THE NEED TO EVALUATE WEATHER

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Evaluation of weather in relation to food production is more than a need; it is a must.

Thoughtful demographers are posing the harsh question: To what purpose do we use modern medicine to save an infant from lethal disease only to let it die of starvation a few years later? (Science 143:916)

Here in the United States the average man on the street would probably regard such a question as unduly farfetched or even nonsensical. His thoughts on food are likely to be confined to: (a) griping about the size of the tab (which covers many nonfood items) when checking out of the local supermarket, (b) developing strategems to avoid overeating and (c) decrying the cost to the taxpayer of government programs related to food surplus.

People view things in the light of their experience. And so we must recognize the general public empathy in the United States with relatively picayune food problems and widespread public apathy over the demands of burgeoning populations over the world for food.

Developing public awareness of the problems we are here discussing is certainly a need.

Most of you are acquainted with the excellent documentation that the Food and Agriculture Organization has brought together on the stark problems facing us if we are even to approach "freedom from hunger" in the years ahead. Some of you attended the World Food Congress in Washington, D. C., in 1963 and collected the vast array of manuscripts testifying to the urgency of meeting food production problems the world over. The formidable evidence makes one shudder.

I hesitate to bore you by repeating some of the statistics, but they ought to be in the record.

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The population of the world is expected to double and exceed six billion by the turn of the century.

World food production must be trebled by the turn of the century if the population is to have enough to eat.

One half or more of the present population of three billion suffer from hunger or malnutrition.

Two and one quarter billion people comprising the populations of Latin America, Africa, the Near East and the Far East receive only an average of 2,150 calories per day with about 80 percent of the diet made up of cereals, starchy roots and sugar. By contrast, the 875 million people in North America, Europe and Oceana receive 3,050 calories of food per day with a little over half coming from cereals, starchy roots and sugar.

In addition to attaining freedom from hunger there is pressing need now to upgrade diets in terms of the proportion of protein.

While recognizing the colossal task now before world leadership in meeting the enormous demands for food over coming decades, we also ought to keep in mind the eternal verity in the old cliche that "man cannot live by bread alone."

We are by nature wild animals "plus"; and the "plus" is the combined effects of civilization.

What is civilization?

Usually, we think of civilization as made up of artistic creations, mechanical devices, books and pictures, enlightened religious ideas, handsome buildings and superhighways, scientific accomplishments, social and philosophical knowledge, political institutions and ingenious ways of doing a wide variety of things. We think of man's abilities in creating these things as being due to his possession of a mind with the capacity to reason.

But what is the first requirement of civilization?

Let me quote a noted anthropologist, Prof. Braidwood of the University of Chicago (Agricultural History 28:41, 1954):

Historically oriented anthropologists agree that the one absolute necessity for the appearance of civilization (in a fully meaningful sense of the word) would
be full, efficient food production. Subsequent appearance of other attributes of civilization are contingent upon the original appearance of food production.

The history of ancient Sumeria provides eloquent testimony to support Prof. Braidwood's thesis. The fabulous cities with magnificent buildings that the Sumerians built in the third and second millennia B.C. were made possible by full and efficient food production from an irrigation agriculture based on a brilliantly engineered canal system. Basically, weather events destroyed this civilization. Flood waters coming down the Tigris and Euphrates eventually destroyed the canal system through a relentless deposition of sediment. In coping with the sediment Sumeria was largely dependent on the labor of captured slaves.

Some historians have indicated that the high level of civilization in ancient Mesopotamia was destroyed by the vicious raids of Mongols led by Hulagu Khan in 1258 A.D. But recent evidence by archeologists Jacobsen and Adams (Science 128:1251, 1958) indicates that Hulagu and his horsemen found nothing but a devastated scene when they invaded the region and ever since have been unjustly blamed for causing the devastation. These investigators found that by the 12th century, floods delivering sediment into the irrigation waters had caused far greater devastation to the irrigated land, and thus to the food supply of the cities, than any invading horde could have done.

This anthropological evidence drives home the point that in our consideration of weather and food we must go much beyond that needed merely to maintain man as a wild beast. We must provide for the "plus," the "plus" which is civilization.

We see from the foregoing that all the magnificent attributes of advanced civilization we have here in the United States rest solidly on the capacity of a relatively few American farmers to provide the basic requirements of full and efficient food production. One might even conclude that producing a bit of surplus food may not necessarily be an evil.

