of farming and the resulting social structure of the rural community (1). The study includes the impact of these environmental variabilities on the production of crops, forages and domestic animals. Agricultural meteorology includes the design of farm management options which avoid unfavorable weather events or ameliorate the atmospheric condition. The definition of the economic benefits and disbenefits from weather events for farmers and the agricultural infrastructure is also included in agricultural meteorology. Thus, almost every topic studied in agricultural meteorology also involves an application from a physical, biological, or engineering science or from economics.

Research in agricultural meteorology involves investigations which innovates further "weatherproofing" of the agricultural system. Currently these research efforts are being conducted in Agricultural Research, SEA, and Economics Statistics and Cooperatives Service of the United States Department of Agriculture (USDA), and the Agricultural Experiment Stations. Of these agencies the research of the Agricultural Experiment Stations comprises the largest total in manpower and money.

Probably because of the events of the 1970's (Russian wheat deal, Sahel drought and the U.S. midwestern drought of the mid-1970's) the U.S. research and development efforts in agricultural meteorology have received considerable analysis. The National Research Council (NRC) sponsored one study (2) which dealt with the identification of research needs dealing with the effects of climatic fluctuations on agricultural production. The NRC also included an evaluation of the effect of climatic resources on food and nutrition under a study requested by President Ford (3).

In 1975 the USDA and the Land Grant Universities conducted an evaluation of research priorities for agriculture. These efforts culminated in a conference in Kansas City at which farmers and other clientele groups attended. A long "shopping list" of research needs was identified (4), but water research was ranked at the highest priority. Later, USDA (5) presented a detailed study to the Congress on the effects of weather and climatic variabilities on agriculture.

The Agricultural Experiment Stations have been involved with agricultural meteorology research since the mid-1940's. Recently the University of Missouri (6) conducted a two-day seminar on the use of technologies to avoid the weather hazards for agriculture. In October 1979 the State Agricultural Experiment Stations joined SEA, USDA in sponsoring a symposium on the research needs dealing with the effects on agriculture of weather and climatic events. At workshops held in conjunction with this symposium the two hundred participating scientists identified important research areas. This report summarizes their conclusions.

2. RESEARCH NEEDS

A. Definition of weather-imposed stress on grain crops, meadows and range lands.

Plants are stressed by several different environmental events and in many degrees of intensity. In fact, plant stress in the field is probably a usual and regular event rather than a rare occurrence. But, as used here plant stress is an unfavorable plant condition (usually visibly apparent) from which the plant cannot completely recover.

Weather-imposed stress may come from episodal weather events, such as lethal or near-lethal high and low temperatures; or stress may be associated with the accumulative effects from sustained weather patterns, such as continued dry weather. Stress may also be imposed by weather on plant systems indirectly through insects, disease and weeds. In the first case, the stress occurs because weather favorable for the pests increases the pest population to a level adequate for stressing plants.

There are two major unknowns concerning plant stress. First, it is difficult to recognize the point in time and space at which plant stress begins and to quantify the intensity of stress. This problem is particularly critical for stress imposed by the effects of weather. Research to find methods for recognition of the onset and the intensity of plant stress should focus on soil water budgeting and remote sensing. Secondly, the effects of stress on plant development and subsequent yields are not known. When weather imposes a stress on a field of grain, one can only qualitatively estimate yield reduction. Similarly, reduction in production through stress over areas as large as a state or region cannot be quantitatively estimated. Research to develop appraisal methods of yield reductions due to stress is yet to be developed.

The definition of stress and its effect on yield is important to agriculture. Quantitative estimates of grain production require information on stress; and the operation of farm management options, such as irrigation, pest management and frost protection, require quantitative information on plant stress and its effects.

It should be noted that some of the research objectives dealing with stress on plants will be studied by the new Regional Stress Laboratory being established by Agricultural Research, SEA.

