# 6.6 A SEASONALLY ADJUSTED INDEX FOR PROJECTING AGRICULTURAL DROUGHT

Patrick E. Guinan[1,2,*], Wayne L. Decker[1] and Anthony R. Lupo[1]

[1]Department of Soil, Environmental, and Atmospheric Sciences and [2]Missouri Climate Center
302 ABNR Building
University of Missouri-Columbia
Columbia, MO 65211

## 1. INTRODUCTION

Drought and its impacts are a complex issue, but it is generally defined as a period when insufficient water is available to meet the needs (Redmond, 2002). Examples of impacts include water shortages that can affect hydropower, irrigation, navigation, recreation and wildlife habitat. Additionally, depleted soil moisture supplies can stress various forms of vegetation during the growing season. Agriculture is especially affected by drought because lack of water can lead to reductions in crop yields and forage growth. Insufficient water and feed supplies may also be taxing on livestock. All these impacts can lead to social and economic burdens for people in addition to environmental stress.

Missouri experienced back-to-back agricultural droughts in 2002 and 2003 with northwestern sections of the state especially hard hit. According to the National Drought Mitigation Center's Drought Monitor map, which is posted and archived at their web site, portions of northwestern Missouri were in a drought for 98 consecutive weeks (July 9, 2002 – May 18, 2004). Agricultural impacts primarily occurred the first year with hydrological and agricultural impacts felt the second year.

Unfortunately, row crops suffered over portions of Missouri during these years. A joint drought assessment estimate issued by the Food and Agricultural Policy Research Institute (FAPRI) and Commercial Agriculture Program at the University of Missouri, and based on the final 2002 crop report from the Missouri Agricultural Statistics Service (MASS, 2003) estimated lost farm revenues in Missouri due to crop losses of $244.4 million (FAPRI, 2003). The primary losses were due to reduced yields in corn and soybean production. FAPRI generated an informal report for Missouri's agricultural drought of 2003 and estimated statewide crop losses at $325.2 million for the state (E-mail communication with Patrick Westhoff of FAPRI, 2004).

Crop Reporting District 1, which constitutes 15 counties in northwestern Missouri (Figure 1.1), experienced the brunt of the 2-year agricultural drought with 2002 corn and soybean production reduced 25% and 15%, respectively, compared to the previous 5-year period average (1997-2001; MASS, 2003-04). In 2003, average corn and soybean yields in Crop Reporting District 1 declined 18% and 29%, respectively, compared to the previous 5-year average (1998-2002). Although no dollar estimates were made on the lost revenues from corn and soybeans for Crop Reporting District 1, it is likely financial hardships were experienced by many producers and local communities in northwestern Missouri.

*Corresponding author address: Patrick E. Guinan, Univ. of Missouri, Department of Soil, Environmental, and Atmospheric Sciences, 302 ABNR Building, Columbia, MO 65211; E-mail: guinanp@missouri.edu

Knowing that agricultural drought is a recurring phenomenon in Missouri, it is important that producers develop a strategy and preparedness plan to combat the impacts of future dry spells. If producers are aware of the potential for a drought before and during the growing season, and monitor the situation throughout the period, they could devise a management strategy to lessen the impacts. The goal of this paper is to provide the farmer with an operational tool in the form of a seasonally adjusted index that will monitor and project the likelihood of an agricultural drought for a region in Missouri. The region used in this study is Crop Reporting District 1 of northwestern Missouri.


Figure 1.1 Missouri Crop Reporting Districts

## 2. DATA COLLECTION AND ANALYSES

### *2.1. Data Collection*

Crop yield data were obtained from the USDA's National Agricultural Statistics Service (NASS) Data Base (http://www.nass.usda.gov:81/ipedb/ ) and included average annual corn and soybean yields from each county in crop reporting district 1 (CRD 1) for Missouri. The periods of record for corn and soybean yields are from 1920-2003 and 1944-2003, respectively.

Weather data consist of 84 years of daily precipitation records from 1919 through 2002 for all counties located in Missouri's CRD 1. Three separate data sets were collected with the first one obtained from the Midwestern Regional Climate Center (MRCC) database and consisting of weekly precipitation records from 10 weather stations affiliated with the National Weather Service (NWS) cooperative observer program (COOP). The period of record collected from the 10 cooperative weather stations in Missouri CRD 1 is from 1919 to 1948.