We now need to consider the potential supply of arable land that may be available for this full and efficient food production needed by rapidly expanding populations.

FAO reports that arable land now available for crop production over the earth is 3,500,000,000 acres. This acreage can be more effectively used by application of better technology.
Dr. Charles E. Kellogg, deputy administrator of the Soil Conservation Service, has recently completed a study of total potential land area available for crop production and finds this to be 6,589,000,000 acres. He emphasizes that this potential increase of 3,089,000,000 acres is made possible to a large extent by research findings on land reclamation and land use over the past 30 years.

Use of the potentially additional arable land over the earth will be especially susceptible to constraints imposed by weather, soil management practices, adapted varieties and pest control. More specifically, when we compare the weather-imposed problems on lands now used for food with comparable problems on lands that may be brought into production in the future, we can have full confidence that the tough ones remain to be solved. The apples on the low limbs are the easiest to pick.

If anyone doubts the profound influence of weather on the capacity of arable lands to produce food, it is suggested that they read the terse review by Dr. L. P. Smith on "Weather and Food" published by the World Meteorological Organization as Basic Study #1 in 1962. I am particularly delighted to note that Dr. Smith emphasizes the urgency of bringing new facts, new thinking and new knowledge into an evaluation of the whole array of weather factors that bear on crop production. Even so, we are not likely to eliminate the stricture so well emphasized by Maximov that water is the main limiting factor in crop production the world over.

Actually, our concern with weather in relation to food production would be largely abated should someone find the means to emasculate the "iffiness" that inordinately prevails. Let us consider an actual case.

When a wheat grower in Stanton County, Kansas, plants his grain in the fall, he can be quite certain of a bumper harvest the following summer:

- If there is a good supply of available moisture in the subsoil at the end of the fallow period;
- If rains occur in September and October to provide surface moisture essential for germination and seedling growth;
- If leaf rust does not appear during the fall as a result of extensive dewfall or rainy weather with resultant weakening of the young plants;
- If fall weather does not foster an infestation of "green bugs" which seriously weaken the young plants for tolerating winter cold;

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If warm weather during the fall does not abet an infestation of mites that transmit the "mosaic" virus which can wipe out a crop;

If the plants are not winter-killed by sudden cold snaps following warm periods in the absence of snow cover;

If the plants are not blasted by soil blowing as a result of dry surface soil and high wind velocities during early spring;

If late spring frosts during anthesis do not bring about sterilization of the flowers;

If there is an adequate amount and distribution of late spring rains to provide necessary soil moisture to carry the grain through to maturity;

If heavy dews and rainy periods in the spring do not foster an infection of leaf and stem rust, which damage or even kill the plants;

If hot weather with desiccating winds does not occur during the time of filling resulting in low test weight of the grain;

If hot, dry weather does not foster a scourge of voracious grasshoppers to devour the crop;

If convective storms during late spring and early summer do not bring on a barrage of hail to destroy or severely damage the crops;

Finally, if the wheat grower could be liberated from all of the preceding "ifs," he would "have it made."

The foregoing list of suppositions does drive home the formidable array of imponderables that the wheat grower must face over the course of a season in his planning of operations. It emphasizes that this grower has little alternative than to base his decisions on a wealth of invalid assumptions and a dearth of accurately accrued information. In other words, the decisions the grower must make with respect to weather inputs essentially place him in a poker game with Mother Nature, in which she holds most of the aces and has a knack for drawing the one-eyed jacks.

Actually, the alternative decisions a farmer must make in the face of sequential weather events imply that he should be an authority on the theory of games if he expects to win, i.e., make a profit.

Thus, it is appropriate that we mention a few broad areas of information that are urgently needed to enable the food producer to more consistently win
while playing the game with Dame Nature. Thus, we need to be far more knowledgeable on:

1. The phenology of crop plants.
2. Weather probabilities.
3. Making alternative decisions in management practices in relation to sequential weather events.
4. Weather prediction.

**Phenology of Crop Plants**

The growth and development of any plant are determined by the environment in which it is grown within the limitations of its genetic poten­
tialities.

This nice terse statement would be much more useful if we could measure "environment" by some single-valued function such as we use pH to measure the acidity of soil. Unhappily, environment is the integrated resultant of a large number of widely fluctuating variables over time. Insofar as a given crop is concerned, plant performance is the only reliable integrator of this intricate complex, and each variety appears to have its own secret values for the parameters.

