Weather x Crops

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WEATHER VARIATION AS A COST-PRICE UNCERTAINTY FACTOR AS IT AFFECTS CORN AND SOYBEAN PRODUCTION

by Roy L. Black

"There is enough evidence of cyclical patterns in weather variability, however, to advise against treatment of weather as a random variable; but variability is not rythmic enough to produce a prediction equation."

INTRODUCTION

The process of attempting to predict climate and its resultant impact on agricultural output and prices is hardly a new venture. Herschel conducted a detailed study of solar activity in the late 1700's, noting an apparent relationship with severity of climate. He subsequently compared these relationships with wheat price statistics compiled by Adam Smith for Wealth of Nations. Wallace, in 1920, used multiple regression methods to estimate the impact of meteorological variables on corn yield. This work contributed to the idea of the ever-normal granary. A number of studies examining climatic variability and food reserve policy were developed in the mid-1960's at the Center for Agricultural and Economic Development at Iowa State University and in the USDA.

Many authors, in the late 1960's and early 1970's, suggested drouth would occur in the Great Plains and Western Corn Belt in the mid-1970's. Borchert (1971), for example, delivered his presidential address before the Association of American Geographers on the topic "The Dust Bowl in the 1970's." Newman (1969) suggested similar climatic deviations could

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be expected in other middle latitude continental areas of the world including certain parts of the USSR, Eastern Europe, and Australia. However, the severity of the dry years of the 1930's and 1950's was not likely to occur until the end of the second and fourth decades of the next century.

Long-term temperature changes have received much attention too. Studies reveal a cooling trend in the middle latitudes, starting in the 1940's as can be seen in Figure 1. As a result, the growing season is two weeks shorter in England than it was in the 1930's. At Madison, Wisconsin, there has been a 8 percent increase in heating-degree-days, an index associated with fuel consumption. Review articles on climatic change and its impact on agriculture include Bryson (1974), Kalnicky (1974), Newman (1974), and Thompson (1975).

Price policy implications of climatic change, for agriculture, and for the general economy, have received more attention in the current context than in the 1930's and 1950's since feed grain "surpluses" existed during earlier dry periods. The administrator of the National Oceanic and Atmospheric Administration, for example, commissioned a study in 1973 of the influence of climate on grain yields to insure that agricultural export policy be formulated in a manner consistent with best climatological judgement (McQuigg, 1973). In 1975, climatologists briefed White House Aides and testified before the House Agricultural Committee.

This article reviews an attempt to integrate climate into price forecasting methodology, to develop supply implications for use in formulation of inventory policy, and to assess impacts on cost of production.

CONCEPTUAL FRAMEWORK

An examination of the impact of weather on supply and demand functions provides a useful starting point. The impact on the production function and on producer strategies in resource and product allocation has received considerable study. Two points stand out. As variability increases, output forthcoming from the system for a particular input configuration is less than it would be under a less variable system. Second, producers, as a result of price and yield risk, employ fewer inputs than if their expected prices were held with certainty. These are important points to consider in forecasting planted acreage, yield per acre and resources demanded. Further, since the demand for feed grains and soybeans is a derived one, variability in price and supply has a similar impact as on the supply side.

The precision with which weather variables can be forecast is an important element in the analysis. At the farm level, perception of the odds of alternative weather events influences the level of resource use including irrigation and choices among crop combinations. Impacts on financial management are substantial and contractual considerations including the percent of crop to forward contract or hedge must be carefully weighed. There is a tendency, as the level of aggregation increases, for good and bad events to cancel. But, even on the international scale, there is evidence drouth periods tend to occur simultaneously in the feed grain and wheat producing areas of the middle latitudes. In the mid-1930's, for example, yields were poor in Russia, Argentina, and Australia as well as in the U.S. Thus, in developing projections for export demand, it becomes important to be able to characterize weather events on a global basis.

What is the evidence for cyclical patterns? Is drouth a random event or does it exhibit a re-occurrence at regular intervals? It is important to recognize, at the outset, that there have been nearly as many climatic cycles reported in the literature as there have been "cycle hunters." Analysts must be exceedingly careful to not dredge up artifacts; it is important to be able to develop relationships on plausible physical relationships.

Much of the work in climatology is analagous to economics. Early work involved searching out empirical relationships, including attempting to find cycles. Later, climatologists moved toward developing more systematic general equilibrium models; in the last 20 years, particularly in the decade, much work has been done to develop computer simulation models of the earth's climate (Matthews, 1971). As in economics, fairly simple models may forecast as well or better than more complicated formulations. Budgets for research in this area have been expanded as a result of the importance in assessing man's impact upon climate.

