CROP WEATHER CYCLES: MYTH OR REALITY?

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Introduction

Serious Corn Belt drought has followed an apparent 19-year cycle for 200 years. What is the risk of severe drought during the coming six years (2005-2010)? The climate is changing and will likely continue to do so, but will this change the size and suitability of the Midwest as far as Corn and Soybean production is concerned? The cycle suggests that risk of drought is greater during the next 6 years (2005-2010) than it was during the past 12, and history shows that the years of reduced yields seem to appear suddenly just when new record highs are being realized. There are some indicators of increased crop production risk, but there is no reason to assume that 2005 will be the "first drought of the new century."

Summary of Indicators of 2005

The 2004 crop proved to be a record setter. A like weather pattern occurs about once every ten years. It may not be the "best" strategy to assume that next year will be the same and that the best varieties of crop during the 2004 season will be the best in 2005. Then again do not fully rule it out; there is a 1-in-10 chance it will happen again.

- May – August 2004 was anomalously cool. The July-August period of 1992 was even colder and a record high corn yield was realized. Soybean yield was near record. September was warmer than usual both years. Corn set a new record high both years.
- Years when September temperature averaged near the August temperature yields have near or above record yields.
- A persistent "60-day" moisture cycle dominated 2004 in the Central US. This has not been observed to this extend heretofore. We do not know the full crop impact of this type of weather pattern and will be surprised if it happens again.
- Overall water stress in 2004 was not a major factor in the Corn Belt (it was for some localized areas), and the soil moisture reserve to go into 2005 appears to be building in a normal manner (with excess in some areas).
- The winter season is not expected to be excessively cold and the western Corn Belt may expect above usual winter moisture
- The 19-year cycle of weather risk to agricultural production is transitioning into the high-risk 6-year period. Historically there are 2 serious Corn Belt droughts during the six years, a 1 in 3 risk of drought for any given year. This is compared with the previous 12 years when the historical drought risk was 1 in 12. The 400% increase in historical drought risk makes modification of risk management procedures advisable.
- A weak El Niño has developed (fall of 2004). This will likely result in favorable fall

moisture and temperatures less likely to be extremely cold through the Midwest winter. El Niño events tend to persist for an average of 14 months. There is no record of widespread drought during an El Niño event in the U.S. Corn Belt. Accordingly, for the 2005-2010 period, the historical drought risk is less than 1 in 3 if an El Niño is in place and is greater if a La Niña develops.

- There are no indicators of widespread drought showing up just yet in the Corn Belt for 2005. There is one indicator, warm sea surface temperature north of Hawaii, of a return to drought in the High Plains and in the Intermountain West.
- With no strong trends in place, yields for 2005 are expected to exceed the trend by 2% (about 42 bu/a nationally for Soybean and 145 bu/a for Corn).

Weather conditions are seldom such that highly reliable forecasts are feasible. Leading weather indicators, however, have proven useful in the anticipation of above or below trend crop yields during the past decade. Indicator models are usually reliable to +/- 5% of actual yield.

Early Indicator: Soil Moisture

Crops are not sensitive to rain; they are sensitive to soil moisture. 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, however, is independent of rain. The crop is not independent of soil moisture availability. Only rarely is rain synonymous with soil moisture availability. 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).

The meteorologist may define drought differently than 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 year 2000 growing season, considerable confusion was engendered by the U.S. Government announcement of severe Midwest drought. The annual precipitation was some 13 inches deficient, and that "had to have an impact." The impact was 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 miscomputation of grain market conditions. There is no such thing as a 13-inch deficit of plant-available water. 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 "Palmer Crop Moisture" and the "Long-term Moisture" computations are well known. Both products are estimates. The Crop Moisture analysis is published every week (generally) and is of direct value to crop production risk assessment.

