Investigating the Relationship between Yield Risk and Agri-Environmental Indicators

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Abstract

Crop insurance provides risk reduction benefits yet may increase planted acres in risky areas. This paper investigates the relationship between environmental quality and crop insurance induced changes in cropping pattern. Results suggest that yield risk and soil erosion are positively correlated for the majority of acreage in the study area.

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INTRODUCTION

The history of agricultural production in the United States (U.S.) shows a multitude of changes in how and where producers of agricultural commodities choose to produce their goods. Most of these shifts in production are thought to be the result of increases or decreases in international trade and the subsequent increase or decrease in competitive and comparative advantage, advancements in agricultural related technologies, and urban expansion. It has long been accepted that the commodity price support programs encourage production. Less well understood is the extent to which the support mechanisms for yield risk have increased plantings. Both the disaster assistance programs (which are effectively a 100% subsidized crop insurance) and the Federally subsidized crop insurance programs undoubtedly have some influence on changing land-use patters (Griffin, 1996; Skees 1999).

The Federal Crop Insurance Program (FCIP) was reformed in 1980 to replace a disaster assistance program in large part because the disaster programs were thought to encourage production in riskier areas of the country. Crop insurance was originally intended to protect producers of agricultural commodities against crop losses resulting from natural disasters. In 1986 the U.S. government began to subsidize crop insurance in an effort to increase participation among producers. Although FCIP was originally designed to reduce yield risk and income variability, some researchers now believe that the program has evolved into one of income enhancement and has begun to promote production in riskier areas of the country much like the disaster assistance program it attempted to replace.

Due to the design of crop insurance subsidies, higher levels of transfer payments are given to comparatively higher-risk areas of production. Since many producers respond to income transfers by increasing production, high-risk areas are likely to see increases in production as well as increases in transfer payments. Subsidies for crop insurance are currently allocated according to a percent of the premium on the insurance policy.

Because premium rates are a reflection of the amount of risk associated with a parcel of land, subsidies provide greater transfers to farmers who are operating under risky conditions. To be clear, consider two farmers who farm in different regions. For unsubsidized insurance one farmer would pay $10 per $100 of liability; the other $20 per $100 of liability for the same insurance policy. In relative risk terms, the farmer paying $20 would have yields that are two times more risky for that insurance policy. Given a 50 percent subsidy, the lower risk farmer receives a $5 per $100 of liability transfer and the higher risk farmers receive $10. Any expected utility models for risk averse decision makers would suggest that this design encourages both farmers to not only increase their level of production, but to possibly increase it onto riskier, marginal lands as well.

Marginal lands make up what is referred to as the "extensive margin" or areas of farmland that are of a lower quality in terms of crop yield and productivity. Many times marginal lands are acres located on the edge of production and are likely to be used given an increase in commodity prices or a decrease in production costs. While marginal lands are not homogeneous across space, they are often associated with a particular set of environmental characteristics, the most notable of which is soil erosion. If crop insurance is promoting production on marginal lands, and these lands are found to be highly erosive, crop insurance may be contributing to erosion of farmland, buildup of sediment in nearby waterways, and other negative environmental impacts.

Subsidies for crop insurance may also promote environmental degradation in that increases in production may result in increases in chemical usage for crops. Wu (1999) found that crop insurance for corn in Nebraska caused a shift in production from hay and pasture to corn. This shift resulted in increased erosion and chemical use at the extensive and intensive margin. Wu also points out that an increase in chemical application rates may be due to the 'moral hazard' created by crop insurance. Subsidized insurance affects application rates by decreasing farmers' production risk and reducing their incentive to apply the prescribed amount of chemicals.

The literature is clear that subsidies in crop insurance have resulted in more plantings, particular at the extensive margin (Skees (2000); Young et. al (1999). Estimates of how much more vary widely due to difficulties in estimating these effects. Skees (2000) argues that for every acre that was taken out of production for CRP, nearly a new acre was added because of the combined effects of free disaster payments and subsidies in crop insurance. The environmental consequences of such offsetting policies have not been considered.

Not only do subsidies for crop insurance affect decision-making at the farm level, but changes also occur regionally. As risk profiles change from region to region, so do farmers' willingness to accept risk. Such behavior may result in shifts in production from one area to another. This is illustrated by Skees in the gains and losses of crop share for the top six U.S. crops. It is evident that a shift in crop share has occurred from the Southeastern U.S. to the Plains states (Skees, 2000; Young et.al (1999). It is important to ask what such a shift might imply in terms of changes in environmental quality. The Environmental Benefits Index (EBI) used by the Conservation Reserve Program (CRP) concludes that the great majority of environmental benefits to be gained or lost due to the implementation of CRP acres are found in the Eastern and Southeastern U.S., particularly if these benefits are weighted by population (Heimlich, 1994). It is important to note that shifts in production from one region to another do not necessarily imply decreases in production in one area and increases in another. Total production may still increase for both areas, albeit at a slower pace for one region compared to another.

Crop insurance may be encouraging environmental losses in yet another way. As Griffin (1996) and Skees (2000) suggest it is possible that crop insurance along with disaster assistance may be offsetting the environmental gains achieved through the CRP. If these programs do in fact offset one another, environmental benefits achieved through the CRP may be diminished by production increases resulting from crop insurance.

Theoretical Development and Data

This study develops a model to estimate the correlation between crop yield risk and a set of agri-environmental indicators. The data used in this study is aggregated to the county or FIPS level. Each FIPS is attached to a Farm Resource Region (Region) as defined by the USDA ERS (Figure 1). The Regions are derived from four sources: (1) the Farm Production Regions- Northern Plains, Delta, etc., (2) a cluster analysis of farm characteristics in the U.S. (Sommer and Hines, 1991), (3) the USDA Land Resource Regions, and (4) the National Agricultural Statistics Service's (NASS) Crop Reporting Districts (CRD). Regions were constructed based on the types of commodities grown, along with environmental and physiographic factors such as soil, climate, and water. Regional boundaries conform to CRD's but state boundaries were not a factor in the aggregation process. The nine regions are: the Basin and Range (Region 1; BR), Northern Great Plains (Region 2; NGP), Heartland (Region 3; H), Northern Crescent (Region 4; NC), Fruitful Rim (Region 5; FR), Prairie Gateway (Region 6; PG), Mississippi Portal (Region 7; MP), Southern Seaboard (Region 8; SS), and Eastern Uplands (Region 9; EU).

Given the grouped, spatial nature of the data, it was anticipated that group-wise heterscedasticity would be an issue. Furthermore, there is no reason to believe that model coefficients would be same in each region. Hence, a model similar to Seemingly Unrelated Regression is utilized to correct for spatial heterogeneity and to allow separate parameter estimates for each Region.

Following Greene (1990) each Region is treated as a separate regression equation. The data comprising the 9 Regions is grouped and stacked by equation following Equation 1.

$$\begin{aligned} Y_1 &= X_1 b_1 + \varepsilon_1 \\ Y_2 &= X_2 b_2 + \varepsilon_2 \\ &\vdots \\ Y_9 &= X_9 b_9 + \varepsilon_9 \end{aligned} \tag{1.}$$

In (1) Y represents the dependent variable arranged in a column vector, X is a matrix comprised of a constant and relevant independent variables, b is a column vector of parameters or solution values, and ε is the unknown error term. Stacked and converted to matrix form, Equation 1 can be expressed as Equation 2.