The earth is a closed system except for energy from the sun; variation in solar activity and in the earth's orbit and tilt of the polar axis are the principal exogenous variables which determine climatic variation.[1] But, only solar activity exhibits significant variation over short (relatively) periods. For example, a rapid change occurs when day turns into night as a result of the amount of solar energy that a point on earth receives; daily temperature exhibits a well defined 24 hour cycle. Similarly, the rotation of the earth about the sun affects the amount of energy that various points on the earth receive, giving rise to seasonal changes in climate.

Sunspot activity, therefore probably solar energy, tends to exhibit cyclical behavior. Further, there appears to be a relationship between sunspot activity and climatic cycles; in North America and corresponding latitudes, sunspot activity and climatic change appear to be related in an approximately 22 year cycle consisting of two 11 year cycles. Each 11 year cycle is, however, different; at the beginning of each cycle the polarity of the magnetic field associated with sunspots completely reverses between the two solar surfaces. Thus, the charged particles reaching the earth's upper atmosphere from the sun behave differently from one cycle to the next.

The two cycles do not have the same influence on climate. In one 11 year cycle (minor), sunspot activity has little impact on climatic change. In the other cycle (major), both maximum and minimum activity produce a shift in climate. Climatologists have observed striking differences in the general circulation of the earth's atmosphere from one 11 year period to the next. Periods of drouth tend to begin near the end of the minor effect period as sunspot activity approaches a minimum; drouth tends to continue until the following peak in sunspot activity during the major cycle. Major effect minimum sunspot periods occurred in 1866, 1888, 1912, 1933 and 1954.

Periodicities in the sunspot cycle are well established with short-run peaks estimated at 10.9 to 11.3 years; however, prediction of maxima and minima remains impercise with cycles ranging between 9 and 13 years. A longer frequency, perhaps 90 years, has been estimated; if true, major characteristics should repeat themselves every 180 years.

Figure 2 depicts sunspot activity and drouth in Nebraska for the last 200 years. Sunspot numbers for the major cycles are plotted above the "0" axis, for the minor cycles below. Vertical lines depict the beginning of each major cycle; the horizontal lines depict drouth periods. A relationship between sunspot numbers and drouth exists, one too strong to ignore in decision making; however, a substantial portion of the variation remains unexplained. Two problems, from a forecasting perspective, exist. First, the start of the drouth period relative to the beginning of the major cycle must be predicted. Use of a two year lead has been a common rule-of-thumb that would have worked well for the 1930's and 1950's but poorly in earlier periods. Further, all Nebraska drouths did not end at the peak of the major cycle.

Figure 3, based upon Thompson (1970), depicts Central and Western Corn Belt corn yield levels adjusted to 1973 technology; vertical lines depict the period from the beginning of the major cycle to its peak. Forecast accuracy is improved by taking explicit account of cyclic patterns.

What about the 1970's? The current sunspot cycle, a minor, was projected, in 1969, to reach a minimum in 1974-75; it has been longer than average, nearly 13 years. More recently, December 1974, the minimum level of sunspot activity was projected to occur between late 1975 and 1977. The next cycle is expected to have a broad peak, perhaps reaching its maximum sunspot activity in 1982, a pattern similar to the late 1800's.

FORECASTING 1975-76 CORN AND SOYBEAN PRICES

An appraisal of our view of the role of applied price outlook, as it relates to management and policy decision making, is in order. Price forecasts and management decisions need to be considered jointly. For example, producers ask "To what extent should I adjust production plans to expected changes in prices and in production relationships?" It becomes important to be able to characterize not only the expected value of the forecast but meaningful measures of its dispersion, perhaps including a description of the odds of different events where events are defined as prices or supplies forthcoming.[2] Too, knowledge of the range of outcomes and whether or not certain of the extremes which could arise under a strategy are acceptable is useful.

Therefore, in October 1974, a group of us with extension outlook, management, and policy responsibilities met to formulate our program for Fall 1974 and 1975. With feed grain and soybean stocks expected to be near pipeline levels at the end of the 1974-75 crop year, weather was going to be a critical determinant of supply forthcoming. Our initial work was characterizing impacts of U.S. weather; subsequent events, and a more detailed study of climatology, suggest more effort should have been devoted to a characterization of weather on an international scale at the expense of other modeling work.

Our basic thrust was to estimate the odds of alternative corn, soybean, and wheat yields, to place each event in a general supply-demand framework to predict the probable grain, oilseed, and livestock prices associated with the weather event, and, ultimately, to develop the odds of alternative prices. The odds of alternative levels of export demand, based upon international weather events, were not developed; this was a critical shortcoming.