The second data set was compiled by the Midwestern Regional Climate Center, and contains weekly data from all active National Weather Service Cooperative weather stations in Missouri's CRD 1 during the period 1949-1980. A computer program was developed at MRCC, which extracted weekly precipitation data from cooperative stations located within crop reporting districts. All cooperative weather station data in Missouri's CRD 1 were averaged together in order to develop a weekly precipitation average for each year within the region. Data, however, could only be collected after 1948, which is the year climate data became digitized nationwide.

The third data set was obtained from the Missouri Agricultural Statistics Service (MASS) and contains daily precipitation observations from each county in Missouri's CRD 1 from 1981 through 2002. The MASS data set was established in 1981 when MASS had the foresight to recognize the need for an available infrastructure capable of providing an extensive precipitation monitoring network for every county in Missouri. MASS purchased 114 rain gauges (plastic with funnel, tube, and outer cylinder) for each Farm Service Agency (FSA) county office and supplied employees with log books to record daily precipitation observations. The network has been operational for over 23 years and has accumulated an extensive and very important climate database for Missouri.

### *2.2 Crop Yield Analyses*

Corn and soybean yield data were collected for Missouri's Crop Reporting District 1. Upon analysis the data revealed the trend of increasing yields for both crops, which was primarily due to the introduction of fertilizer, improved seed genetics and better farm management practices. Graphical representations of the yields are shown in Figures 2.1 and 2.2.

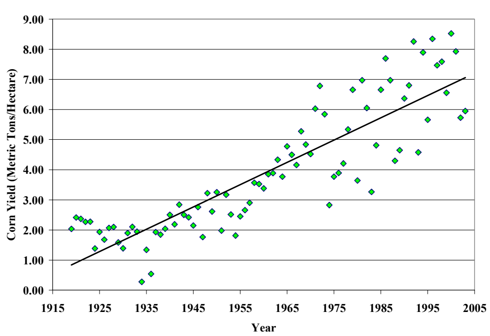


Fig 2.1 Corn Yields in Missouri CRD 1 (1919-2003)

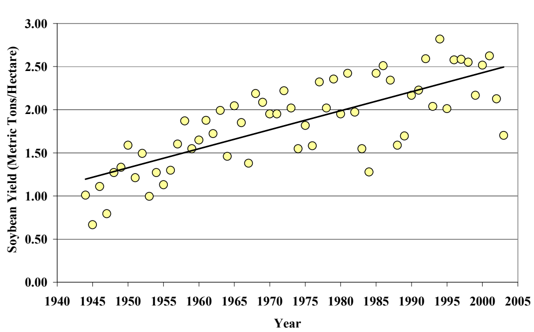


Fig 2.2 Soybean Yields in Missouri CRD 1 (1944-2003)

As shown in the crop yield charts, it is evident that technology over the years has improved corn and soybean yields. Average corn yields in Missouri's Crop Reporting District 1 increased from 2.01 metric tons/hectare in the 1920's to 6.97 metric tons/hectare during the 1990's. Soybean yields increased from 1.01 metric tons/hectare in the 1940's to 2.36 mt/ha during the 1990's. In order to show the effects of weather and climate on yields, it is important to eliminate yield bias due to technological improvements.

The detrending approach used in this study is a uniquely simplified process. One similarity includes using a method used by Thompson (1963,1966) where he removed the technological influence on crop yield in order to reveal the effects of weather. Thompson revealed that 95% of the corn yield variability in Iowa was due to weather and technology and that optimal yields for corn and soybean would occur if temperature and precipitation patterns were average throughout the growing season. In this case, 1990's technology is compared to earlier years in order to eliminate yield bias, therefore revealing the effects of precipitation on yield. The following statements describe the methodology in accomplishing this goal.

First, historical precipitation records for Missouri's Crop Reporting District 1 indicate sufficient and timely rainfall generally occurs in 5 out of 10 years during the growing season, therefore, allowing optimal crop development with minimal stress due to weather. Using this assumption, the average of the five highest corn and soybean yields for each decade were calculated for Missouri's CRD 1. These highest 5-year yield averages for each decade define rainfall as not being a detriment for yields therefore revealing the effects of technology as the primary factor for improving yields through the decades.

