The Value of El Niño Forecast Methods For the U.S. Winter Wheat Producers, Do They Differ?

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Abstract

The value of improved climate forecasts to winter wheat producers is estimated. Two El Niño/Southern Oscillation based forecasting methods are compared. In most regions, a five phase approach is more valuable than the more commonly used three phase approach. Economic value and distributional aspects have implications for producers, policy makers, and meteorologists.

Keywords: El Niño, Southern Oscillation, Value of Information, Winter Wheat

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The 1997-1998 El Niño, an El Niño/Southern Oscillation (ENSO) event, captured both the scientific community's and the general public's attention. Regularly, the news media reported weather events whose cause was attributed to El Niño. Although it is not possible nor correct to attribute single weather events to El Niño, weather patterns experienced over a longer time frame can be attributed to the phenomenon. The ability to attribute longer time period weather patterns to ENSO events may provide the basis for improved climate forecasts. ENSO events are anomalies in the tropical Pacific, which are linked (teleconnected) to seasonal climate variations in parts of the world (Bjerknes; Ropeleski and Halpert 1986, 1987, 1989; Kiladis and Diaz). Importantly, the teleconnections are lagged, implying improved seasonal climate forecasts may be possible.

Classifying ENSO events is, however, not standardized. Current methods rely on sea surface temperature anomalies, sea surface air pressure differences across the Pacific, or some combination of these and other weather parameters. Methods using sea surface air pressure differences rely on the Southern Oscillation Index (SOI). Within the SOI, at least two different classification schemes are used. The most commonly used method divides ENSO events into three phases (3P): warm (El Niño), other, and cold (El Veijo or La Niña) (Climate Prediction Center). A second method used divides ENSO events into five phases (5P): consistently positive, consistently negative, rapidly falling, rapidly rising, and consistently zero (Stone and Auliciems).

Previous studies report the use of ENSO based forecasts may have value to producers at the field level (Hill *et al.*; Mjelde *et al.*; Marshall, Parton, and Hammer). Hill *et al.* show Texas sorghum producers may increase expected profits by including 3P climate forecasts into their management decisions. Their results are site and scenario specific with increases in net returns ranging from 3.1%

to 132.9%. Using experimental plot data, Mjelde *et al*. estimate the 3P ENSO forecasts provide little value to east-central Texas sorghum producers, but corn producers could benefit from using the forecasts. Marshall, Parton, and Hammer found the value of the 5P forecast system ranged between A$3.70/ha (Australian dollars) for a risk neutral producer to A$3.83/ha for a typically risk averse producer. Adams *et al*. illustrate the use of 3P forecasts at the aggregate level (allowing for price changes) may reduce producer surplus, but overall society benefits.

The objective of this study is to compare the two SOI-based forecast methods to determine which provides greater value to U.S. winter wheat producers. To value the different methods, wheat yields are simulated using historical daily weather data and various management practices for the major U.S. winter wheat growing regions. Decision theory is used to value the two forecast methods at the field level. Only SOI-based forecast methods are considered here because sea surface temperature data are not available for a sufficient period to provide meaningful comparisons.

Methodology

Field level data over a sufficient time period is not available. A crop growth model is used to provide winter wheat yields given different nitrogen application levels, planting dates, and weather conditions. Eighty-five years of weather data are used. Yields at six different sites within the U.S. are simulated. The production data is then used in into an economic model to obtain optimal management practices assuming different climate forecasts are used.

Economic Decision Model

Decision theory (Hilton) is used to derive the climate forecast's value assuming a risk neutral decision maker. First, the input combination which maximizes expected net returns for a given price under climatological (historical) distribution of weather is obtained. It is assumed the decision maker's prior knowledge is the climatological distribution and each year of historical data is equally likely. Site specific optimal input combinations are obtained using the following model:

$$\max_{n,d} E(\pi) = \frac{1}{T} \sum_{j=1}^{T} [p \; y_{ij}(n,d) - r_1 n - r_2 \; y_{ij}(n,d)] - vc_i \qquad \textbf{(1)}$$

where $E(\pi)$ is the expected net returns per acre (ac), T is the number of weather years, p is expected price ($ per bushel (bu)), y_{ij} is yield (bu/ac) associated with site i and year j, n is applied nitrogen in pounds (lb)/ac, d is planting date, r_1 is nitrogen cost in $/lb, r_2 is harvest costs in $/bu, and vc_i is other variable costs in $/ac.