2.

$$\begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_9 \end{bmatrix} = \begin{bmatrix} X_1 & 0 & \dots & 0 \\ 0 & X_2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & X_9 \end{bmatrix} \begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_9 \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_9 \end{bmatrix}$$

$$Y = Xb + \varepsilon$$

The X matrix in Equation 2 has a special "block-diagonal" form. It is this form that allows estimation of separate parameter values for each Region.

The spatial nature of the data is anticipated to give rise to group-wise heterogeneity. Specifically, each Region is hypothesized to possess a unique variance term (σ_{ii}) that is grouped in a matrix Σ (Equation 3).

3.

$$\Sigma = \begin{bmatrix} \sigma_{1,1} & 0 & \cdots & 0 \\ 0 & \sigma_{2,2} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \sigma_{9,9} \end{bmatrix}$$

Again, the form of Σ accounts only for cross-sectional heterscedasticity. The issue of spatial autocorrelation is left to further study.

Assuming that each cross-section (or Region) contains the same number of observations, the appropriate covariance matrix of the errors terms is expressed as Equation 4

4.

$$E[\varepsilon\varepsilon'] = V = \Sigma \otimes I$$

In Equation 4, I is an m by m identity matrix where m is the number of observations in each cross-section. Given V, the solution values (or parameters) of Equation 2 (i.e., b) are determined using feasible generalized least squares (GLS) as expressed by Equation 5.

5.

$$b_{GLS} = \left[X'V^{-1}X\right]X'V^{-1}Y$$

Here b_{GLS} is more efficient than regression (OLS) equation by equation or regression using an alternative estimation technique like fixed effects or random effects if and only if the σ_{ii} terms in Σ are statistically different (i.e., there is statistical evidence of group-wise heterogeneity). Presence of group-wise heterogeneity, thus the appropriateness of this regression model, is demonstrated in results.

Next follows discussion of the dependent and independent variables used in this study. To estimate the correlation between yield risk and the environmental variables, data from various sources is used. The National Agricultural Statistics Service (NASS) provided crop yield data by county for the years 1950-2000. These data were used to estimate the yield risk statistic. Data for the environmental variables comes from the Natural Resource Conservation Service (NRCS) Resource Assessment Division. Geographic information on Farm Resource Regions was provided by the Economic Research Service (ERS).

Dependent Variables

The dependent variable is designed to reflect the level of yield risk at the county level. NASS data was gathered for the years 1956-2000 on each of the major program crops: corn, soybeans, wheat, grain sorghum, cotton, and barley. The dependent variable of the model is the coefficient of variation for the total normalized percent deviation from the trend yield in a county. To arrive at the yield variable, several calculations were performed. First, the normalized percent deviation from the trend was calculated by taking the percent deviation from the trend and dividing by crop share for each county. This weighed the percent deviation from the trend for a given crop in such a way as to represent the share of that crop in the county in that year. Next, the sum of all the normalized percent deviations from the trend is taken for a given year and multiplied by 100. The standard deviation divided by the county mean then creates the coefficient of variation. The yield variation variable uses only those observations where the percent deviation from the trend is negative. Such a negative number should better reflect actual yield loss. Since negative deviations from the trend are often very large (as is the case of a catastrophic loss due to drought, major freezes, and excess rain) eliminating positive deviations from the trend, which are often small, provides a more accurate measure of the yield risk used to determine crop insurance subsidies. The estimation is expressed mathematically as (Equation 6);

$$\text{Normalized Deviant} = \sum (AY/TY_{tc}) * CS_{tc} + \ldots (AY/TY_{t6}) * CS_{t6} \tag{6.}$$

Where AY represents average yield, TY represents trend yield for the crop over the time period t, t represents time in years 1950-2000, C represents one of the six crops studied, and CS represents crop share. The coefficient of variation was calculated as the standard deviation of the normalized deviant divided by the mean of the normalized deviant.

The calculated yield variation for each county included in this study is illustrated in Figure 2. The reported yield variation (in percent) is also the aggregate premium rate for crop insurance in the county. Note that counties were included in this investigation only if 10,000 acres of the 6 program crops are historically planted in the county. Of the 2339

US counties that grow, at least, one of the 6 program crops, 693 counties did not meet the 10,000 acre threshold and were deleted. However, these 693 counties represented only 1.2% of the acreage across the 2339 counties. Unlike the theoretical model in Equations 4 and 5, each Region has a unique number of qualified counties. The number of counties included in each Region is reported in Table 1.

Independent Variables

The study uses five explanatory variables along with an acreage control variable to examine the relationship between yield risk and the environmental attributes of the extensive margin. The variables chosen account for the majority of the environmental impacts of agriculture found throughout the U.S. All of the agri-environmental indicators are products of the Resource Assessment Division of the NRCS- United States Department of Agriculture (USDA). Table 1 reports the five agri-environmental indicators along with relevant statistical information for the study and by region.

Average Annual Soil Erosion by Water on Cultivated Cropland as a Proportion of the Tolerable Rate (T) is used to determine the distribution of soil erosion by water over the study area. The variable represents estimates of actual soil erosion in 1997 due to water relative to the tolerable soil loss rate (T). Soil erosion is determined by using the Universal Soil Loss Equation (USLE) for individual 8-digit hydrologic units. (A U.S. map with an overlay of 8-digit hydrologic units can be found in Appendix 3.3- 8 Digit Hydrologic Units.) The T factor or the soil loss tolerance is used in conjunction with the USLE. The tolerable rate is defined as the “maximum rate of annual soil erosion that will permit crop productivity to be sustained economically and indefinitely” (Soil Erosion by Water, 2001). Using location specific NRI data the USLE is calculated as: A = RKLSCP, A is the computed soil loss per unit area, R is the rainfall factor, K is the soil erodibility factor, L is the slope length factor, S is the slope steepness factor, C is a cover and management factor, and P is a conservation practice factor (Soil Erosion by Water, 2001).

Data for the soil erosion variable was gathered from the 1997 Natural Resources Inventory (NRI). Cultivated cropland is defined as land devoted to row or close crops, summer fallow, aquaculture in crop rotation, or other cropland not planted including set-aside, double-cropped land devoted to horticulture, or land in hay or pasture previously in row or close crops in one of the past three years.