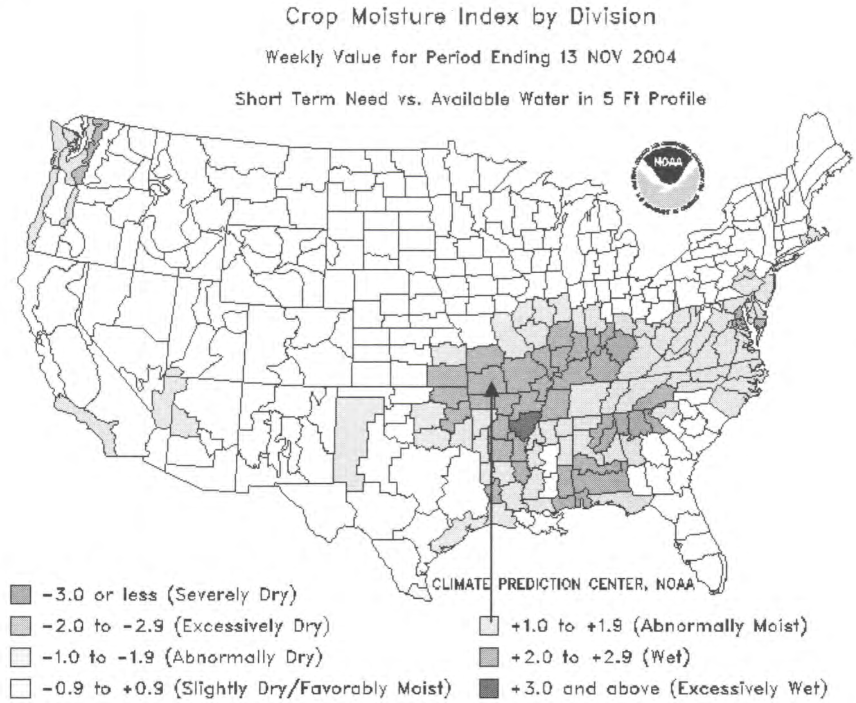

Figure 1. Crop Moisture Index. By mid-November 2004, most of the Corn Belt was either near normal moisture levels in the soil or moisture was in excess of usual. Overall a "first" positive indication of a favorable crop during 2005. (www.usda.gov/agency/oce/waob/jawf/wwcb.html)