To obtain the value of using the different ENSO forecasts, the 85 years of data are classified into the three or five category ENSO phases. The economic model is then modified to provide optimal input combinations and associated expected net returns, yields, and nitrogen use by ENSO event. A more complete explanation of T is necessary. For the historical model, T represents the 85 years. When forecasts are used, T represents the number of years in the relevant phase. Overall, expected net returns associated with using the ENSO forecasts are then obtained by weighting the expected net returns associated with each phase by the probability of the phase. The value of the ENSO based forecasts are obtained by subtracting the expected net returns using the decision maker's prior knowledge from the expected net returns associated with the ENSO forecasts. The value of perfect knowledge is obtained by determining the optimal input combination for each year. Expected net returns are the mean of the net returns obtained using each year's optimal input combination. Obtaining the value of forecast is consistent with numerous value of information studies (Hill *et al*.; Mjelde *et al*.; Hilton).

Crop Growth Simulation Model

The use of crop growth simulation model provides an effective way to obtain production data when "real world" data are not available (Dillon, Mjelde, and McCarl; Hammer, Rosenthal, and Butler). In equation (1), $y_{ij}(n,d)$ represents outcomes from CERES Wheat-V2.10 (Godwin *et al.*), a process-oriented simulation model. CERES-Wheat V2.10 is capable of simulating wheat yields under different management combinations and weather conditions.

Site Descriptions and Data

Six sites within major winter wheat producing areas in the United States are modeled (Table 1). The sites are in Kansas, Oklahoma, Illinois, Michigan, Ohio, Texas, and Washington. The most common soil proportionately in each representative area appropriate for wheat production is used. Soil information is obtained from the GRASS and MUUF data bases (U.S. Army Corp of Engineers --CERL; Baumer, Kenyon, and Bettis). Wheat class varies by site.

Daily precipitation and temperature data for the fall 1910 to summer 1995 (exact dates vary by site because of growing conditions) are used to simulate 85 crop years. The data is from the United States Historical Climatological Network, a subsection of the Carbon Dioxide Information Analysis Center (Easterling *et al.*). Solar radiation is approximated using a solar radiation generator (Richardson). For sites missing precipitation and/or temperature data, the missing data is approximated with data from a nearby location or if no location is available by the use of a random weather generator WGEN (Richardson).

Other variable costs in equation (1) are obtained from the USDA-Economic Research Service regional farm budgets for the years 1989-1995. Fixed costs in the budgets are not included. Costs are adjusted to 1997 prices assuming an annual three percent inflation rate. Mean nitrogen prices are from the USDA-NASS Agricultural Prices for 1989-1995. The range of wheat prices are obtained from historical wheat prices by wheat class (USDA -ERS). Nine prices for each wheat class are used.

Table 1. Site and Parameter Description for Modeled U.S. Winter Wheat Sites

Site Name[1]	Location[2]	Soil Type	Wheat Type[3]	Planting Days[4]	Seed Rate[5]
Illinois	39 -89	Medium Silt Loam	Soft Red	250, 265, 280	1400000
Kansas	38 -98	Medium Sandy Loam	Hard Red	240, 255, 270	1400000
Ohio	41 -84	Medium Silt Loam	Soft Red	250, 265, 280	1900000
Oklahoma	36 -98	Deep Silt Clay	Hard Red	240, 255, 270	1400000
Texas	33 -99	Deep Silt Clay	Hard Red	240, 255, 270	750000
Washington	48 -118	Deep Silt Loam	Soft White	240, 255, 270	100000

1. Site modeled. 2. Latitude and longitude. 3. Wheat type. 4. Day of year in Julian days. 5. Seeds per acre.

Classification of the years into the 3P method are from the Climate Prediction Center, whereas the 5P classification scheme is from Stone and Auliciems. Because winter wheat is planted in the fall, classification of the ENSO events is based on the September classification of the SOI by the two methods. The 5P classification is missing for the years 1914 and 1931. Missing phase classification are obtained by interpolating the first available month on either side of September.

