

CLIMATE TRENDS AND AGRICULTURAL MANAGEMENT

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EXECUTIVE SUMMARY

Weather conditions from year to year are more variable than those of 40 years ago. Average precipitation has increased over the period, resulting in an increased frequency of flooding. Subsoil moisture and the state of the El Niño cycle are useful indicators of long-term weather trends. Near trend crop yields since 1996 have been associated with the low risk portion of the 18-year cycle (Benner cycle).

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INTRODUCTION

Climate changes; it always has and always will. As we learn more about climate, we get an indication of the extremes to be expected. Some changes appear to be cyclic, giving us some indication of what to expect next.

CYCLES

Diurnal Cycle

The diurnal cycle is so well known it need not be mentioned. Some aspects of the day-night cycle should, however, be emphasized. The temperature is higher in the day than at night, but there are exceptions. Wind speeds are higher in the day than at night, but there are exceptions. Thunderstorms and tornados can develop any time, but are most common in the evening.

Annual Cycle

The summer is warmer than the winter, but the record high temperature in January is warmer than some very cold days that have occurred in July. Precipitation can occur any time, but June or July is often the “wettest” month of the Year.

El Niño Cycle

The El Niño as originally named is part of the Annual Cycle, but the event of sufficient strength to influence weather beyond the vicinity of Peru develops every 4 to 7 years. The “strong” event has come to be known as El Niño around the world. The typical El Niño lasts 14 months and has a measurable impact on weather in the central United States. The El Niño is often followed by La Niña with quite the opposite weather impacts and an average duration of 10 months. The average duration is not to be considered as a limit to the duration of these events. A 3-year La Niña has contributed to drought conditions in the U.S. High Plains that have impacted wheat production, range condition, and vulnerability to range and forest fires between 2000 and 2002. The indications of a shift to El Niño during the winter of 2002-2003 bring some promise that over-winter dryness may be less a problem.

Historically, the U.S. Corn Belt has not experienced widespread drought during an El Niño season. The likelihood of flooding is not strongly influenced by El Niño, but the great floods of 1993 occurred during an El Niño event. The more serious drought years tend to be associated with the La Niña phase of this cycle.

Ocean temperatures are the dominant influence on the variability of Earth’s weather and climate. Anomalies of ocean temperature are often long-lived as the heat capacity of the top six inches of the oceans exceeds that of the entire atmosphere. The oceans are readily available as heat sources and as sinks because the turbulent nature of water transfers heat between the surface and deeper layers. The currents of the oceans move vast amounts of heat about the Earth’s surface.

Drought, Flood, and the 18-Year Cycle

Drought severe enough to reduce the nation's corn yield to 90% of the USDA trend line (<http://www.usda.gov/nass/aggraphs/cornvld.htm>) occurred 17 times during the 1900s. Although this puts the risk of drought at about 17%, or one serious drought every six years, it is better to state that three serious droughts occur during an 18-year period. Widespread crop damage from excessive precipitation (sufficient to reduce yield to 90% of trend) occurred only twice during the past 100 years. Local floods and local drought are not explained by the known cyclic behavior of the weather.

The pattern of favorable crop years and drought years is apparent from weather records, crop yield records and growth of trees as expressed in annual growth rings. Samuel Benner, a Midwest farmer of the 1880s, published a depiction of the repeating 16-18-20 year price cycle for grains and pig iron. Farmer Benner's outlook extended from 1885 until 2000 and proved accurate to ± 1 year.

90-Year Erratic Cycle

The consistent weather of 1940-1972 is often termed the "benign years." Post 1972 weather has been increasingly erratic. Periods of consistent and erratic weather have been identified to cycle with a period of approximately 90 years. The events appear to be in synchrony with the Gleissberg Cycle (Perry, 1995; Damon, 2001) of solar activity (the Gleissberg cycle is usually considered to be about 88 years, but variations of the period are expressed by some authors to as short as 70 years). If the weather patterns that have repeated over the past 800 years continue, the harshest years of this century will be observed near the year 2025, and a benign period will follow.

Longer Cycles

Weather cycles of 400-500 years influencing Midwest precipitation have been suggested but not well verified. Numerous weather cycles may exist that repeat over the millennia. The 100,000-year cycles of glaciations appear to be consistent within the geological record.

Non-cyclic Climate Change

The increase of annual precipitation in the Midwest has not been identified as consistent with known cyclic behavior. The rate of global (and possibly of planetary) warming is an issue that is held by many to be the result of human activity and not a result of natural climate variability.