Table 1 depicts our estimate of the odds of alternative yields levels for corn. The odds were developed in a "quick and dirty" fashion consistent with our budget and time constraints. A trend was estimated for the period 1938 to 1973, dropping the blight year. The odds were developed from the distribution of percentage yields deviations about trend; little formal work was done with the covariance of corn and soybean yields, although a high positive one was assumed in our price analyses.[3]

The next step required making adjustments from trend for 1975 conditions including seed quality, input availability and the impact of fertilizer and chemical prices on application rates, land quality and increased odds of drouth in the Western Corn Belt to establish an adjusted expected value. The odds were calculated with respect to that base. Table 1 was estimated in October 1975 with subsequent updating and revision.

What prices did we predict in October 1974? The corn price associated with the most likely yield, 91 to 92 bushels per acre, was $2.40 per bushel, U.S. farm average for the crop year. A bumper crop, odds of 1 out of 15, was placed at $1.70 while the poorest crop was set at $3.25-$3.50. Prices, in varying detail, were calculated for the balance of the feed grain livestock sector. The forecasts were made available in our outlook extension program (e.g., Black and Ferris, 1975), farm press, to the USDA and, to a limited extent, through project COIN (1975).

FURTHER IMPLICATIONS

There are a number of shortcomings, impacts of which we hope to reduce in the coming year. First, our climatological foundations were weak; much of what has been reported here has developed in Summer 1975. As the crop year progresses, a general assessment of the conditional probability of different events based upon weather developments through the season should be made. Baker (1975), for example, attempted to assess the odds of recharge of soil moisture for Southwestern Minnesota. Finally, a more formal model with a strong international component is needed to improve the forecasting process and insure greater consistency. Work is well along here too.

The relevance of this framework for agricultural policy is readily apparent. The odds, for example, would be important in projecting cost per unit of production and governmental cost of alternative target prices. Work on the odds of alternative events, netted out on an international basis, is crucial to reserve policy including inventory policy formulation for the major grain exporting firms.

Table 1. U.S. Corn Crop Prospects

Odds	Yield, bu./harvested acre	Crop bill. bu.
1 in 15	75	4.9
1 in 10	83	5.4
1 in 5	87	5.7
1 in 3	91 - 92	6.0
1 in 5	96	6.3
1 in 15	102	6.7

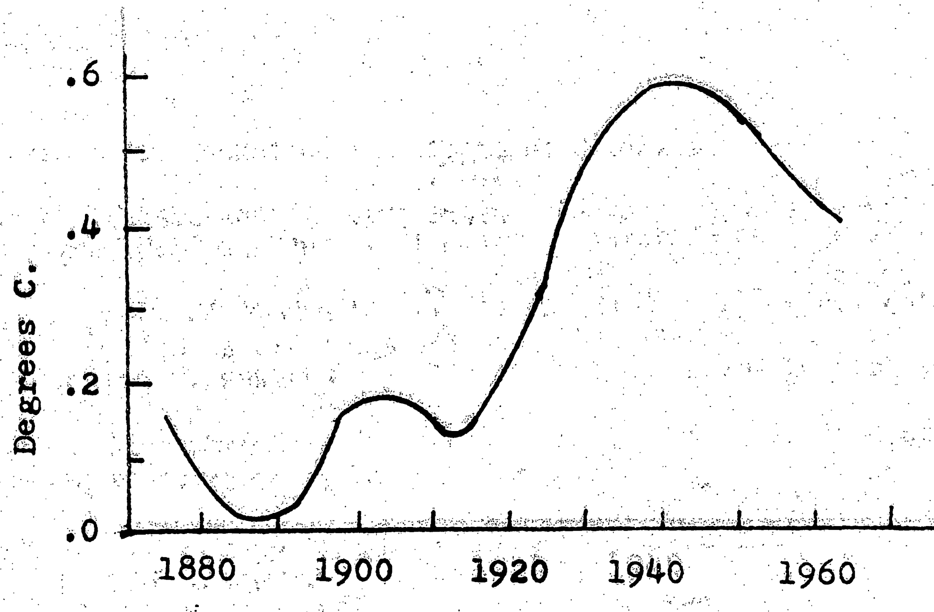

Figure 1. Variation of the Northern Hemisphere Temperature from the 1885-1890 Mean