A summary of the years which fall into the 3P and and 5P categories is presented in Table 2. With the 3P method, 24% of the years are in the warm phase. Cold event years comprise 14% of the years. Sixty-two percent of the years fall into the other category. The percentage of years falling into phases 1-5 in the 5P classification scheme are 20, 28, 8, 13, and 30%. The majority of the warm phase years are classified as in phase 1 in the 5P method. Eleven of the twelve cold phase years are classified as phase 2 in the 5P method with the remaining year classified in phase 4. A major difference between the classification scheme is evident in examining the years classified as “other” in the 3P method. The 5P method classifies the “other” years in all 5 phases.

Table 2. Number and Proportion of Years in Each Phase for Both Methods

3P \ 5P	1 Phase Prop.*	2 Phase Prop.	3 Phase Prop.	4 Phase Prop.	5 Phase Prop.	Total Prop.
Warm	0.13	0.00	0.05	0.00	0.06	0.24
Cold	0.00	0.13	0.00	0.01	0.00	0.14
Other	0.07	0.15	0.04	0.12	0.24	0.62
Total	0 .20	0.28	0.08	0.13	0.30	1.00

Source: Computed from Climate Prediction Center and Stone and Auliciems.

Results

The value of the 3P, 5P, and perfect forecasts vary by site (Table 3). Use of the 3P method in Illinois and Ohio has no value for the decision maker over using climatological information. At the four other sites, the value ranges at the lowest price from $0.66 at Texas to $1.10/ac in Oklahoma. At the highest price, the value of the forecast ranges from $0.20 in Kansas to $1.77/ac in Oklahoma. Differences between sites are also noted in the pattern of values over the range of prices. In Kansas, the value of the forecasts decreases as wheat price increases, whereas in Oklahoma an opposite pattern is noted. Both Texas and Washington exhibit a general pattern in which the value of the forecasts increases with wheat price increases over the lower range of prices, whereas over the higher range of prices, the value of the forecasts declines.

Very similar patterns are observed with the 5P method. Illinois and Ohio decision makers obtain no value from using the 5P method. At the four remaining sites, the value ranges from $0.67/ac in Kansas to $2.46/ac in Oklahoma at the lowest price level. At the highest price level, the value ranges from $0.02 in Kansas to $3.96/ac in Oklahoma. The same patterns of increasing and decreasing value of the forecasts are exhibited by site as in the 3P method, except for Washington.

Table 3. The Value of 3 Phase, 5 Phase, and Perfect Forecasts ($/acre)

Price Level	Illinois	Kansas	Ohio	Oklahoma	Texas	Washington
			3 phase method			
1	0.00	0.81	0.00	1.10	0.66	0.50
2	0.00	0.72	0.00	1.18	0.70	0.55
3	0.00	0.44	0.00	1.43	0.49	0.62
4	0.00	0.33	0.00	1.50	0.41	0.65
5	0.00	0.28	0.00	1.54	0.40	0.59
6	0.00	0.23	0.00	1.65	0.36	0.54
7	0.00	0.22	0.00	1.67	0.35	0.50
8	0.00	0.22	0.00	1.68	0.35	0.51
9	0.00	0.20	0.00	1.77	0.40	0.54
			5 phase method			
1	0.00	0.67	0.00	2.46	1.81	1.43
2	0.00	0.62	0.00	2.65	1.96	1.42
3	0.00	0.33	0.00	3.21	1.78	1.05
4	0.00	0.25	0.00	3.35	1.66	0.94
5	0.00	0.21	0.00	3.44	1.59	0.80
6	0.00	0.12	0.00	3.69	1.55	0.76
7	0.00	0.10	0.00	3.74	1.57	0.72
8	0.00	0.09	0.00	3.76	1.57	0.69
9	0.00	0.02	0.00	3.96	1.64	0.64
			perfect forecasts			
1	3.63	9.38	5.06	14.04	7.82	10.44
2	3.94	9.61	5.50	14.87	8.22	10.76
3	4.44	9.94	6.20	17.30	8.82	11.82
4	4.62	10.00	6.45	17.96	8.91	12.13
5	4.82	10.04	6.71	18.36	8.96	12.39
6	4.94	10.17	6.86	19.48	9.11	12.47
7	5.06	10.20	7.03	19.68	9.13	12.56
8	5.65	10.21	7.81	19.77	9.15	12.63
9	5.97	10.34	8.19	20.69	9.27	12.74

At the Washington site, the value of the forecast decreases as wheat price increases.