The next step is to apply 1990's technology to the earlier decades and eliminate any yield bias due to technology, thereby leaving precipitation the primary variable affecting crop yield. The following equation was developed for this research to calculate the effects of precipitation on crop yield:

$$(\mathbf{Y_{year}}/\mathbf{Y_{decade}})(\mathbf{Y_{1990's}}) = \mathbf{Y_{precip}}$$

Where,

$\mathbf{Y_{year}}$ = average yield for each year

$\mathbf{Y_{decade}}$ = regression estimate from the average of 5 highest yield years for each decade

$\mathbf{Y_{1990's}}$ = regression estimate from the average of 5 highest yield years during the 1990's

$\mathbf{Y_{precip}}$ = estimated yield for $\mathbf{Y_{year}}$ due to the effects of precipitation

After detrending, the average yields for the entire periods are 6.97 metric tons/hectare and 2.29 metric tons/hectare for corn and soybeans, respectively.

### *2.3. Precipitation Analyses*

The three precipitation data sets collected from counties located in Missouri's Crop Reporting District 1 were merged to create weekly averages for the entire 84 year period from 1919-2002. The final breakdown of rainfall periods were then established.

Three multi-weekly and seven biweekly periods were selected. The first three intervals are multi-weekly and are defined as the fall and early winter (9/3-12/31), winter and early spring (1/1-4/1) and spring (4/2-5/27) periods. The remaining 7 intervals are biweekly periods beginning with the 2-week period of 5/28-6/10 and ending with the 2-week period of 8/20-9/2.

There are two primary reasons for selecting these multi-weekly and biweekly periods. First, two of the multi-weekly periods (9/2-12/31 and 1/1-4/1) are not critical periods for growth and development of corn and soybean. Total precipitation that falls during these periods is more important than when the rain falls. The 17-weeks from 9/2-12/31 is an important period where, hopefully, sufficient precipitation will fall over northwestern Missouri and recharge the soil profile. During the Jan 1 to April 1 period, evapotranspiration rates are minimal and precipitation continues to act primarily as a recharge or runoff element. Rainfall is important from April 2 through May 27 in Missouri, but it is not as critical when compared to summer on a weekly or biweekly basis. As the season progresses into summer, the corn and soybean crops enter critical growth stages where weekly and biweekly periods may have a large influence on yield. It's important to study these shorter periods during the summer to determine, typically, when the most important periods for yield potential occur in northwestern Missouri.

The second reason for selecting these periods involves picking biweekly periods instead of weekly. Biweekly periods were selected in order to lessen the complexities related to calculating the probabilities for receiving certain precipitation amounts. The statistical approach which was taken to estimate these probabilities requires that the variable for precipitation, x , be greater than zero. There were many occurrences of weekly precipitation averaging 0.00 during the summer in northwestern Missouri, compared to only one occurrence for zero precipitation during a two week period in Crop Reporting District 1.

The next step is to construct frequency distributions for all 10 precipitation periods in order to estimate probabilities for precipitation values that fall within a range of values. Figure 2.3 is a frequency distribution chart for the 2-week precipitation period Jun 25-Jul 8 in Missouri CRD 1.

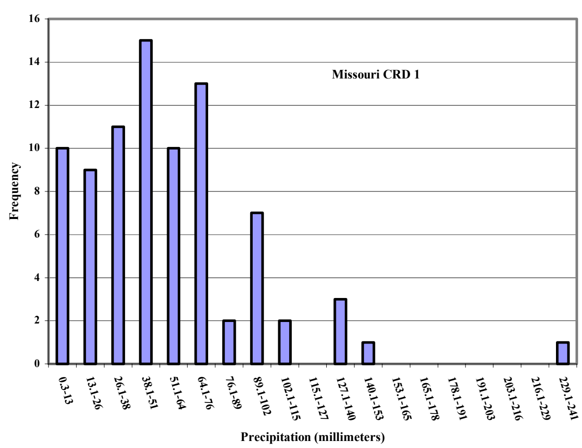


Figure 2.3 Histogram of Precipitation for the 2-Week Period Jun 25-Jul 8 (1919-2002)

Through observation, it is evident the precipitation values are not distributed symmetrically around the mean. Instead, all the precipitation periods exhibit frequency distributions that are skewed and, in all cases, the mode is less than the mean. The frequency distributions are therefore positively skewed which is typical for precipitation amounts over these particular time periods.