Leading Weather Indicators

The risks associated with weather may be assessed on the basis of occurrence during the past century. A finer evaluation of immediate risk (drought, flood, heat, cold, etc.) may be derived from existing weather condition. The conditions or indicators that have proved most useful for anticipating weather of the coming year are: existing subsoil plant-available moisture, the 18-year cycle, El Niño, and the 90-year cycle. Over a slightly shorter time period the positions of the semipermanent High and Low pressure regions and persistence of existing weather conditions may be considered.

USING LONG-RANGE FORECASTS IN RISK MANAGEMENT

Soil Moisture

Crops are not sensitive to rain. It is true that pounding rain can physically damage a plant or may erode soils, and wetness on the vegetation may influence disease. Overall, crop success is independent of rain. The crop is not independent of soil water availability. Only rarely are rain and soil moisture availability synonymous. In regions where growing season precipitation is not sufficient for optimal crop growth and development, initial plant-available subsoil moisture is critical to crop yield.

In western Iowa, growing season precipitation is sufficient for crop needs only 20% of all years. Initially, dry soils result in a 60% to 70% chance of severe yield reduction. An initial high soil moisture level reduces the chance of drought-related yield reduction to 28%. Growing season precipitation meets crop needs in half of all years in eastern Iowa, and an initial dry condition results in only a 50% to 55% risk of severe yield reduction (Shaw, 1983).

A meteorologist may define drought differently from a farmer. To the meteorologist, a drought is a period of substantially reduced precipitation. To the farmer, a drought occurs when plants do not have sufficient water available for normal growth and development, or may include insufficient drinking water for livestock. During the 2000 growing season, considerable confusion was engendered by the U.S. Government's announcement of severe Midwest drought. Annual precipitation was 13 inches deficient, and that had an adverse impact, mainly on hydrologic conditions including river flow and municipal water supplies. The impact on Midwest plant-available subsoil moisture was slight. Many, if not most, crop yield outlooks anticipated severe drought impacts that were not likely to develop. The misinterpretation of the water situation resulted in a multi-billion dollar miscalculation of grain market conditions. There is no such thing as a 13-inch plant available water deficit. The maximum deficit possible is 10 inches, the field capacity of the subsoil layer. The deficit of the subsoil at the time of the U.S. Government advisory was about 5 inches and could be completely eliminated by normal May and June precipitation in the central United States (as was the case in most of the region).

Several soil water assessments are available for risk analysis. The better known are the Crop Moisture, and the Long-term Moisture, Palmer computations. Both products are estimates. The Crop Moisture analysis is generally published every week and is of direct value to crop production risk assessment (Fig. 1).

Using Climate Cycles

Cycles of climate range from a 24-hour cycle of day and night to the 100,000-year cycles of glaciers. The annual cycle essentially determines agricultural production. Though less reliable than the annual or daily cycles of weather, some multi-year cycles are beneficial to production risk planning. The "Benner Cycle" of some 18-19 years was established by the year 1885. Initially derived from 80 years of variability for grain prices, the cycle was immediately recognized as well correlated with the tree-ring record of climate. The Gleissberg Cycle of solar activity appears to have a close connection with the variability of weather over the approximate 90-year period of solar activity and may be the cause of an apparent 90-year "global temperature" cycle indicated in the

weather observations of the past two centuries and implied in proxy records over the past millennia.

The risk of drought is one in six, as deduced from seventeen drought events over the past 100 years. Analysis of annual crop yield records indicates that the distribution of the drought events is not random. Samuel Benner (1891) proposed that the drought pattern is governed by an 18-19 year cycle. Others have proposed that the cycle is 20-22 years. It is difficult to identify the exact period of cycles that have high "noise" levels, as is the case with the Benner cycle. Tree ring analysis over the past 800 years indicates that the period is closer to 19 years than to 22. There is some desire to know the fundamental "cause" of a cycle, and the 22-year sunspot cycle and the 18.6-year lunar cycle are popular candidates for the driving force, but no clear-cut favorite has been identified. The pattern is, however, sufficient for risk planning. Benner proposed that there is a 6-year high-risk phase and a 12-13 year low risk phase of the cycle. Two droughts are likely in the high-risk phase and one (moderate) drought is likely during the subsequent 12 to 13 years.

When subsoil moisture is low during the high-risk six year time period, the risk of severe drought is greater than would be expected during the 12 low-risk years. Using the Benner cycle to manage risk is of greater utility than assuming random occurrence of 17 droughts and 21 high-yield years over a century. Using the Benner cycle and the subsoil moisture situation is an improvement over the Benner cycle alone, in that the likelihood of an individual year being of high or low yield can be estimated rather than just assuming the normal 1-in-3 chance for the high-risk years.