Water erosion is defined by the NRCS as the “process of detachment, transport, and deposition of soil in which the primary agent is water” (Water Quality and Ag., 1997). Water erosion can be caused by sheet, rill, and gully erosion but is only measured by sheet and rill for this analysis. Sheet and rill erosion is characterized by the removal of a thin layer of topsoil by runoff water. This type of erosion typically forms small eroding channels a few inches in depth. Soil erosion by water in the U.S. is found primarily east of the 100th meridian, where rainfall is heaviest. (Water Quality and Ag., 1997)

The NRCS refers to the wind erosion variable by the title, Average Annual Soil Erosion by Wind on Cultivated Cropland as a Proportion of the Tolerable Rate (T). This variable uses data from the 1997 NRI to measure actual soil erosion by wind for each 8-digit hydrologic unit. Actual soil erosion for the variable is calculated using the average annual Wind Erosion Equation (WEQ). Wind erosion is defined as "The process of detachment, transport, and deposition of soil by wind" (Soil Erosion by Wind, 2001). The WEQ is "an erosion model designed to predict the long-term average annual soil losses from a field having specific characteristics" (Soil Erosion by Wind, 2001). The functional form is E = f(IKCLV) where E, measured in tons per acre per year, is the estimated average annual soil loss, I is the soil erodibility, K is the soil ridge roughness factor, C is the climatic factor, L is the equivalent unsheltered distance across the field along the prevailing wind erosion direction, and V is the equivalent vegetative cover. Wind erosion occurs primarily in the western U.S. and is especially prominent in Minnesota, Texas, Oklahoma, New Mexico, Colorado and areas of Montana. (Soil Erosion by Wind, 2001)

The third NRCS variable used in this study is Potential Nitrogen Fertilizer Loss from Farm Fields, Based on Production of 7 Major Crops. Potential nitrogen loss was measured using land use data from the 1992 NRI along with fertilizer use data and crop yield data from NASS. Nutrient application rates by state as well as the percentage of acres treated with nitrogen were imputed to NRI sample points by state and crop. Crops included in the study were corn, soybean, wheat, cotton, barley, sorghum, and rice. Excess nitrogen was calculated on a per acre basis in pounds for each NRI sample point. Excess nitrogen was calculated as the difference between the application rate and the estimated amount of nitrogen likely to be taken up by the crop grown and removed from the field at harvest. Nutrient uptake was calculated as the percent of nutrients in the harvested crop biomass multiplied by the acre-based county crop yield five- year average (1988-1992). By dividing the excess nitrogen loading per watershed (accounting for the percent of acres treated in each watershed) by total acres of non-federal rural land in the watershed, an average per-acre rate for each watershed was determined. (Potential Nitrogen Fertilizer, 1996)

The category Pesticide Leaching and Runoff Potential by Watershed for 13 Crops is used to derive the fourth and fifth variables used in the study. Five determinants of pesticide loss were used in a simulation including: 1. intrinsic potential of pesticide runoff or leaching losses from a given soil type, 2. chemical properties of the pesticides, 3. annual rainfall and its relationship to leaching and runoff, 4. cropping patterns, and 5. chemical use. Loss estimates were estimated for NRCS by Don Goss (Texas Agricultural Experiment Station, Temple, Texas) using the Groundwater Loading Effects of Agricultural Management (GLEAMS) field-level process model. Estimates for leaching and runoff were made for 240 pesticides applied to 120 soils for 20 years of daily weather from 55 climate stations in the U.S. Pesticide runoff was defined as movement beyond the edge of the field and included pesticides in solution as well as pesticides in soil and organic matter. Pesticide leaching was defined as movement beyond the bottom of the root-zone. Irrigated and non-irrigated conditions were accounted for in separate estimates. Using 1992 NRI sample points as representative fields along with land use data and a national chemical use database, pesticide loss results were integrated to simulate potential pesticide loss on thirteen crops including: barley, corn, cotton, oats, peanuts, potatoes, rice, sorghum, soybeans, sugar beets, sunflowers, tobacco, and wheat. An estimate of the expected level of pesticides applied by crop and by state, along with the percent of acres treated was obtained by NRCS for over 200 pesticides. Their estimates reflect average chemical use over the years 1990-93. To estimate potential pesticide loss, chemical application rate data was combined with state and crop-specific NRI sample points. Maximum levels of runoff and leaching over the 20-year period of study were attributed to NRI sample points using match-ups by soil and proximity to the climate stations. Total loss from each NRI sample point was measured by summing over loss estimates for all potential chemicals used on the crop grown and was adjusted for percentage of acres treated. Total losses from NRI sample points were then aggregated over all points within a watershed using NRI expansion factors and weights and were then averaged by dividing the acres of nonfederal rural land in the watershed. (Pesticide Leaching 1996, Pesticide Runoff 1996)

The acreage control variable was calculated by taking the acreage in each county devoted to the production of the six focus crops and dividing that number by the total number of acres in the county and multiplying by 100. This gave the percentage of acreage devoted to the production of the six study crops in each county. This value is a reflection of cropping intensity within a county. Data on total number of acreage in each county was not limited to land devoted to agriculture. Thus, total county acreage reflects all lands within a county, regardless of land cover and does not reflect the percentage of agricultural land within a county devoted to the six crops in the study.

Results

First round OLS estimation using Equation 7 for each Region was conducted to test for data issues including multicolliniarity, infinite error variance (IEV), heteroscedasticity (within the Region), autocorrelation (also within the Region), omitted relevant variable bias (OVB), and non-linearity.

$$y\_var_{i,j} = b_0 + b_1 nitfert_{i,j} + b_2 e\_h2o_{i,j} + b_3 wind_{i,j} + b_4 p\_roff_{i,j} + b_5 p\_lea_{i,j} + b_6 pac_{,j} \quad 7.$$

Where	y_var	Crop Yield Variation
	nitfert	Potential Nitrogen Fertilizer Loss from farm fields
	e_h2o	Soil Erosion from farm fields
	wind	Wind Erosion from farm fields
	p_roff	Pesticide Run-Off from farm fields
	p_lea	Pesticide Leached from farm fields
	pac	% of Program Crop Acreage to Total Acreage in the county
	i	= 1 to n observations within a Region
	j	= 1 to 9 regions

Results indicated the presence of severe multicollinearity in the data. Using factor analysis it was determined that the independent variables nitfert, p_roff, and pac acted as a group in explaining the dependent variable. Similarly, the independent variables e_h2o and p_lea acted as a group. Factor analysis provides principal components called factor scores that can be used to create group variables. The first group variable representing nitfert, p_roff, and pac is called “crop” because these variables have to do with application of chemical to crops and crop acreage. The second group variable representing e_h2o and p_lea is called “water” because these two variables are related to water quality. Note that a one unit increase in a group variable is associated with a one unit increase in one or more of the variables comprising the group. Calculated values for water, wind, and crop for each county included in this study are illustrated, respectively, in Figures 3, 4, and 5. Table 1 reports relevant statistical information for variables water, wind, and crop for the study and by region.

Further data evaluation for each region was conducted using the modified version of Equation 7 (Equation 8).

$$y\_var_{i,j} = b_0 + b_1 water_{i,j} + b_2 wind_{i,j} + b_3 crop_{,j} \qquad 8.$$

Where	y_var	Crop Yield Variation
	water	A composite variable representing e_h2o and p_lea
	wind	Wind Erosion
	crop	A composite variable representing nitfert, p_roff, and pac
	i	= 1 to n observations within a Region
	j	= 1 to 9 regions

Results indicate that the data from 6 Regions (NGP, H, NC, PG, MP, SS) suffers from IEV. However, because IEV is most problematic in small samples, this problem was ignored. First order autocorrelation (FOA; within a Region) was detected and the data corrected for this problem in 2 Regions (NGP and MP). Within the cross-section heteroscedasticity was detected and the data corrected for this problem in all Regions. Interestingly, Box-Cox analysis indicates that a log-linear structural form is preferred to the linear structure imposed in Equation 8. ORV could be an issue in 3 Regions (NGP, SS, and EU). However, given the results of Box-Cox, it is likely that a non-linear functional form, and not omitted variables is the true issue in these regions.