B. Modeling plant and pest response to weather and other environmental events.

Modeling, as used here, refers to analytical treatments of the effects of weather on plant growth, plant development and economic yield. The plant responds to the weather through its dependence on the environment by many complicated physical and biological processes. Through these processes, plants take carbon dioxide from the atmosphere to produce dry matter and cool the "biological machinery" by using soil water for evapotranspiration. There are, of course, many feedbacks between photosynthesis and the cooling processes. To make real progress in research for understanding how plants grow and produce grain, one must study the entire soil-plant-air system. This interdisciplinary approach requires input from soil physicists, plant physiologists and micrometeorologists.

In one form, modeling attempts to express mathematically the biological response to weather variability by defining the change with time of the rates of photosynthesis, respiration, translocation and other important biological processes. These processes are often mathematically expressed in terms of differential equations, which must have the initial conditions mathematically defined, experimentally derived coefficients, and complicated feedback relationships between the biological processes. In the true sense, this modeling technique attempts to simulate growth and grain production through mathematical expressions. Research needs to focus on finding, through experimentation, the coefficients of these mathematical expressions. These coefficients can be expected to vary with crop and stage of plant development. Even after the growth processes for a particular stage of development are effectively simulated, it is still necessary to determine how plants advance from one development stage to another, e.g., how plants produce additional nodes, flower, set fruit or grain, etc.

A second form of modeling deals with mathematical expressions which simulate the direct effects of weather variabilities on yields. In this case, grain production from large areas, such as the Great Plains, U.S. Cornbelt, etc., is estimated from the observed weather in these areas through regression equations. These regression techniques provide input for most regional and national yield estimates by governments and other assessment groups. Most current regression models do not account for variations in the planting, flowering, and fruit-set times from year to year. Thus, this method of assessment requires investigations to find ways of determining crop growth stages for different years over large areas. Operationally, investigations should focus on the development of methods for using remote sensing to determine planted areas for different crops and the stage of crop development. Further research into developing regression methods for large area modeling of production is not as demanding as with developing methods for modeling biological response. In fact, some scientists believe that progress in the estimation of production for large areas is impeded by deficiencies in the models for the biological response.

Insects, disease pathogens and weeds also respond to weather, and these relationships must be expressed in mathematical terms. Perhaps the greatest research challenge involves the development of mathematical expressions which explain both pest and plant development; and, when solved, indicates the effect of pests on plant development and subsequent crop yield.

The use of models of crop and pest response to varying weather has three important applications to agriculture. First, the mathematical relationships provide estimates of crop production in the agricultural production areas throughout the world. These estimates are essential for formulating marketing, storage and production goals. These models can provide an early warning for disasters imposed by weather-related events such as drought, disease, etc. Second, plant breeding could be enhanced by the identification of the life stages in plants and the biological processes for which the weather and climate events are critical to plant survival and high yields. Models should identify the plant characteristics that plant breeders need to observe in screening plants to isolate superior individuals and varieties. Third, models of crop response provide information concerning farm management options. Models can identify the penalties from unfavorable weather, so that the risk to a farm operation from unfavorable weather can be evaluated from climatic data. This risk analysis will lead to the selection of the best farm management option for a given climatic area and cropping practice. Of course, modeling pest response from the weather is essential to cost effective and environmentally responsible pest management programs.

C. Meteorological Research to Support the Agricultural Meteorological System

Because of the nearly total dependence of agriculture on climate and weather, nearly every phase of meteorological research has an effect on agriculture. But in the context of these remarks, attention will be focused on the research needs in meteorology which either directly affect the growth processes of plants or are involved in the operation of the agricultural management and/or marketing systems.

The diffusion processes of the lower atmosphere, which transports carbon dioxide into the plant canopy and removes the water vapor, are generally understood; but the application of these processes to a given crop canopy requires adaptation to the local wind and temperature conditions. These local, or micrometeorological conditions, are site specific; but they are also related to the large-scale weather and climate conditions. The linkage between the micrometeorological and the circulation features at the scale of synoptic meteorology needs study.