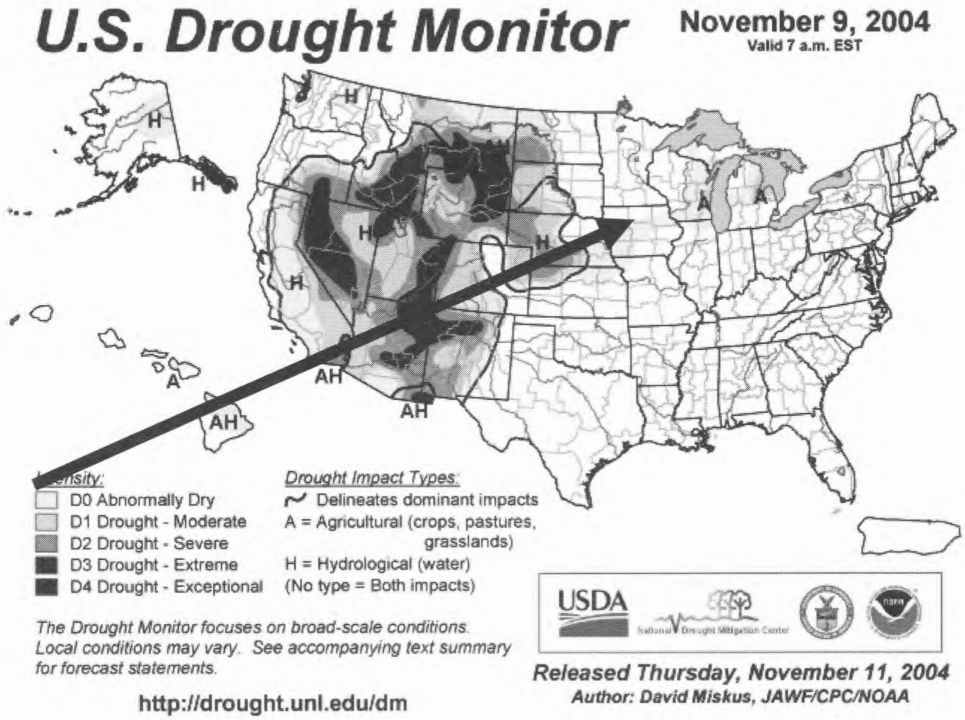

Figure 2. The US Drought Monitor in early November gave no indication of drought persisting in the Corn Belt, although a slightly dry area was identified in parts of NE, IA, and WI. A 4-year drought is persisting in the Inter-mountain West.

The newer "U. S. Drought Monitor" product is intended to provide detailed analysis and to employ state of the art methodology in drought assessment. It is anticipated that drought mitigation is feasible when assessments are well made. The drought monitor program has not yet yielded information concerning crop risk that is superior to the crop moisture index. The drought monitor may be viewed at: www.drought.unl.edu/dm.

Weather Cycles and Trends

Three, multiyear, weather cycles top the list of weather trends impacting crop production. First is the El Niño that has gained enormous notoriety during the past 20 years. The second is the so-called 18 or 19-year cycle. Third is the 89-year tendency of climate to move through harsh and favorable periods. Cycles of climate range from a 24-hour cycle of day and night to the 100,000-year cycles of glaciations. 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 60 to 90-year "global temperature" cycle indicated in weather observations of the past two centuries and implied in proxy records over the past millennia. The El Niño has been known in South America from colonial times, but the impacts in the US Corn Belt have only been fully recognized since 1982.

The risk of drought is one in six as deduced from seventeen widespread 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 climate pattern is, however, sufficiently reliable 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. The Benner Cycle, as originally published, transitions from low-risk to the high-risk phase by the year 2005.

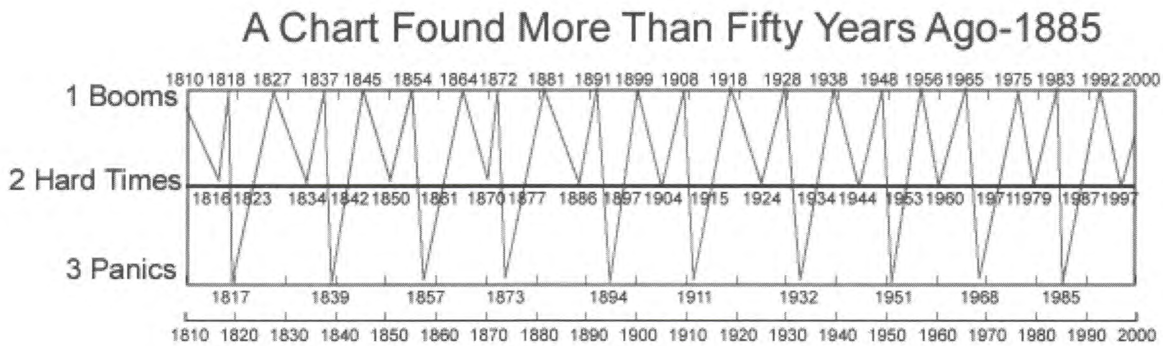

Figure 3. The "Benner" cycle is about 18.6 years. Historically, two widespread droughts develop during the years from the Panics to the Booms condition (about a 6-year period). Extrapolation of the chart indicates that 2005-2010 may be expected to produce two drought events.

When subsoil moisture is low during the high-risk six year time period, the chance 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 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 the 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).

ENSO

The El Niño exhibits a strong apparent influence on crop yields in many tropical and extra tropical localities. Risk planning in the U.S. Corn Belt can be made purely on the phase of ENSO (El Niño Southern Oscillation) events. During La Niña years, the "risk" of drought is double that of 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.