Group-wise heteroscedasticity was detected using procedure outlined in Greene (1990). Hence, Equation 2 is the appropriate model specification. The matrix Σ (Equation 3) was constructed using appropriate estimates of σ_{ii} for each region (e_i^2/n_i for each Region i is a consistent estimate of σ_{ii}). Given appropriate data corrections for FOA and heteroscedasticity in each Region, the block-diagonal matrix from Equation 2 was formed and the parameters of Equation 9 estimated following Equation 5.

In Equation 9 the subscript m ranges from 1 to the total number of observations (1645), the sum of the n_i (the number of observations) for the i = 1 to 9 Regions. The first half of each variable name represents the parameter to be estimated (X0 is the corrected intercept term, WD is wind erosion, WR is the water variable, and CR is the crop variable). The second half of each variable represents the Region as defined above. Each variable was created by multiplying the appropriate stacked variable (X0, wind, water, and crop) by an appropriate dummy variable where the dummy variable held the value of 1 if the variable was from a specific region and was 0 otherwise.

$$
\begin{aligned}
y\_var_m = \; & b_1X0\_BR_m + b_2WD\_BR_m + b_3WR\_BR_m + b_4CP\_BR_m + \\
& b_5X0\_NGP_m + b_6WD\_NGP_m + b_7WR\_NGP_m + b_8CP\_NGP_m + \\
& b_9X0\_H_{im} + b_{10}WD\_H_m + b_{11}WR\_H_m + b_{12}CP\_H_m + \\
& b_{13}X0\_NC_m + b_{14}WD\_NC_m + b_{15}WR\_NC_m + b_{16}CP\_NC_m + \\
& b_{17}X0\_FR_m + b_{18}WD\_FR_m + b_{19}WR\_FR_m + b_{20}CP\_FR_m + \\
& b_{21}X0\_PG_m + b_{22}WD\_PG_m + b_{23}WR\_PG_m + b_{24}CP\_PG_m + \\
& b_{25}X0\_MP_m + b_{26}WD\_MP_m + b_{27}WR\_MP_m + b_{28}CP\_MP_m + \\
& b_{29}X0\_SS_m + b_{30}WD\_SS_m + b_{31}WR\_SS_m + b_{32}CP\_SS_m + \\
& b_{33}X0\_EU_m + b_{34}WD\_EU_m + b_{35}WR\_EU_m + b_{36}CP\_EU_m
\end{aligned}
\tag{9}
$$

Results from the estimation of Equation 9 are reported by region in Table 2. The estimated model explains 87% of the variation in the dependent variable Y_Var (yield variation). The independent variables of the model, as a group, contribute to our understanding of Y_Var with 95% confidence.

The intercept terms for the 9 regions (x0_BR, x0_NGP, x0_H, x0_NC, x0_FR, x0_PG, x0_MP, x0_SS, and x0_EU) capture the average value of yield variation in the respective district for given values of wind, water, and crop. Setting wind, water, and crop to 0 (i.e., evaluating yield variation at the intercept), results indicate that yield variation is highest in the Northern Great Plains (15.65) and is lowest in the Heartland (7.73; Table 2). Ranked by region from highest mean yield variation to lowest we find the following: Northern Great Plains (15.65), Prairie Gateway (15.33), Southern Seaboard (15.03), Fruitful Rim (12.15), Eastern Uplands (10.69), Northern Crescent (9.10), Mississippi Portal (8.43), Basin and Range (8.38), and Heartland (7.73). Each of these variables is statistically different from zero with 95% confidence. Further investigation reveals that mean yield variation is not different at the 10% level of significance in the Northern Great Plains, Prairie Gateway, and Southern Seaboard, in the Fruitful Rim and Eastern Uplands, and in the Northern Crescent, Mississippi Portal, Basin and Range, and Heartland regions. Based on estimate yield variation, the data in this investigation can be grouped into 3 semi-contiguous regions.

The relationship between yield variation and the variables wind, water, and crop is best described by the individual parameter estimates (or slope terms). Note that causality is not being argued in this investigation. Specifically, it is not possible to state that a one-unit change in wind, water, or crop "causes" a change in yield variation. Parameter estimates are best described as indicating the correlation between wind, water, and crop and yield variation. Furthermore, parameter estimates of interest are those where one rejects the null hypothesis that the estimate in question is different from 0 with 90% confidence or better. The underlying hypothesis is that wind, water, and crop are positively correlated with yield variability, thus the sign of individual parameter estimates is expected to be 0 (assuming that the parameter estimate is also statistically non-zero with 90% confidence).

For the water variable, water erosion and pesticide leaching are statistically correlated with yield variation only in 5 of the 9 Regions. In all cases, water erosion and pesticide leaching is negatively correlated with yield variation. In order of magnitude from smallest to largest change in (negative) slope, the regions are ranked as follows: Northern Crescent (-0.23), Eastern Uplands (-0.67), Northern Great Plains (-0.70), Prairie Gateway (-0.94), and Southern Seaboard (-1.38). F-tests across the groups reveal that the slope terms for these 5 regions are statistically the same with 95% confidence.

For wind erosion, 6 regions are statistically correlated with yield variation with 95% confidence. Of the 6 regions, in 5 cases the correlation is positive. For the 5 regions where the correlation between wind erosion and yield variation (as indicated by the slope term) is positive, the correlation is largest in the Eastern Uplands (103.14) and smallest in the Northern Crescent (0.11). The remaining regions are ranked in order as follows: Prairie Gateway (0.46), Heartland (0.18), and the Fruitful Rim (0.12). However, F-tests across the groups indicate that the bottom 3 regions (Heartland, Fruitful Rim, and Northern Crescent) are not statistically different with 95% confidence. In the Southern Seaboard, wind erosion is negatively correlated with yield variation. Furthermore, F analysis indicates that the negative slope in the Southern Region is statistically different with 95% confidence from the slopes in the other 5 regions.

Finally, for the crop variable, nitrogen fertilize loss, pesticide runoff, and percent crop acreage are statistically different from 0 (statistically correlated with yield variation) in all regions but the basin and range. In the case of crop, the correlation with yield variation is negative. In order of magnitude from smallest to largest slope, the regions are ranked as follows: Heartland (-0.06), Mississippi Portal (-0.07), Fruitful Rim (-0.16), Northern Crescent (-0.17), Eastern Uplands (-0.35), Northern Great Plains (-0.42), Prairie Gateway (-0.42), and Southern Seaboard (-0.46). Note that this ordering is roughly reverse of that for mean yield variations. Based on crop, the regions can be aggregated into two groups. F-tests across the groups indicate that the slope terms associated with the Heartland, Mississippi Portal, Fruitful Rim, and Northern Crescent are statistically the same with 95% confidence. The slope coefficients for the Eastern Uplands, Northern Great Plains, Prairie Gateway, and Southern Seaboard are also statistically equal.

Finally, the Northern Crescent, Prairie Gateway, Southern Seaboard, and Eastern Uplands are the only regions where all 3 slope terms (water, wind, and crop) are statistically different from 0 (with 95% confidence). Of these four regions, the Southern Seaboard has the smallest slope terms for water, wind, and crop. Alternatively, the Northern Crescent records the largest slopes for water and crop (but the 3rd largest slope for wind). Only the Basin and Range reports slope terms where none is statistically different from 0 (with 95% confidence).