All the histograms of the designated weekly and mulit-weekly were identified as having asymmetrical distributions with a positive skew. It was determined that the preferable method to do a probability analysis was to use a gamma distribution and fit it to the precipitation totals. Gamma distributions are commonly used for queuing analysis when studying variables that have skewed distributions and were first used on precipitation amounts over short periods by Barger and Thom (1949). The equation for the gamma probability density function is:

$$f(x;\alpha,\beta) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{\alpha-1} e^{-\frac{x}{\beta}}$$

Where x is greater than zero and the value at which one wants to evaluate the distribution. Alpha and Beta are parameters to the distribution. The maximum likelihood estimations (Thom, 1958) of the parameters are:

$\alpha = 1/4A[1 + (1+4A/3)^{1/2}]$
where:
$A = \ln \bar{x} - \Sigma \ln x / n$

and
$\beta = \bar{x} / \alpha$

The probabilities of the precipitation totals calculated by the gamma distribution were divided into five classes to represent the variability of multi-week and biweekly precipitation in Missouri's CRD 1. Quintiles were chosen such that the 50% probability would occur in the near normal classification. Specifically, these five classifications are identified in Table 2.1.

Table 2.1 Precipitation Classifications according to Five Probability Ranges

| Quintile | Probability of Receiving Less Total Precipitation | Precip. Classification |
|---|---|---|
| 1st | ≤.200 | 1: Much Below |
| 2nd | .201-.400 | 2: Below |
| 3rd | .401-.600 | 3: Near Normal |
| 4th | .601-.800 | 4: Above |
| 5th | ≥.801 | 5: Much Above |

### 2.3. *Economic Threshold Analyses*

In this research agricultural drought is defined in terms of below-normal precipitation, below-normal crop yields and financial hardship. Analyses of historical precipitation data and crop yield data revealed below-normal precipitation periods and below-normal crop yields, but estimation of an economic yield threshold, where financial burden is incurred by the producer, is needed. There are numerous variables to consider among producers such as land, labor, capital, and management but general calculations indicate that if production is 10% below the average trend yield then financial hardship would likely be experienced, i.e., a negative cash flow would be incurred for the year and could lead to carryover impacts for future years. The average trend yield during the 1990's in Missouri Crop Reporting District 1 for corn and soybeans was 6.97 metric tons/hectare and 2.29 metric tons/hectare, respectively. This implies financial hardship may occur for the producer if yield falls at or below 90% of average production, i.e. $\leq$6.28 metric tons/hectare for corn and $\leq$2.09 metric tons/hectare for soybeans.

## 3. INDEX DEVELOPMENT

In order to determine the impact of each multi-weekly and biweekly precipitation period on corn and soybean yields, annual tables were constructed according to the Precipitation Classes 1 through 5, as discussed, and corresponding yield for that particular year. The number of occurrences where corn and soybean production was at or below the economic threshold yield for each period are given in Tables 3.1a and 3.1b, respectively.

Table 3.1a The Number of Occurrences where Corn Yields were ≤ 6.28 metric tons/hectare according to Period and Precipitation Class (1920-2003)

| Corn | Precipitation Classification | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Period | Much Below | Below | Near Normal | Above | Much Above |
| (prior year)Sep 03-Dec 31 | 9 | 2 | 8 | 4 | 4 |
| Jan 01-Apr 01 | 5 | 7 | 6 | 8 | 1 |
| Apr 02-May 27 | 6 | 2 | 6 | 7 | 5 |
| May 28-Jun 10 | 5 | 3 | 5 | 7 | 7 |
| Jun 11-Jun 24 | 6 | 7 | 4 | 7 | 3 |
| Jun 25-Jul 08 | 5 | 4 | 6 | 4 | 6 |
| Jul 09-Jul 22 | 11 | 7 | 2 | 5 | 2 |
| Jul 23-Aug 05 | 11 | 9 | 1 | 1 | 4 |
| Aug 06-Aug 19 | 7 | 7 | 5 | 3 | 5 |
| Aug 20-Sep 02 | 6 | 3 | 6 | 5 | 6 |
| Total | 71 | 51 | 49 | 51 | 43 |