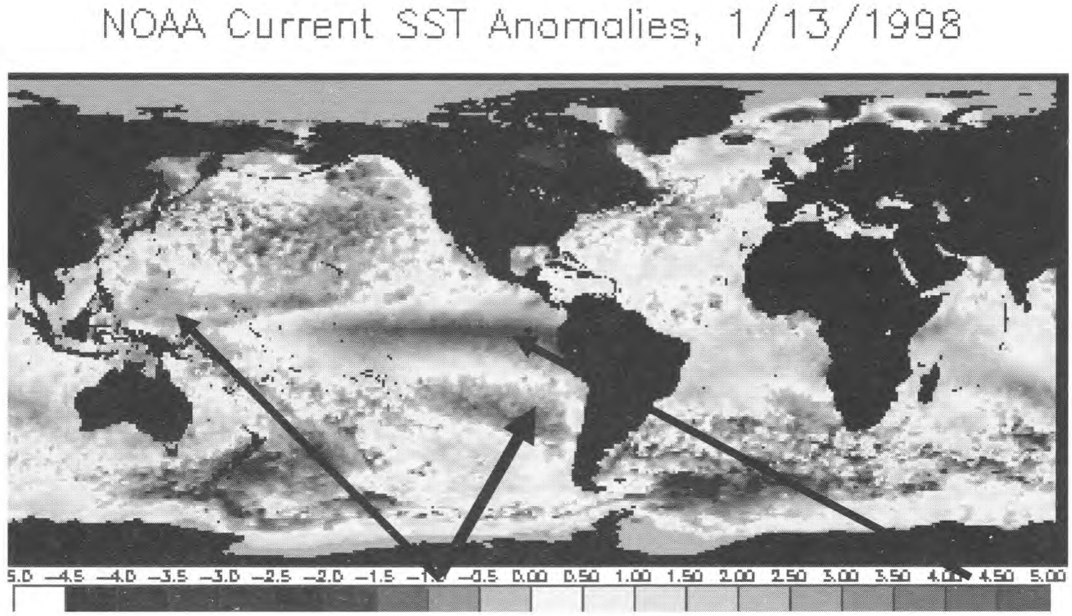

Figure 4. When the sea surface temperature is markedly warmer than usual in the Eastern Equatorial Pacific, El Niño conditions exist.