Decision makers at all sites obtain value from the use of perfect climate forecasts. Depending on price and site, the value ranges from $3.63 to $20.69/ac. Decision makers in Illinois and Ohio, generally, gain the least. Within any site, the value of perfect forecasts increases as price increases, a pattern not consistent with the ENSO-based forecasts at all sites.

Certain observations result from comparing the three methods. First, the value of improved climate forecasts is not uniform across regions, raising distributional issues. Secondly, the value of the 3P and 5P methods within a region is not equal except for Illinois and Ohio decision makers. With the exception of the Kansas region, the 5P method has superior results to the 3P method.

For discussion purposes, consider the lowest and highest prices. The 3P method in Kansas, Texas, and Washington captures 9%, 8%, and 5% of the value of perfect forecasts at the lowest price. At the highest price, the 3P method captures roughly 1% of the value of perfect forecasts in Kansas and 3% in Texas and Washington. In Oklahoma, the 3P method captures approximately 8% of value of perfect knowledge at both the highest and lowest price. The Midwestern sites capture none of the value of perfect forecasts.

The 5P method captures a higher percentage of the value of perfect forecasts for all sites except Kansas, if the sites with no value are ignored. At the lowest price, the percentage of the value of perfect forecast captured by the 5P method for Kansas, Oklahoma, Texas, and Washington are 7%, 18%, 23%, and 14%, whereas at the highest price these percentages are 0%, 19%, 18%, and 5%. These percentages of the value of perfect forecasts are remarkably high for Texas, Washington, and Oklahoma. ENSO based forecasts and perfect forecasts have the largest absolute value at the Oklahoma site.

These high percentages suggest skill is present in climate forecasts currently available. Economic results mirror meteorological relationships between ENSO events and weather patterns. The strongest relationships between ENSO and weather patterns have been found in the South and Northwest. These findings correspond to a higher value for the forecasts in Oklahoma, Texas, and Washington. Much weaker signals have been found for the Midwest and great plains (Ropelewski and Halbert 1986, 1987, 1989). Weather, soil types, and wheat type also appear to play a role in determining the value of the ENSO-based forecasts. Illinois and Ohio are areas of fertile soils and have higher rainfall than the other areas, winter wheat is grown early in the season. Combining the growing environment of these areas with weak ENSO signals causes ENSO-based forecasts to have little or no value. The growing conditions also appear to lower the value of perfect forecasts. In Oklahoma, ENSO-based forecasts may capture a large percentage of perfect forecasts value because Oklahoma lies near the boundary between two Pacific North American (PNA) atmospheric pressure patterns. Wallace and Gutzler show the PNA is an important teleconnection pattern in the U.S. It appears there are interactions between the PNA and ENSO (Nemanishen).

The question is, does knowledge of every phase or does knowledge of only certain phases provide value to the decision maker? Using Oklahoma and Washington as examples, the phases which provide enough information for decision makers to change input usage (a requirement for the information to have value) are illustrated. Again, site specific results are noted. The difference in expected profits of using ENSO based forecasts and climatological probabilities for the two methods are presented in Figure 1 by phase for price level 3. In Oklahoma, changes in input use occurs only for the cold phase when using the 3P method, thus changes in expected profits occur only during knowledge of this phase. Decision makers using the 5P method alter their input usage over the climatological strategies in two of the five phases, 2 and 5. Phase 2, is almost equivalent to the cold event in the 3P, whereas phase 5 corresponds to the other event in the 3P method (Table 2 and Figure 1). In contrast, decision makers in Washington alter input use in all phases when using either the 3P or 5P forecasts (Figure 1).