Table 3.2b The Number of Occurrences where Soybean Yields were ≤ 2.09 metric tons/hectare according to Period and Precipitation Class (1944-2003)

| Soybean | Precipitation Classification | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Period | Much Below | Below | Near Normal | Above | Much Above |
| (prior year)Sep 03-Dec 31 | 10 | 1 | 6 | 3 | 2 |
| Jan 01-Apr 01 | 3 | 5 | 4 | 8 | 2 |
| Apr 02-May 27 | 5 | 2 | 1 | 8 | 6 |
| May 28-Jun 10 | 3 | 1 | 5 | 6 | 7 |
| Jun 11-Jun 24 | 4 | 6 | 3 | 5 | 4 |
| Jun 25-Jul 08 | 3 | 5 | 4 | 5 | 5 |
| Jul 09-Jul 22 | 8 | 5 | 3 | 5 | 1 |
| Jul 23-Aug 05 | 10 | 4 | 2 | 2 | 4 |
| Aug 06-Aug 19 | 7 | 6 | 2 | 3 | 4 |
| Aug 20-Sep 02 | 7 | 2 | 4 | 2 | 7 |
| Total | 60 | 37 | 34 | 47 | 42 |

In order to show the level of influence that each multi-weekly and biweekly period has on corn and soybean yields, weighting factors were assigned to each period. These weights were calculated according to the frequencies of each multi-weekly and biweekly period having yields that fell at or below the economic threshold yield of 6.28 metric tons/hectare for corn and 2.09 metric tons/hectare for soybeans during the period of record (1920-2003). For example, during the 9/3-12/31 period, there were 19 occurrences where precipitation was much below-normal (Precipitation Class 1). Of these 19 periods, there were 9 occurrences where the corn production fell below its economic threshold yield of $\leq$6.28 metric tons/hectare (Table 3.1a). In other words, when much below-normal precipitation occurs during the period 9/3-12/31, corn yields the following year are below the economic threshold yield 47% (9/19= 0.47) of the time.

Similar calculations were performed for all Precipitation Classes (1-5), multi-weekly and biweekly periods and their respective corn and soybean yields. The percentages were then summed for each Precipitation Class and weights were assigned to each multi-weekly and biweekly period accordingly. For example, the total sum of Precipitation Class 1 for corn was 417%. Dividing the 9/3-12/31 period percentage (47%) by the total sum (417%) yields a weight of 0.11 for the fall period.

The focus of this research is on agricultural drought, therefore, precipitation classes 1 and 2 (much below and below-normal precipitation) and their associated multi-weekly and biweekly periods were examined more closely in their relationship to corn and soybean yields. Weights were assigned to the combined classes to show which precipitation period has the strongest influence on below economic threshold crop yields.

Upon inspection, it is evident that the two consecutive biweekly periods of 7/9-7/22 and 7/23-8/5, have the largest impact on yield determination for both crops. This is not surprising since these periods are associated with critical growth stages for corn and soybeans. According to the Missouri Agricultural Statistics Service (MASS), the majority of corn in Missouri goes through the silking stage during July with 58% of the corn normally silked by the second week of July to nearly 90% by the last week of the month (MASS, 2003). Alternatively, critical growth stages for soybean occurs during the bloom and pod development period (Shaw and Laing, 1965). The soybean crop in Missouri typically goes through these stages during the latter half of July and first half of August.

The calculated weights indicate the influence of deficient precipitation during each precipitation period on corn and soybean yields over northwestern Missouri and can be used in developing a drought index. Specifically, this Agricultural Drought Projection Index (ADPI) is a seasonally adjusted index that will monitor and project agricultural drought according to its effects on crop yields over northwestern Missouri. The ADPI initiates at the beginning of the year, using the first index value evaluated from the fall period (9/3-12/31). As the year progresses, the ADPI value for each precipitation period is accumulated. The formula for the ADPI is:

$$\text{ADPI} = \sum_{i=1}^{10} (P_{i,\,year})(W_{i,\,year})$$

$P_{i,year}$ = Precipitation Class Number for Precipitation Periods 1 through 10 of a particular year

$W_{i,year}$ = Assigned corn or soybean weight for Precipitation Periods 1 through 10 of a particular year