CONCLUSIONS

Investigating the relationship between yield risk and the environment brings to light several potentially relevant policy issues. This paper subscribes to the notion that risk management programs, particularly crop insurance, are creating incentives for farmers to increase production at the extensive margin. Firstly, it must be stated that if risk management programs are encouraging production at the national level, there must necessarily be a resulting increase in nitrogen and pesticide use and likely an increase in soil erosion as well. Secondly, if risk management programs are encouraging increases or shifts in production at the farm level, a careful look must be taken at the additional acres being brought into production.

The purpose of this study is to investigate the relationship between yield risk and the environment. Previous studies have shown that risk management programs such as disaster assistance and crop insurance have caused shifts in the production of six major crops in the U.S.. Additionally, research has shown that these programs are likely to encourage production expansions onto the extensive margin, at both the farm level and regional level. It has been proposed elsewhere that expansions and shifts in production may result in environmental damages. This study attempts to indirectly assess the potential environmental impacts of such shifts and expansions by looking more closely at the relationship between yield risk and a set of agri-environmental indicators.

The results suggest that increases in production as a result of farmers reactions to risk management programs are likely taking place primarily in the Northern Great Plains, and the Prairie Gateway. The environmental attributes associated with this area of the county are in many cases vastly different from those in other regions of the U.S. Thus, as marginal land is brought into production, it becomes imperative that the environmental characteristics of that land be considered when designing agri-environmental policies such as the targeting of green support payments.

The results of this study suggest that as farmers take advantage of subsidies that pay more to those who produce in higher risk regions, increases in soil erosion from water are likely in the Heartland and Northern Great Plains. As these two regions make up over half of the U.S. acreage devoted to the six crops in the study, this is of particular concern. Elasticities for the two regions suggest that a one-unit change in water erosion in the Heartland is associated with a 0.11 unit increase in yield variability. A similar result is found for the Northern Great Plains. Soil erosion by wind is significantly correlated with yield variation in the Heartland and Prairie Gateway regions. As these two regions make up over 65% of the acreage devoted to the six crops in the study, wind erosion is also of particular concern. Elasticity values from the two regions suggest that a one-unit increase in wind erosion in the Heartland is associated with a .026 unit increase in yield variability. The elasticity value for the Prairie Gateway reveals a .059 unit increase in yield variability. This suggests that as farmers take advantage of subsidies that encourage production in higher risk regions, wind erosion in the Heartland and Prairie Gateway is likely to be a result.

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Table 1: Statistical information for the dependent and independent variables used in this study.

For the Study

Variable	N	Mean	Std Dev	Minimum	Maximum
y_var*	1645	8.5355623	3.4402415	3.0000000	29.0000000
nitfert	1645	11.1392030	9.7572316	0	52.0231426
e_h2o	1645	0.8541789	0.5688562	0	6.2141463
p_roff	1645	2.3404255	0.7051090	0	3.0000000
p_lea	1645	1.9355623	0.9105924	0	3.0000000
pac	1645	26.8308114	22.1112524	0.2805533	95.3075100
crop	1645	17.2242381	13.0405755	0.1413534	59.6172336
water	1645	-1.2695258	3.2991164	-12.6545537	9.4721180
wind	1645	1.3613387	3.3429386	0	52.1296810

By Region

Region 1: Basin and Range

Variable	N	Mean	Std Dev	Minimum	Maximum
y_var	49	8.9387755	2.0249297	5.0000000	13.0000000
nitfert	49	1.9956619	2.3555015	0	7.6387912
e_h2o	49	0.7153782	0.7005748	0	2.4452505
p_roff	49	1.5510204	0.8431396	0	3.0000000
p_lea	49	1.6326531	1.2860449	0	3.0000000
pac	49	5.0113294	4.7788940	0.2805533	24.9643954
crop	49	3.5610977	2.9937991	0.1413534	14.2991561
water	49	1.3485893	0.9579711	-0.3147594	2.9638041
wind	49	1.3595653	1.8291485	0	7.3520672

Region 2: Northern Great Plains

Variable	N	Mean	Std Dev	Minimum	Maximum
y_var	159	11.4088050	3.4681441	4.0000000	22.0000000
nitfert	159	3.5277808	3.1895031	0.0053508	15.9741397
e_h2o	159	0.3464493	0.1651953	0.0423823	0.9747524
p_roff	159	1.6981132	0.6137116	1.0000000	3.0000000
p_lea	159	1.0251572	0.5840679	0	3.0000000
pac	159	19.1194492	11.8189385	0.4458427	44.0447602
crop	159	10.5412118	6.0291828	0.9023982	22.5549219
water	159	-0.9019927	1.6548057	-5.0608754	3.1395827
wind	159	3.0667237	2.2363276	0.2538016	11.3965542

* Variable Key

y_var	Crop Yield Variation
nitfert	Potential Nitrogen Fertilizer Loss from farm fields
e_h2o	Soil Erosion from farm fields
p_roff	Pesticide Run-Off from farm fields
p_lea	Pesticide Leached from farm fields
pac	Percent of Program Crop Acreage to Total Acreage in the county
crop	A composite variable representing nitfert, p_roff, and pac
water	A composite variable representing e_h2o and p_lea.
Wind	Wind Erosion

Table 1 (Continued): Statistical information for the dependent and independent variables used in this study.

Region 3: Heartland

Variable	N	Mean	Std Dev	Minimum	Maximum
y_var*	526	6.0513308	1.7433488	3.0000000	14.0000000
nitfert	526	20.4490561	10.1948596	1.3338254	52.0231426
e_h2o	526	1.0104412	0.4884111	0	3.1438946
p_roff	526	2.8878327	0.3277110	1.0000000	3.0000000
p_lea	526	1.7262357	0.9627124	0	3.0000000
pac	526	43.7404234	23.9699957	1.4808121	95.3075100
crop	526	28.6909310	13.6501517	1.8250693	59.6172336
water	526	-3.7732199	3.6305936	-12.6545537	3.1344922
wind	526	0.5203297	1.1332440	0	8.4258437

Region 4: Northern Crescent

Variable	N	Mean	Std Dev	Minimum	Maximum
y_var	185	7.6216216	2.9094239	4.0000000	22.0000000
nitfert	185	8.5713979	6.6048449	0.8950056	32.0372639
e_h2o	185	0.8638790	0.5379435	0	2.3019995
p_roff	185	2.6756757	0.5240962	1.0000000	3.0000000
p_lea	185	2.1189189	0.6228606	0	3.0000000
pac	185	15.9335480	11.2988839	0.6246720	55.7721981
crop	185	11.4527235	7.2576637	1.4898992	33.7635757
water	185	0.3757443	1.4466827	-4.6335388	2.7287310
wind	185	0.9804797	1.2707892	0	6.3687197

Region 5: Fruitful Rim

Variable	N	Mean	Std Dev	Minimum	Maximum
y_var	38	11.3157895	2.5585602	7.0000000	18.0000000
nitfert	38	6.9140542	3.3257869	0.1093596	15.1410653
e_h2o	38	0.6504613	0.3422731	0.0459215	1.5290000
p_roff	38	1.6052632	0.9736938	0	3.0000000
p_lea	38	2.2368421	0.7141130	1.0000000	3.0000000
pac	38	13.9354420	14.4851050	0.3689618	61.4059454
crop	38	9.7285508	7.6305539	0.5365876	31.9812222
water	38	1.2362324	1.5956312	-4.0651189	4.6370832
wind	38	4.2501203	6.5528753	0	19.3344576

* Variable Key

y_var	Crop Yield Variation
nitfert	Potential Nitrogen Fertilizer Loss from farm fields
e_h2o	Soil Erosion from farm fields
p_roff	Pesticide Run-Off from farm fields
p_lea	Pesticide Leached from farm fields
pac	Percent of Program Crop Acreage to Total Acreage in the county
crop	A composite variable representing nitfert, p_roff, and pac
water	A composite variable representing e_h2o and p_lea.
Wind	Wind Erosion

Table 1 (Continued): Statistical information for the dependent and independent variables used in this study.