Conclusions

The objective of this study is to compare two currently available SOI-based forecast methods to determine which provides greater value to U.S. winter wheat producers. For three of the six sites modeled, the 5P method provides more valuable information than the 3P method. The 3P method

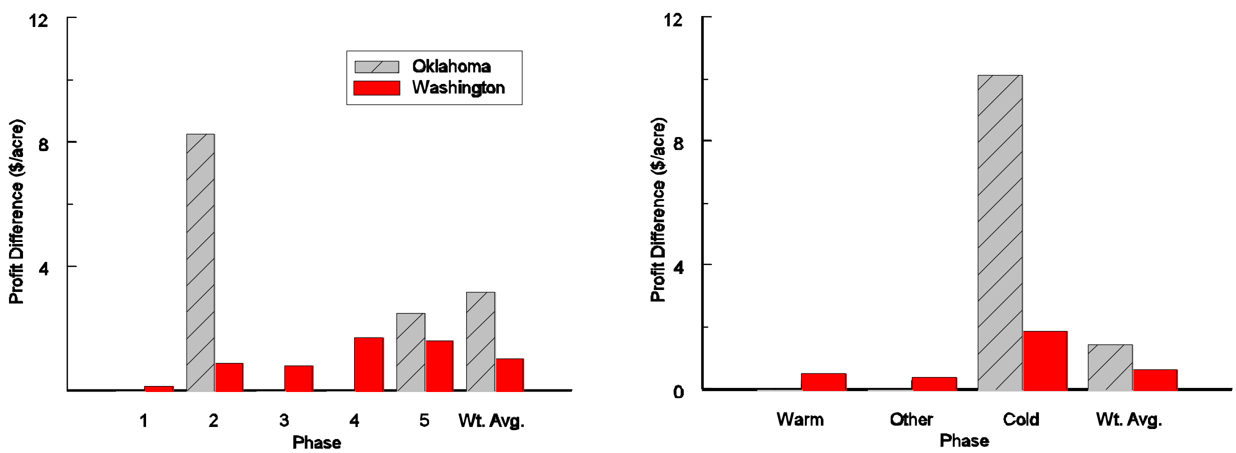

Figure 1. Increases in Net Returns by Phase for Oklahoma and Washington Sites by Forecasting Method.

is more valuable at only one site. Neither method provides any information of value at two of the sites. Depending on price, site, and method considered between zero and 23% of the value of perfect forecasts are captured using the ENSO based forecasts.

Overall, the results suggest the 5P method provides more value to producers than the 3P method. The 5P method provides more precise classification of years falling into the "other" phase in the 3P system. Warm and cold events are, generally, classified in comparable categories. This conclusion has implications for the U.S. weather forecasting system and decision makers using the information. It also illustrates the need for multidisciplinary interaction/research between decision makers, social scientists, and physical scientists if improved climate forecasts are to reach their full potential.

Future research should focus on enhancing SOI-based forecasting methods by incorporating other factors beyond relative air pressure differences. The experimental multivariate ENSO index currently being used by NOAA may be a step towards improved forecasting classification, but unfortunately the data necessary to generate this index is currently not available over an extended period. This study considers decision makers who face fixed prices. When aggregate price effects of decision maker's responses to climate forecasts are considered it is likely the value of this information will vary.

References

Adams, R.M., K.J. Bryant, and B.A. McCarl. "Value of Improved Long Range Weather Information." *Contemporary Econ. Policy* 13(July 1995):10-19.

Baumer, O., P. Kenyon, and J.Bettis. MUUF v2.14 User's Manual. National Resources Conservation Service. (1984): pp.520.

Bjerknes, J. "Atmospheric Teleconnections From the Equatorial Pacific." *Monthly Weather Review*. 97(March 1969):163-172.

Climate Prediction Center. El Niño (ENSO) - Previous Warm and Cold Episode Years. National Oceanographic and Atmospheric Agency, web site (http://nic.fb4.noaa.gov:80/products/analysis_monitoring/ensostuff/index.html.

Dillon, C.R., J.W. Mjelde, and B.A. McCarl. "Biophysical Simulation Models: Recommendation for Users and Developers." *J. Computers and Electronics in Ag.* 6(1991):213-224.