A 90-year cycle (Gleissberg) may be of use in national planning but is not of great utility in year-to-year risk assessment. It is noted that crop variability from 1940-1973 was much less than in previous or subsequent decades (Taylor, 1996). Tree ring analysis indicates that episodes of reduced weather (and thus yield) variability are periodic and can be of potential utility (Stahle et al., 1998).

El Niño Cycle (ENSO)

When I first studied the El Niño in the early 1960s, it was said that it "reversed the tropical rain pattern" and had little or no impact elsewhere. Because the 90-year cycle was in the low yield variability portion of the cycle, this may have been true for the time. Subsequent to 1972, the El Niño has exhibited a strong apparent influence on crop yields in many extra tropical localities. Risk planning in the U.S. Corn Belt can be made purely on the phase of the ENSO (El Niño Southern Oscillation) events. The Southern Oscillation Index (SOI) is a simplified indicator of the status of the ENSO (<http://www.longpaddock.qld.gov.au/SeasonalClimateOutlook/SouthernOscillationIndex/30DaySOIValues/>). During La Niña years, the "risk" of drought is double the long-term average. When combined with the initial subsoil moisture situation and the phase of the Benner cycle, crop yield of above or below the trend can be anticipated at a confidence level of 80% in the U.S. Corn Belt.

Carlson, Todey and Taylor (1996) evaluated risk associated with the Southern Oscillation Index (SOI) for the U.S. Corn Belt. The analysis was for strongly positive (La Niña), neutral, and for strongly negative (El Niño) conditions in each of the central U.S. states. Very large crop yields are most likely during the negative SOI, and a tendency for drought is signaled by a positive SOI. The agricultural signal was derived from 5-month averages of the SOI. Operationally, the 30-day and 90-day moving averages are used to evaluate and to anticipate the condition of the ENSO-related events.

The 30-day trend gives a reasonable 90-day change indicator and the two combine to give a reasonable approximation of the 5-month results (Taylor, 2002, in process).

Week-by-week general information on the ENSO can be found at numerous locations on the World Wide Web. The daily view of cloud, land, and sea temperatures is also of some general utility to the person watching the long-range forecasts. Good sites for these include: www.ssec.wisc.edu/data/g9/latest_g9wv.gif
www.elnino.noaa.gov
www.dnr.qld.gov.au/longpdk

LEADING AGRICULTURAL WEATHER INDICATOR APPLICATIONS

Initial subsoil moisture, phase of the Benner cycle, and the SOI comprise the "Leading Agricultural Weather Indicators" during the time between harvest and the establishment of a crop. Risk analysis using the three indicators has proven 80% reliable during the past 80 years for the central U.S. It must be noted that the magnitude of each parameter is geographically dependent, and risk factors are accordingly different in Nebraska and Indiana even if the soil moisture is initially identical.

Seasonal weather patterns that tend to persist from May through August are often apparent by mid-April. The principal patterns for agriculture are the Persistent Pacific Negative Anomaly (low pressure in the Gulf of Alaska), the Bermuda High/Reiman Index (RI), and the Pacific Decadal Oscillation (PDO). To some extent these factors are reflected in 6-10-15 day forecasts and in the 30- and 90-day forecasts. Risk analysis should not include both the 30-day forecast from the National Weather Service and the RI and Gulf of Alaska conditions. It is reasonable to compute risk based on observed conditions and to make an independent analysis using the long-range forecasts. The two computed risk plans might then be compared. Each assessment requires that initial conditions be included. Regular monitoring of the RI and of the SOI also gives some confidence that the conditions assumed in the creation of the 30- and 90-day forecasts have not changed abruptly (or that they have changed).

The long-range forecast seems to work best when the crop to date has been assessed, and then the forecast is applied to determine if the risk under consideration is likely to increase or to decrease. The crop condition assessment may be made from the reported crop condition published by the "Statistical Reporting Service" (www.usda.gov/nass/pubs/staterpt.htm) or computed from a resource capture crop model (Shaw, 1983).

An overview of the Shaw (1983) resource capture model is given by Taylor (1999) in "Introduction to Crops and Weather" (www.extension.iastate.edu click on Weather). The model assumes that crop yield is a function of crop water stress. In the U.S. Corn Belt crop yield is usually a function of crop water stress only. During the 1970s, there was yield-limiting disease and occasionally yield is limited by sunlight or by temperature. The temperature effect may be as often as one year in three; light is limiting less than one year in seven in central North America. Resource capture yield models in Europe must include sunlight to be effective. Using the model by Shaw, the reduction in potential yield is computed on a week-by-week basis. The forecast risk is computed by simulating data through the end of the growing season based on the long-range forecast. The Shaw model has proven to be accurate to within 3% of actual crop yield for the state of Iowa.