Region 6: Prairie Gateway

Variable	N	Mean	Std Dev	Minimum	Maximum
y_var*	333	11.5495495	3.5679431	3.0000000	29.0000000
nitfert	333	6.1677237	3.6805828	0.2855901	21.6971902
e_h2o	333	0.6065292	0.3213507	0	1.8819000
p_roff	333	1.8978979	0.5769898	0	3.0000000
p_lea	333	1.8048048	0.6948873	0	3.0000000
pac	333	27.4531880	18.2953471	0.9851959	74.7356468
crop	333	15.3590324	9.0159467	1.0512039	37.6289399
water	333	-1.3086832	2.8568009	-8.4159064	9.4721180
wind	333	3.1932020	5.9904256	0	52.1296810

Region 7: Mississippi Portal

Variable	N	Mean	Std Dev	Minimum	Maximum
y_var	105	7.2095238	1.6623387	4.0000000	18.0000000
nitfert	105	13.6496999	8.1728970	1.1911668	29.9896055
e_h2o	105	1.2357040	0.7461998	0.1909112	3.7944058
p_roff	105	2.8571429	0.3516054	2.0000000	3.0000000
p_lea	105	2.8666667	0.3415650	2.0000000	3.0000000
pac	105	25.3237088	20.9020727	1.5796013	88.1792419
crop	105	17.6958016	11.9584023	2.1143297	48.3481957
water	105	-0.3650344	2.9699301	-9.5221719	3.3296157
wind	105	0	0	0	0

Region 8: Southern Seaboard

Variable	N	Mean	Std Dev	Minimum	Maximum
y_var	163	9.0981595	2.2640909	5.0000000	19.0000000
nitfert	163	7.4812818	4.4249186	0.0450723	18.0977367
e_air	163	0.0319243	0.2170336	0	2.1204002
e_h2o	163	1.0985229	0.8205208	0	6.2141463
p_roff	163	1.9509202	0.3817387	0	3.0000000
p_lea	163	2.7852761	0.4810268	1.0000000	3.0000000
pac	163	11.7098799	7.0265785	1.5347379	39.1538080
crop	163	8.8469242	4.4326804	0.8840953	25.1654368
water	163	1.2782623	1.0256724	-2.6537072	4.6529660
wind	163	0.0319243	0.2170336	0	2.1204002

* Variable Key

y_var	Crop Yield Variation
nitfert	Potential Nitrogen Fertilizer Loss from farm fields
e_h2o	Soil Erosion from farm fields
p_roff	Pesticide Run-Off from farm fields
p_lea	Pesticide Leached from farm fields
pac	Percent of Program Crop Acreage to Total Acreage in the county
crop	A composite variable representing nitfert, p_roff, and pac
water	A composite variable representing e_h2o and p_lea.
Wind	Wind Erosion

Table 1 (Continued): Statistical information for the dependent and independent variables used in this study.

Region 9: Eastern Uplands

Variable	N	Mean	Std Dev	Minimum	Maximum
y_var*	87	7.8160920	1.8647821	4.0000000	14.0000000
nitfert	87	4.0703318	3.0612181	0.1817316	17.0121494
e_h2o	87	1.0135134	0.4317051	0	2.2292864
p_roff	87	2.0574713	0.4136149	1.0000000	3.0000000
p_lea	87	2.2988506	0.7488742	0	3.0000000
pac	87	7.5495382	4.4244826	0.9702246	23.8894299
crop	87	5.6182895	2.7313521	0.8075844	13.0042349
water	87	1.4132594	0.8035010	-1.2381663	2.9930050
wind	87	0.000547492	0.0039439	0	0.0345246

* Variable Key

y_var	Crop Yield Variation
nitfert	Potential Nitrogen Fertilizer Loss from farm fields
e_h2o	Soil Erosion from farm fields
p_roff	Pesticide Run-Off from farm fields
p_lea	Pesticide Leached from farm fields
pac	Percent of Program Crop Acreage to Total Acreage in the county
crop	A composite variable representing nitfert, p_roff, and pac
water	A composite variable representing e_h2o and p_lea.
Wind	Wind Erosion

Table 2. Results of regression estimation reported by region.

	ESTIMATE	Standard Error	T_STAT	Prob > |T|
Region 1: Basin and Range				
Constant	8.382	0.833	10.063	0.0000
Wind	-0.141	0.200	-0.705	0.4811
Water	0.346	0.262	1.321	0.1866
Crop	0.104	0.065	1.586	0.1130
Region 2: Northern Great Plains				
Constant	15.649	0.768	20.366	0.0000
Wind	-0.088	0.145	-0.606	0.5447
Water	-0.700	0.338	-2.071	0.0386
Crop	-0.421	0.105	-3.995	0.0001
Region 3: Heartland				
Constant	7.733	0.198	39.148	0.0000
Wind	0.184	0.066	2.778	0.0055
Water	-0.016	0.032	-0.507	0.6122
Crop	-0.066	0.009	-7.670	0.0000
Region 4: Northern Crescent				
Constant	9.104	0.488	18.653	0.0000
Wind	0.109	0.066	1.658	0.0975
Water	-0.234	0.122	-1.922	0.0548
Crop	-0.171	0.028	-6.171	0.0000
Region 5: Fruitful Rim				
Constant	12.153	1.039	11.693	0.0000
Wind	0.125	0.091	1.375	0.1693
Water	0.054	0.294	0.184	0.8541
Crop	-0.163	0.098	-1.657	0.0978