Crop environment involves isolation, day length, air temperature, humidity, carbon dioxide, air movement, soil moisture, soil temperature, soil aeration, soil fertility and soil toxins. We really know very little with respect to quantifying the interactive effects at varying levels of these entities and at different stages of crop growth.

Although some of these environmental factors such as soil fertility, carbon dioxide and soil toxins are outside the realm of plant phenology, they may be modified in their effects by climatic conditions. High rainfall may accentuate nitrogen inadequacy. Wind influences carbon dioxide availability around leaves during summer days. Low soil temperature depresses phosphorus availability.

Although the interrelationships affecting crop phenology are formidable in their complexity, we must have the information for the various stages of plant development, especially during germination and seedling growth, vegetative development, anthesis and maturation. We have information that prevailing weather during one stage of growth may physiologically precondition a plant with respect to responses at later stages of growth; but quantified evidence is meager.
We need handles with which to grasp this complex. The net curvilinear regression curves such as Louis Thompson finds in his analyses of the phenological effects on grains offer very convenient handles for the initial grasp. And we ought to keep in mind that genetics offers a powerful means of developing adaptation to phenological events.

Weather Probabilities

We are making progress in developing information on probabilities for certain weather events for specific land resource areas. Mr. Goren did not become an expert card player through ignorance of the odds. Likewise, the farmer should plan his operations with full knowledge of the odds when playing the game with Mother Nature.

Let us return to our Kansas wheat grower and the array of "ifs" with which he must cope. He should have information as to the number of years out of 10 a given iffy situation is of no consequence, the number of years in which it is limiting and the number in which it is critically adverse.

We also need to ascertain the degree of intercorrelation of probabilities with respect to sequential weather events. Are wet Septembers in western Kansas associated with wet Octobers? Are wet Mays associated with wet Junes?

Harold Crutcher\(^3\) of the Asheville Weather Center has made a comprehensive study of intercorrelation between sequential weather events over the United States and finds these relationships to be of low significance nationally. However, intercorrelation of these events might be more prevalent in local areas. At this point I would like to applaud the gold mine of data the Weather Bureau maintains at Asheville. We need the means to make better use of these basic data.

Management Decisions in Relation to Sequential Weather Events

As the farmer plans his operations over the course of a season in the face of changing weather conditions he usually must make a series of decisions among possible alternative practices. Ideally, he should have available the techniques of modern production economics that guide him to the alternatives that would tend to maximize profits, or at least minimize losses, over a period of years in relation to prevailing weather probabilities.

We are acquiring a mass of evidence that soil moisture reserves can be an important guide in the farmer's decisions among alternatives.

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How much supplemental nitrogen should he apply to take full advantage of abundant soil moisture during wet years?

In prospective dry years, when soil moisture is limiting, should he spend money on herbicides to minimize competitive soil moisture losses by weeds, or should he avoid the expense of an input that might only add to his net loss?

As A. N. Duckham has pointed out in a recent paper (Reading Univ., United Kingdom, 1964), the modern farmer seeking to attain full and efficient production on an economic basis needs "to apply formal decision-making theory to 'weather chains.'"

Weather Prediction

On the evening of February 25, 1964, the Street Department in Washington sprinkled salt over key streets in anticipation of a 4- to 5-inch snowfall predicted by the Weather Bureau. No snow came.

On other occasions Washington has received a 7- to 9-inch snow when little or none was predicted.

These statements are in no sense an indictment of the Weather Bureau, but rather an illustration of the precarious state of the art. I doubt if we could find a more dedicated and conscientious group than those in the Weather Bureau, but the imponderables they must deal with are indeed frustrating.

On the other hand, a leading farm magazine publishes a chart indicating how much rain will fall and on what days it will come over a month in advance of publication. For example, the issue distributed in late September 1963 predicted that October rainfall in Maryland would be normal and that it would be well distributed over the month. In the Baltimore area, October 1963 was the first month on record in which no precipitation occurred.

To what purpose are farmers given the misinformation just cited?

Yet, one of the greatest needs in the realm of food production is that of the weather prediction. We urgently need reliable weather predictions over five-day periods, the coming month and the coming season. Research effort that would help attain such a goal is certainly of the highest priority.

In bringing together these few random thoughts on weather and food production, let no one doubt my deep conviction that progress in this field is of the greatest urgency for the future well-being of mankind. To those of you who can really do something about this need, I wish you Godspeed!