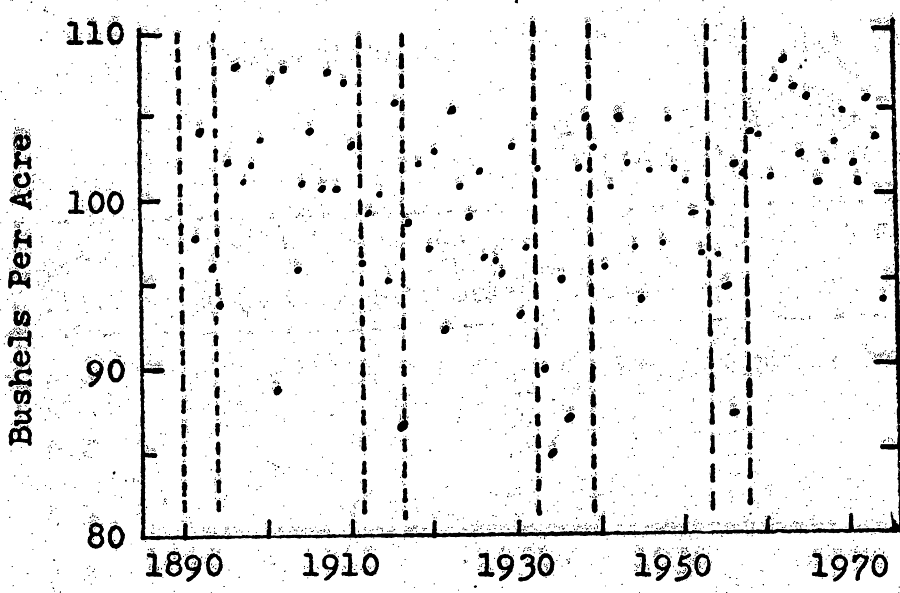

Figure 3. Simulated Five State Weighted Average Corn Yields Using 1973 Technology and Harvested Acreage: Ohio, Indiana, Illinois, Iowa, and Missouri

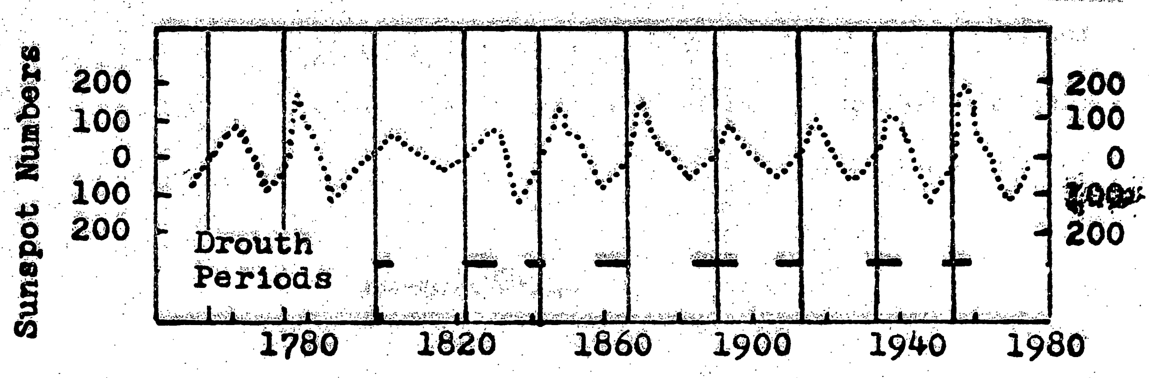

Figure 2. Solar Cycle and Drouth in Nebraska

FOOTNOTES

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The ideas presented were influenced by a number of Agricultural Economists, particularly G. Dike, L. Kyle, P. Hasbargen, and J. Ferris, as well as Climatologist Dale Linvill.

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[1] This section follows Lamb (1972), Newman (1969), and recent articles in Science, Nature, and the Bulletin of the American Meteorological Society.

[2] Note that $E[f(x,y)] \neq f[E(x),E(y)]$ if $f(x,y)$ is nonlinear where x,y are random variables and E is the expectation operator. Further, in examining probability consequences, most weather data is not normally distributed and it appears year effects are often not statistically independent.

[3] Superior methods have been followed; a careful review of the literature is suggested. Unfortunately, the data series are not readily available. See, for example, Heady and Auer (1966), Dale (1961, 1975), Doll (1967), Johnson and Gustafson (1962), Shaw (1964), Stallings (1961), and Thompson (1969, 1970, 1975). Problems include separating weather, technology, irrigation, and location of production impacts. Too, seasonal weather patterns influence crops differentially; it is possible for one crop to be excellent, another near disaster, given the same season.

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