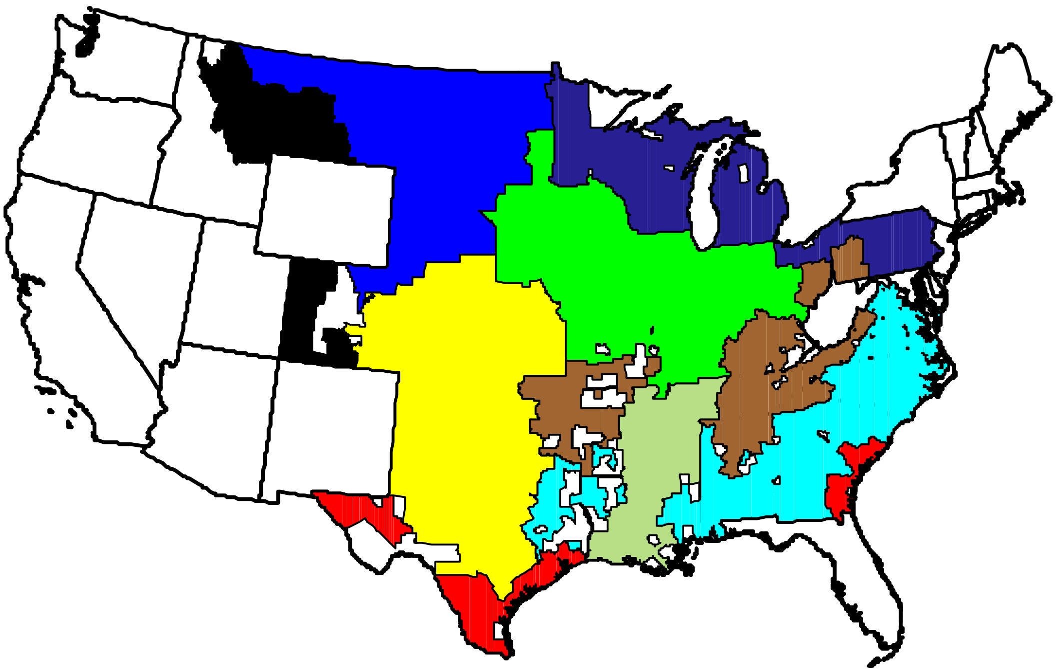
Adjusted R^2 = 0.87
Constant: Estimated mean level of Yield Variation
Wind: Wind Erosion
Water: A composite variable representing water quality derived from USDA ERS measures of water erosion and pesticide leaching.
Crop: A composite variable representing crop production derived from USDA ERS measures of nitrogen fertilizer loss and pesticide runoff and percent of program crop production.

Table 2 (Continued). Results of regression estimation reported by region.

	ESTIMATE	Standard Error	T_STAT	Prob > |T|
Region 6: Prairie Gateway				
Constant	15.331	0.516	29.736	0.0000
Wind	0.465	0.059	7.834	0.0000
Water	-0.941	0.185	-5.084	0.0000
Crop	-0.423	0.051	-8.275	0.0000
Region 7: Mississippi Portal				
Constant	8.429	0.638	13.213	0.0000
Water	-0.082	0.140	-0.584	0.5591
Crop	-0.074	0.035	-2.096	0.0362
Region 8: Southern Seaboard				
Constant	15.034	0.820	18.334	0.0000
Wind	-1.312	0.281	-4.678	0.0000
Water	-1.382	0.224	-6.183	0.0000
Crop	-0.463	0.056	-8.274	0.0000
Region 9: Eastern Uplands				
Constant	10.687	0.733	14.571	0.0000
Wind	103.143	6.688	15.423	0.0000
Water	-0.672	0.263	-2.556	0.0107
Crop	-0.348	0.070	-5.001	0.0000

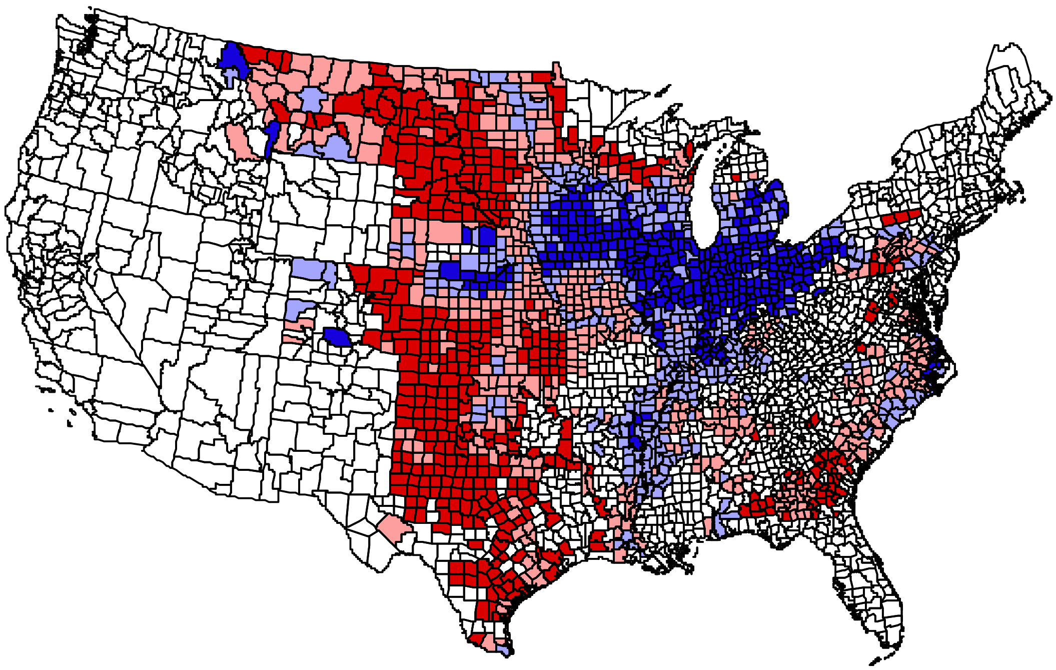
Adjusted $R^2 = 0.87$
Constant: Estimated mean level of Yield Variation
Wind: Wind Erosion
Water: A composite variable representing water quality derived from USDA ERS measures of water erosion and pesticide leaching.
Crop: A composite variable representing crop production derived from USDA ERS measures of nitrogen fertilizer loss and pesticide runoff and percent of program crop production.

Figure 1. E.R.S Farm Resource Regions as attached to studied counties.



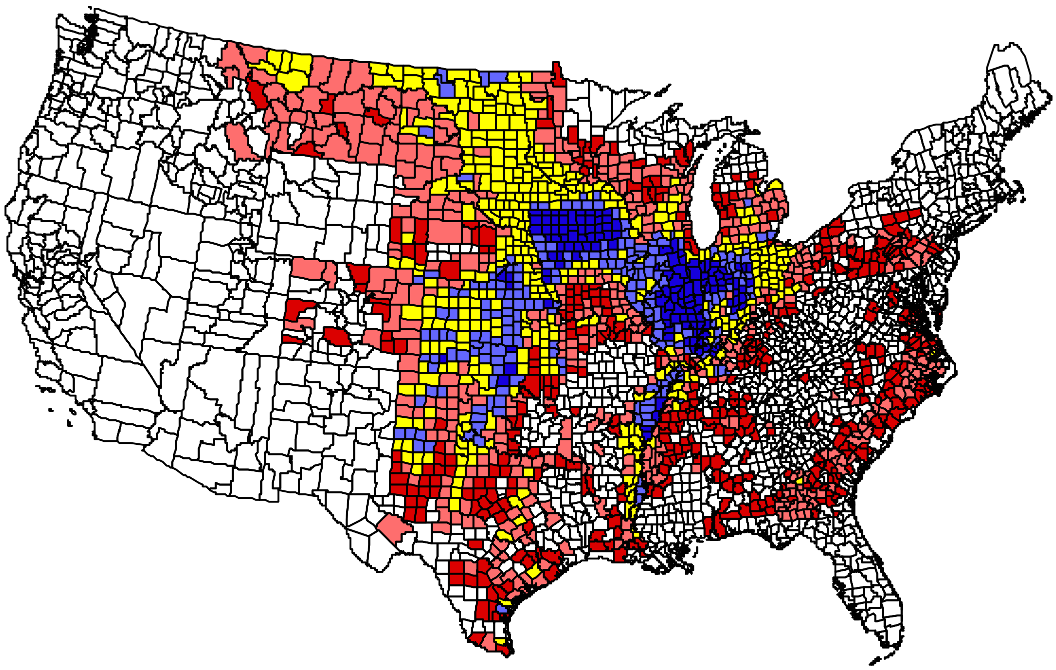
Color Scheme:			
	Black	Region 1	Basin and Range
	Blue	Region 2	Northern Great Plains
	Green	Region 3	Heartland
	Purple	Region 4	Northern Crescent
	Red	Region 5	Fruitful Rim
	Yellow	Region 6	Prairie Gateway
	Olive	Region 7	Mississippi Portal
	Aqua	Region 8	Southern Seaboard
	Brown	Region 9	Eastern Uplands
	Clear		Counties not included in study