Easterling, D.R., T.R. Karl, E.H. Mason, and P.Y. Hughes. *U.S. Historical Climatology Network Daily Temperature and Precipitation Data*. ORNL/CDIAC NDP-042/R1. Carbon Dioxide Information Analysis Center. Oak Ridge National Laboratory. Oak Ridge, TN 1998.

Godwin, D., J. Ritchie, U. Singh, and L. Hunt. *A User's Guide to CERES Wheat V2.10*. 2nd Edition. International Fertilizer Development Center, Muscle Shoals, Alabama. 1990.

Hammer, W. D., G.L. Hammer, and D. Butler. "Predicting Regional Grain Sorghum Production in Australia Using Spatial Data and Crop Simulation Modelling." Forthcoming in *Agricultural and Forest Meteorology* 1998.

Hill, H.S.J., J.W. Mjelde, W. Rosenthal, and P.J. Lamb. "The Potential Impacts of the Use of Southern Oscillation Information on the Texas Aggregate Sorghum Production." Forthcoming *J. Climate* 1998.

Hilton, R.W. "The Determinants of Information Value: Synthesizing Some General Results." *Management Science* 27(January 1981):57-64.

Kaiser, D.P. Climatologist. Personal Communications. Oak Ridge National Laboratory. Oak Ridge, TN 1998.

Kiladis, G.N. and H.F. Diaz. "Global Climatic Anomalies Associated With Extremes of the Southern Oscillation." *J. Climate* 2(1989):1069-1090.

Marshall, G.R., K.A. Parton, and G.L. Hammer. "Risk Attitude Planting Conditions and the Value to a Dryland Wheat Grower." *Aust. J. of Ag. Econ.* 40(December 1996):211-213.

Mjelde, J.W., T.N. Thompson, F.M. Hons, J.T. Cothren, and C.G. Coffman. "Using Southern Oscillation Information for Determining Corn and Sorghum Profit-Maximizing Input Levels in East-Central Texas." *J. Prod. Ag.* 10(March 1997):168-175.

Nemanishen, W. "Drought in the Palliser Triangle (A Provisional Primer)." Prairie Farm Rehabilitation Administration. Agricultural and Agri-Food Canada. Calgary, Alberta. 1998.

Richardson, C.W., and D.A. Wright, 1984: WGEN: A Model for Generating Daily Weather Variables. USDA/ARS-8. 83pp.

Ropelewski, C.F. and M.S. Halpert. "North American Precipitation and Temperature Patterns Associated with the El Niño/Southern Oscillation (ENSO)." *Monthly Weather Review* 114(December 1986):2352-2362.

Ropelewski, C.F. and M.S. Halpert. "Global and Regional Scale Precipitation and Temperature Patterns Associated With the El Nino/Southern Oscillation." *Monthly Weather Rev*iew 115(August 1987):1606-1626.

Ropelewski, C.F. and M.S. Halpert. "Precipitation Patterns Associated with the High Index Phase of the Southern Oscillation." *J. of Climate* 2(March 1989):268-284.

Stone, R.C. and A. Auliciems. "SOI Phase Relationships With Rainfall in Eastern Australia." *Intern. J. Climatology* 12(April 1992):625-636.

U.S. Army Corps of Engineers--CERL. GRASS Reference Manual. Champaign, IL. 1988. GRASS reference manual. Champagne Il: U.S. Army Corps of Engineers.

USDA-ERS. Wheat Farm Prices for Leading Wheat Classes in Region 1977/78-1996-1997. *Situation and Outlook Yearbook*, (March 1997):72-73.

U.S.D.A.-N.A.S.S. Fertilizer and Agricultural Limestone: Prices Paid, Region, and United States. Agricultural Prices, Washington D.C. (April 1996):B-12-B-13.

U.S.D.A.-ERS. "Wheat Costs and Returns Data 1989-1995. Excluding Direct Government Payments." http:/www.econ.ag.gov./Briefing/FBE/CAR/Wheat3.htm. (1997).

Wallace, J.M. and D.S. Gutzler. "Teleconnections in the Geopotential Height Field During the Northern Hemisphere Winter." *Monthly Weather Review* 109(April 1981):784-812.