Quantitatively, the range of the index is $1 \le ADPI \le 5$ with one and five indicating the driest and wettest scenarios, respectively. In order to determine the effectiveness and utility of this formula, an ADPI was calculated using the Precipitation Classifications obtained from1920 through 2003. For example, using the Precipitation Classification numbers that are listed for 2003 and their associated weights, the following ADPI for corn was calculated:

| **Precipitation Period** (i) | **Precipitation Classification** (P) | | **Corn Weight** (W) | $P_iW_i$ |
|---|---|---|---|---|
| 09/03-12/31 | 1 | X | .10 | =.10 |
| 01/01-04/01 | 1 | X | .10 | =.10 |
| 04/02-05/27 | 4 | X | .07 | =.28 |
| 05/28-06/10 | 4 | X | .07 | =.28 |
| 06/11-06/24 | 2 | X | .10 | =.20 |
| 06/25-07/08 | 2 | X | .08 | =.16 |
| 07/09-07/22 | 2 | X | .14 | =.28 |
| 07/23-08/05 | 1 | X | .17 | =.17 |
| 08/06-08/19 | 1 | X | .10 | =.10 |
| 08/20-09/02 | 5 | X | .08 | =.40 |
| | **ADPI for 2003** | | **=** | **2.07** |

Ideally, the ADPI is defined according to precipitation and weights associated with historical corn and soybean yields that fell below their economic thresholds ($\le$6.28 metric tons/hectare for corn, $\le$2.09 metric tons/hectare for soybean). Upon close inspection of all ADPI's calculated for corn between 1920-2003, a crop year for corn is subjectively classified as an agricultural drought year when the accumulated ADPI $\le$ 2.61. Similarly, looking at soybean, the number selected to identify an agricultural drought year for soybean is when the ADPI $\le$ 2.75.

Of course, the selection of these ADPI thresholds are arbitrary and a future consensus on ADPI values defining agricultural drought may be warranted. Using the current ADPI criteria, however, there were 19 years when corn experienced an agricultural drought. However, four of those 19 years (1933, 1946, 1957, and 1971) were misidentified as experiencing an agricultural drought since their corn yields were above the economic threshold. Still, the index accurately identified 15 of those 19 years, or 79%, as agricultural drought years. Similarly, the soybean ADPI's indicated 17 years with agricultural drought. Five of the years were misidentified (1946, 1957, 1971, 1991 and 2002), but 12 years, or 71%, were correctly labeled.

## 4. INDEX PROJECTION

The effectiveness of the ADPI to detect agricultural drought based on crop yield data and precipitation has only been tested with historical information. The premise of the ADPI, however, is to project the likelihood of an agricultural drought according to corn and soybean yields that are expected to fall below their economic threshold yields of 6.28 and 2.09 metric tons/hectare, respectively

The first step in making the ADPI an operational tool for Crop Reporting District 1 is to quantify the ranges of each Precipitation Classification. A listing was developed of the Precipitation Classifications for each of the ten periods and the precipitation ranges that are associated with their respective category. The precipitation ranges were determined using the sorted gamma probability precipitation data. If the precipitation data did not correspond with the upper and lower limits of the probability ranges, they were interpolated.

Now that precipitation ranges have been determined and associated with Precipitation Classifications, the ADPI can incorporate rainfall information for all ten periods. The ADPI begins January 1, such that any individual rainfall total or average total of multiple observations for precipitation period 1, (9/3/12/31), will be the first total assigned with a Precipitation Classification number. The Precipitation Classification number, $P_i$, is plugged into the ADPI equation, $\sum_{i=1}^{10}(P_{i,\,year})(W_{i,\,year})$, and will be the first of 10 elements that will be summed to obtain an ADPI. Beginning January 1, there are nine precipitation periods remaining and the projection aspect of the ADPI comes into play.

The best resources for projecting ADPI values of future precipitation periods are forecast products available from the Climate Prediction Center. Specifically, the monthly forecasts and seasonal outlooks are two products that will be incorporated into the ADPI.