Most long-range forecasts are designed for risk management in that the skill and probability associated with the forecast are given to the user. The U.S. forecasts are available at www.cpc.ncep.noaa.gov/products/forecasts. The world precipitation forecast

associated with the SOI is published in Australia and includes all the "noise" of the years when the SOI was similar to the present. The SOI is not the only factor considered in that this is a correlation type product. When a physical cause/effect model is used, the noise from other factors is not included. The U.S. long-range outlook often includes the mark "CL" in regions without a significant climate signal, advising the user to refer to climate records for guidance; the Australian outlook is a good climatological example (www.dnr.qld.gov.au/longpdk).

ANALOG FEATURES

Recognition of repeatable weather patterns and the usual outcome is known as analog forecasting. Some risk information is gathered from what the weather is doing now and what usually happens next. For example, a major drought to the east of a region in North America is often followed by a local drought later in the season or the following season. Sixteen of the seventeen U.S. droughts of the 20th century began in the southeast U.S. and migrated westerly. One drought began in Manitoba and migrated southeast. No major droughts have originated in the southwest U.S. and migrated northeast. Many have observed that dry localities are likely to stay dry; coupled meteorological forecast models are indeed influenced by the wet and dry soil surface in the forecast region. There are numerous other factors to be considered as analog to expected developments.

ELWYNN'S UPDATES

Comments by the author are regularly available on the Iowa extension web site: www.extension.iastate.edu; click on Weather; click on NPK. The author has regular radio broadcasts on WOI (public) Radio 640 kHz at 12:45 p.m. central time (12:10 p.m.-1 p.m. on Fridays) that can be monitored over the web at: www.woi.org/live .

Crop Moisture Index by Division

Weekly Value for Period Ending 26 OCT 2002

Short Term Need vs. Available Water in 5 Ft Profile

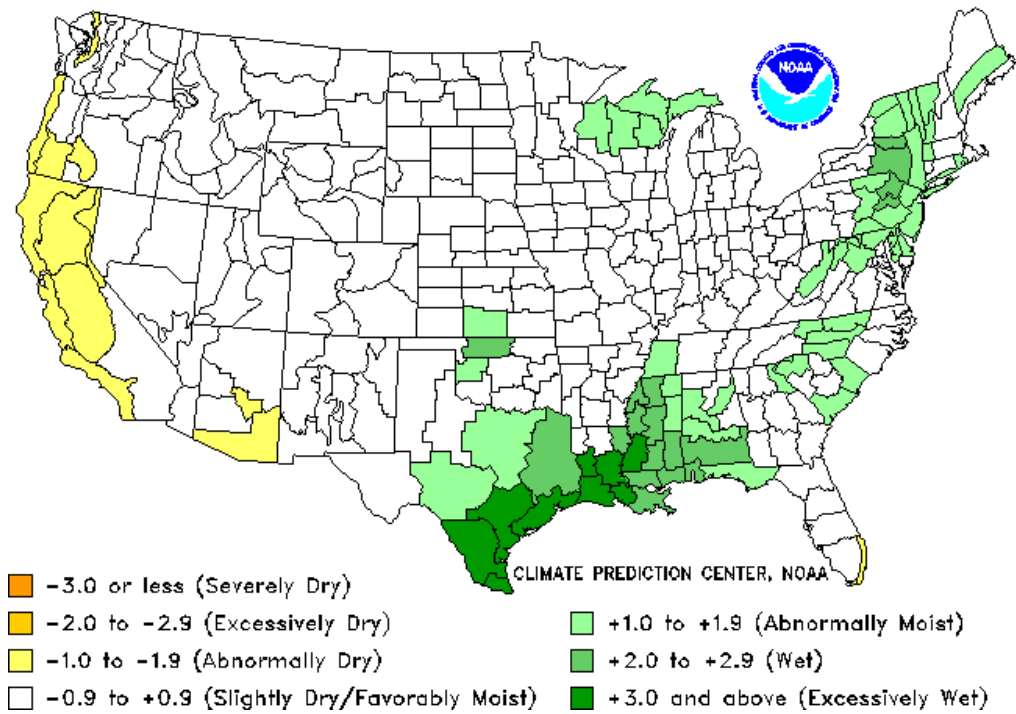


Fig. 1. Crop Moisture Index. (www.usda.gov/agency/oce/waob/jawf/wwcb.html)

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