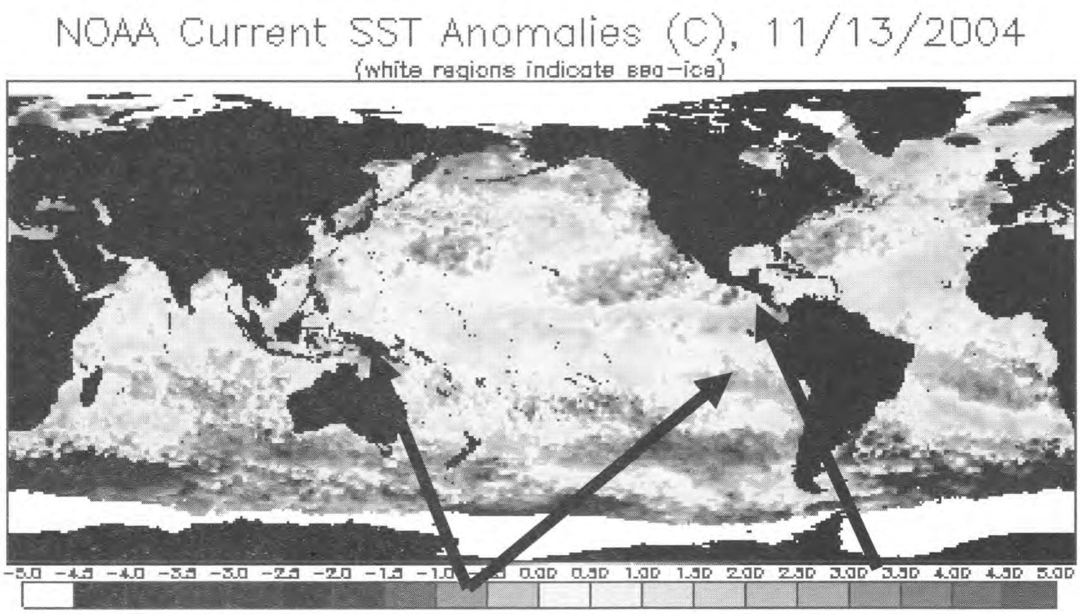

Figure 5. November 2004 conditions indicated the possibility of a weak El Niño event in the Mid-Pacific. Although it may or may not strengthen into a "classic" El Niño, it is likely to be sufficient to result in a Midwest winter that is not bitterly cold and is on the wet side of usual to the west and the dry side of usual in the Ohio River Valley (all positive toward favorable crop conditions in 2005).

Carlson, Todey, and Taylor (1996) evaluated risk associated with the Southern Oscillation Index (SOI) for the U.S. Corn Belt. The analysis evaluated yields as influenced by strongly positive (La Niña), neutral, and 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 average is used to evaluate and 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, 2001, 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) to characterize the flow of moist air from the Gulf of Mexico, 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 issued by the U. S. Climate Prediction Center (CPC). 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 be of greatest utility when crop development to date has been assessed and then the forecast is applied to determine whether 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" or computed from a resource capture crop model (Shaw, 1983) (www.usda.gov/nass/pubs/staterpt.htm).

Taylor (1999) gave an overview of the 1983 Shaw resource capture model 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, yield-limiting disease occurred, and occasionally yield is limited by sunlight or by temperature. The temperature effect may occur as often as one year in three, and sunlight 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.

The impact weather has already had on crop yield is at least as important as the forecast crop yield. Grain traders are often more interested in a good assessment of what has happened so far than in what will happen next. Knowing in early July of 1988 that 1/3 of the U.S. soybean crop had already been lost was of more value than the prediction that it would be 35% by the end of the season. Knowing that temperature and scant rain had already reduced a nation's edible oil production by 20% was more important than the forecast to the end of the season. Accordingly, crop weather models have a substantial real-time value aside from the utility for incorporating forecast weather conditions to give final yield.

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. long-range forecasts are available at www.cpc.ncep.noaa.gov/products/forecasts. A world precipitation forecast associated with the SOI is published in Australia. Because the Australian produce is simply an average of conditions that were observed under similar SOI trends, the product includes conditions incidental (noise) to those caused by the state of the SOI. 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, that is to a product such as the Australian outlook (www.dnr.qld.gov.au/longpdk).

Analog Features

Some risk information is gathered from current conditions and records of conditions that usually follow. 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 southwest. No major droughts have originated in the southwest U.S. and migrated northeast. Many have correctly observed that dry localities are likely to stay dry. Coupled meteorological forecast models are influenced by the persistence of wet and dry soil surface conditions in the forecast region. Beyond soil moisture there are numerous other factors to be considered as analog to expected developments.

Summary

The computed likely hood of above trend corn yield for the U. S. in the 2005 season is 52%. The likely value will increase to 72% if an El Niño event is evident in the spring. The trend yield for 2005 is 142 bu/a. The most likely yield is 2% above the trend or 145 bu/a. Risk is modified according to environmental conditions as the growing season advances.

Soybean yield is greatly influenced by late season (August) weather conditions and early season risk assessment methods have not proven to be as reliable as estimates for corn. It is appropriate to consider that soybean will follow the corn condition until mid-season when computation of soybean yield becomes less uncertain. The most likely U. S. soybean yield, computed as comparable to corn, is 42 bu/a. This does not consider the (yet to be evaluated) risk of severe disease (rust). Should widespread infection of rust be identified in the southern U.S., an attempt will be made to advise as to areas likely receiving significant wind transport of the pathogen. The advisory will be located under "Weather" in www.extension.iastate.edu

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