Insects and pathogens are transported by air currents. This dispersion of pests by winds requires some definitive research which will lead to the use of dispersion models in pest management techniques.

Every farm management scheme designed to "weatherproof" the agricultural system, such as irrigation, animal shelters, tillage methods, grain drying, etc., have capital requirements, energy needs and operational costs. Methods for studying the economic feasibility and societal advisability of the management options, which alter the weather hazard, are required. The design of methods for risk analysis require inputs from economists and climatologists. The research focuses on some very important issues involving water demands by agriculture, mechanization with the use of fossil fuels in farming, the optimal size of farming units and the environmental integrity of land, water and air.

3. Deterrents to Agricultural Meteorology Research

A. Data Sets

To accomplish the research and development outlined here and to verify the integrity of the models produced from this research both current and historical data sets are required. First, a biological data set, in which plant growth, development and yields are reported, is urgently needed. Specifically this data set should involve growth measurements (note initiation, internode growth, dry matter accumulation, etc.), dates of phenological events (planting, emergence, floral initiation, fruit set, and maturation) and yields of grain and stover. The second type of data set is climatological data which relate to the biological development in both time and space. This requires the establishment of climatological observing stations at the experimental farms where the biological data sets are being accumulated.

In some cases, assessments of the large scale impacts of climate variabilities on agricultural production are made using climatic data from a network of Cooperative Climatic Stations. At these stations, maximum and minimum temperatures, rainfall and snow depth are recorded. Traditionally the establishment and maintenance of this network of stations have been the responsibility of the National Weather Service. Agricultural Climatologists fear that the quantity and quality of data from this source have declined.

The administration of observation networks is not attractive to the bureaucracy of government (state and federal) and research institutions (Agricultural Experiment Stations, Research Center of Agricultural Research, SEA). The instrumentation, observations and maintenance of equipment require money which often does not reflect immediate return. Apparently administrators feel that justification of the support of these networks would fail to attain accountability through audits by Internal Review Committees, Government Accounting Office of the Office of Management and Budget. Somehow a justification for these programs must be made so that the necessary data sets are available to the state and federal scientists.

B. Leadership in agricultural meteorology.

Scientists, both state and federal, in agricultural meteorology feel frustrated in attempts to compete with the more traditional aspects of agricultural research. The research efforts in agricultural meteorology are fragmented within the organizational structures of the State Agricultural Experiment Stations, Agricultural Research, Economics and Statistics and Cooperatives Service (ESCS) and other research organizations. It appears that a focal point for agricultural meteorological research should be established in the Science and Education Administration, USDA to assist with the coordination and development of research programs by Cooperative Research and Agricultural Research. A similar focal point may be needed within ESCS.

In the long run a National Agricultural Meteorology Research and Education Center (NAREC) may be required. NAREC would serve the coordination roles described in the previous paragraph and also be involved with the conduct of research projects which are beyond the scope and complexity of the individual research centers in the Agricultural Experiment Stations, Agricultural Research and ESCS. In addition, it would serve federal extension through the development of an education program.

Footnotes and References

1. By the definition used here, the study of Agricultural Climatology forms a subset of topics under Agricultural Meteorology.

2. National Research Council, 1976. Climate and Food, Climatic Fluctuations and U.S. Agricultural Production. National Academy of Sciences, Washington.

3. National Research Council, 1977. Supporting Papers: World Food and Nutrition Study, Vol. 2, Study Team 5, Weather and Climate. National Academy of Sciences, Washington.

4. U.S. Department of Agriculture, 1978. Agricultural and Food Research Issues and Priorities, a Review and Assessment. USDA, Washington.

5. U.S. Department of Agriculture, 1979. Weather and Water Allocation Study, for the President and Congress, USDA, Washington.

6. University of Missouri, 1977. Proceedings (of the) Climate-Technology Seminar, College of Agriculture, Columbia, Mo.