For example, on January 1, the first ($P_{1,year}$ $W_{1,year}$) value for corn and soybeans can be evaluated using the historical precipitation data from precipitation period 1, (9/3-12/31), and associating it with its Precipitation Classification ($P_{1,year}$) and weight ($W_{1,year}$). Projections of the nine remaining values can be made using the monthly and seasonal forecast products available from the Climate Prediction Center. A methodology for assigning Precipitation Classifications to future periods is defined by the following guidelines:

1. The evaluation of the ADPI will begin on January 1.
2. Seasonal and monthly outlooks that indicate a bias toward below or above normal precipitation will be assigned a Precipitation Classification of 2 and 4, respectively. Any forecast of equal chances will receive a Precipitation Classification of 3.
3. When released, the 3-month seasonal outlook for Jan-Feb-Mar will be utilized for precipitation period 2 (1/1-4/1). The remaining future precipitation periods will receive a forecast of climatology, namely, Precipitation Classification 3 (near normal).
4. When released, the 3-month seasonal outlook for Apr-May-Jun will be utilized for precipitation period 3 (4/2-5/27). The remaining future precipitation periods will receive a forecast of climatology, namely, Precipitation Classification 3 (near normal).
5. When released, the monthly outlook for June will be used to determine the Precipitation Classification for precipitation periods 4 (5/28-6/10), and 5 (6/11-6/24). The remaining precipitation periods will

receive a forecast of climatology, namely, Precipitation Classification 3 (near normal).

6. The ADPI will be updated at the end of each biweekly period.
7. When released, the monthly outlook for July will be utilized for the Precipitation Classification of precipitation periods 6 (6/25-7/8), 7 (7/9-7/22), and 8 (7/23-8/5). The remaining precipitation periods will receive a forecast of climatology.
8. When released, the monthly outlook for August will be utilized for the Precipitation Classification of precipitation periods 9 (8/6-8/19) and 10 (8/20-9/2).
9. All precipitation periods will be updated at their conclusion.
10. If a precipitation period has not concluded and the forecasted Precipitation Classification value for the period has been exceeded, the Precipitation Classification will be adjusted accordingly. For example, if an average of 2.23 inches of rain has occurred over Crop Reporting District 1 by July 15 and the projected Precipitation Classification is 2 (0.65-1.22") for precipitation period 7 (7/9-7/22), then the Precipitation Classification will be adjusted to 4 (1.99-3.19").

## 5. SUMMARY AND CONCLUSIONS

It has been shown that the Agricultural Drought Projection Index has a 79% and 71% success rate for corn and soybeans, respectively, in identifying an agricultural drought according to historical precipitation records and yield data for Crop Reporting District 1 of northwestern Missouri. Additionally, using northwestern Missouri as a test case, the ADPI incorporated near real-time precipitation data and monthly and seasonal outlooks for 2004 in order to monitor and project the likelihood of an agricultural drought affecting the region.

Overall, the ADPI's performance during 2004 was accurate, indicating concern for agricultural drought at the beginning of the forecast period. As the year progressed, favorable precipitation patterns evolved and the threat of an agricultural drought diminished. The final ADPI of 3.65, at the end of precipitation period 10 (8/20/04-9/2/04), was well above the limit which defines an agricultural drought for corn, ADPI $\leq$ 2.61, and soybeans, ADPI $\leq$ 2.75. Toward the end of the 2004 growing season, crop reports from northwestern Missouri were indicating a high potential for excellent corn and soybean yields. According to the Missouri Agricultural Statistics Service, 82% and 78% of the corn and soybeans, respectively, were reported to be in good to excellent condition in early October 2004 (MASS, 2004).

The ADPI has been effective in Crop Reporting District 1 of northwestern Missouri, but the true usefulness of this index will be its ability to assess and project agricultural drought over other major crop production areas of the United States. Other variables such as soil, farm management practices, temperature etc. may have a larger influence on crop yields in different parts of the country compared to northwestern Missouri. The methodology used in evaluating and defining the ADPI for northwestern Missouri may not be sufficient for all crop reporting districts; index adjustments may be necessary.

Additionally, economic threshold yields were defined as a 10% reduction in the trend yield for corn and soybeans that resulted in financial hardship for the average producer. Adjusting the economic threshold yield to identify a "disaster" threshold yield could make the ADPI an important tool for USDA disaster relief declarations.

The ADPI was developed according to historical corn and soybean yields that fell below an economic threshold and long-term weekly precipitation records. The projection component of this index incorporates seasonal and monthly outlooks provided by the Climate Prediction Center and climatology. Opportunities for enhancing the ADPI exist by using additional weather forecasting tools and incorporating other variables.

It is evident the Agricultural Drought Projection Index has regional application and the potential to become an important operational tool for monitoring and projecting agricultural drought across major crop production areas of the United States.

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