Figure 2. Program Crop Yield Variation by County



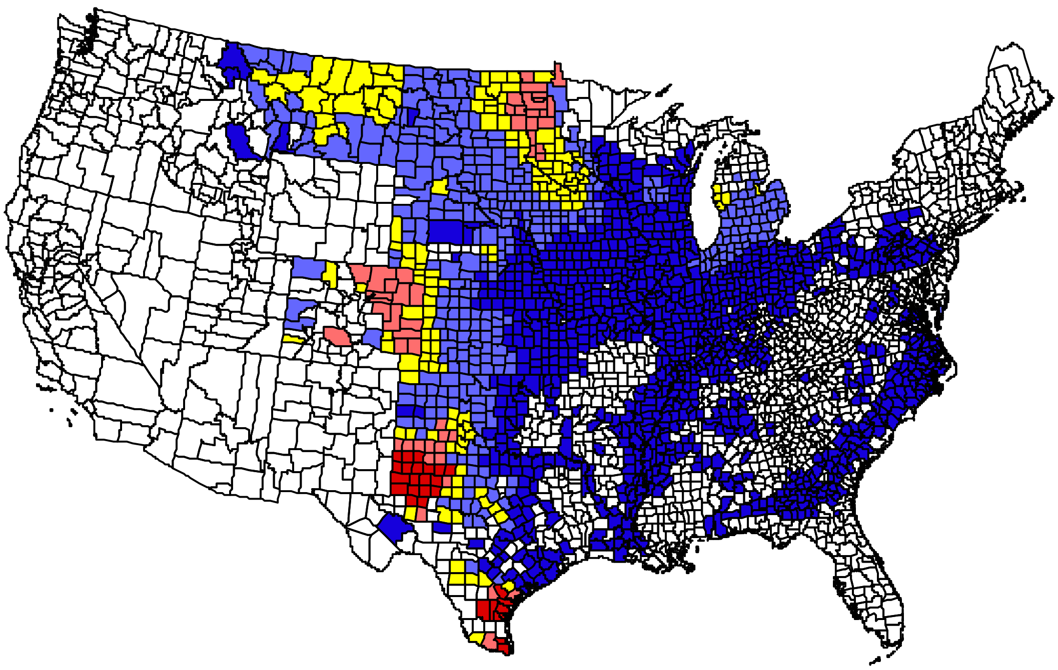
Color Scheme:	Red	10.0 < Yield Variation < 100.0
	Pink	7.5 < Yield Variation < 10.0
	Light Blue	5.0 < Yield Variation < 7.5
	Blue	0.0 < Yield Variation < 5.0

Figure 3. County values for water; a composite variable representing water quality derived from USDA ERS measures of water erosion and pesticide leaching.



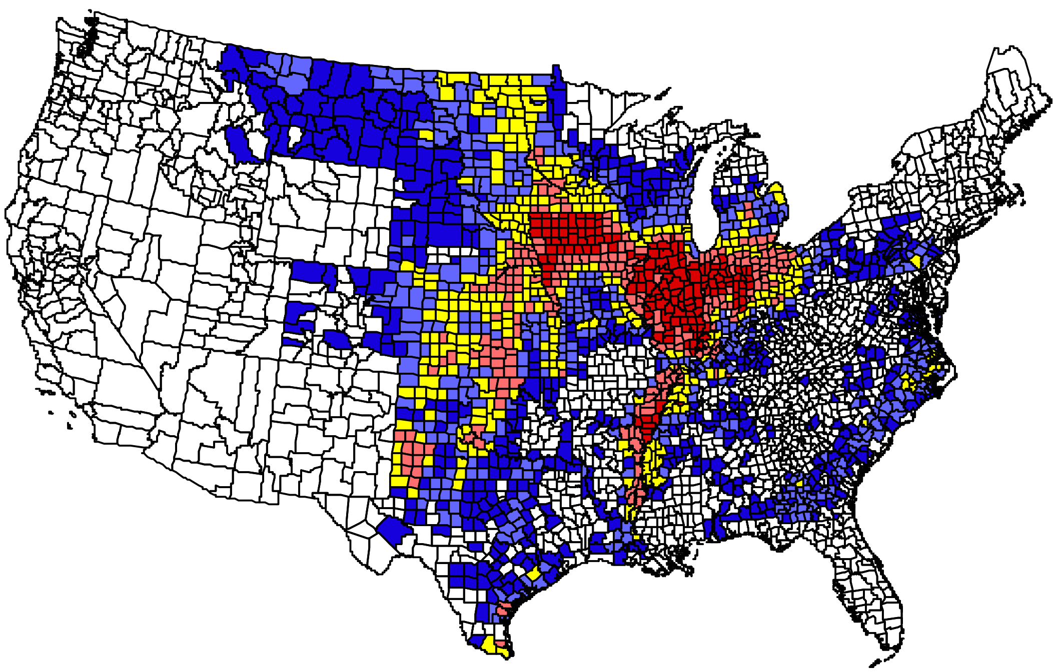
Color Scheme:	Blue	-12.655 < Water < -6.799
	Light Blue	- 6.799 < Water < -3.508
	Yellow	- 3.508 < Water < -0.898
	Light Red	- 0.898 < Water < 1.200
	Red	1.200 < Water < 9.472

Figure 4. County values for wind derived from USDA ERS measures of air erosion.



Color Scheme:	Blue	0.000 < Wind < 0.908
	Light Blue	0.908 < Wind < 2.818
	Yellow	2.818 < Wind < 6.123
	Light Red	6.123 < Wind < 11.626
	Red	11.626 < Wind < 52.130

Figure 5. County values for crop; a composite variable representing crop production derived from USDA ERS measures of nitrogen fertilizer loss and pesticide runoff and percent of program crop production.



Color Scheme:		
	Blue	0.141 < Crop < 8.095
	Light Blue	8.095 < Crop < 15.912
	Yellow	15.912 < Crop < 25.780
	Light Red	25.780 < Crop < 38.312
	Red	38.312 < Crop < 59.617