2002

INVESTIGATING THE RELATIONSHIP BETWEEN YIELD RISK AND AGRIENVIRONMENTAL INDICATORS

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ABSTRACT OF THESIS

INVESTIGATING THE RELATIONSHIP BETWEEN YIELD RISK AND AGRI-ENVIRONMENTAL INDICATORS

The U.S. crop insurance program provides subsidies and risk reduction benefits to producers. In response to enhanced income and decreased risk, farmers increase planted acres, often in more risky areas of production. The primary objective of this thesis is to determine the relationship between the environment and acreage brought into production as a result of crop insurance. This thesis does so indirectly, by examining the relationship between yield risk and a set of agri-environmental indicators. An ordinary least squares (OLS) model is used to examine this relationship. It is hypothesized that as acreage becomes more risky in terms of yield, environmental damages resulting from production will increase. Results suggest that while this is not always the case, there is a strong correlation between yield risk and increased soil erosion for the majority of the acreage in the study area.

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THESIS

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science in the
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CHAPTER ONE
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. In recent years some researchers have speculated that these changing land-use patterns may also be the result of government agricultural support programs, namely the Federal Crop Insurance Program (FCIP) (Griffin, 1996; Skees 1999).

FCIP was reformed in 1980 to replace a disaster assistance program that was at the time 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.

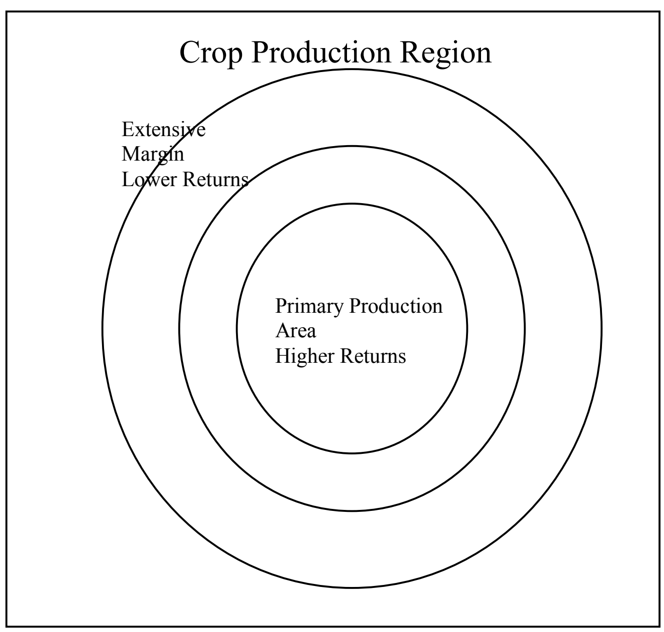
Due to the design of crop insurance subsidies, higher levels of transfer payments are given to comparatively higher-risk areas of production. Since many producers respond to income transfers by increasing production, high-risk areas are likely to see increases in production as well as increases in transfer 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. Skees (2000) provides an example of how such a policy might function:

> Consider two farmers who face different premium rates. For the lower risk farmer, the rate is $10 per $100 of liability. The higher risk farmer would be charged $20 per $100 of liability without subsidies. Given a 50 percent subsidy, the lower risk farmer can expect a $5 per $100 of liability transfer over time. The higher risk farmer expects $10 per $100 of liability.

Such an incentive structure would likely encourage 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 (Figure 1.1). 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 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.

Figure 1.1 Extensive Margin Versus Primary Production Areas



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. Additionally, Skees (2000) points out that for every 10 percentage point increase in participation in crop insurance, an estimated 5.9 million additional acres are put into production for the top six crops in the U.S. This number suggests that on a national level, roughly 25 to 30 million acres of crops may have been put into production as a result of crop insurance. This increase in production is likely to result in increased usage of chemical inputs used in the production process.

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). 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.

However, crop insurance may be encouraging environmental losses in another way. As Griffin pointed out in his 1996 study, it is possible that crop insurance along with disaster assistance may be offsetting the environmental gains achieved through the CRP. His study suggests that for every acre of land taken out of production by the CRP, another acre is added because of crop insurance and disaster assistance. 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.

Objective

Environmental organizations and interest groups are suggesting that subsidized crop insurance and disaster aid is encouraging production on environmentally sensitive lands by promoting production at the extensive margin. While this is almost certainly the case in some areas of the country, Heimlich (1994) and others show that environmental impacts may differ considerably depending on the geographic, spatial, and environmental attributes of the extensive margin. Given that the extensive margin, and the environmental impacts of production are not homogenous across space, it is my intent to analyze the relationship between risk and the environment on a level that better accounts for the physiographic, soil, and climatic traits found in various regions of the U.S.

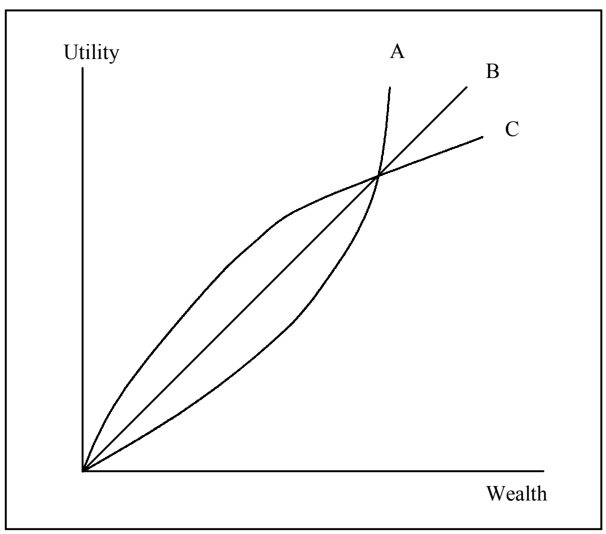
Thesis Organization

The first chapter of this study provides a background of crop insurance in the U.S. and explains the motivations and relevance of this research. Chapter Two, a literature review, is divided into two parts. The first is a review of the guiding economic and philosophic principles of this research, the second focuses primarily on studies that address the environmental impacts of crop insurance. Chapter Four defines the methodology of the study while Chapter Five discusses the empirical analysis and results. Chapter Six draws conclusions from the results of the study.

CHAPTER TWO
LITERATURE REVIEW: PART ONE

The first part of this chapter is focused on the guiding economic principles of this thesis, primarily risk, utility, moral hazard, and adverse selection. Risk, and more specifically yield risk, is generally recognized as one of the guiding factors in producer behavior. Individuals base their actions in part on the level of utility they expect to derive from a particular action. (For a detailed description of risk as it applies to utility see von Nuemann and Morgenstern (1944).) If utility is viewed as a function of wealth for instance, it can be said that a risk averse individuals' utility curve is concave with respect to wealth (Figure 2.1). Conversely, if an individual is risk preferring or favors risk, the individuals utility curve is convex with respect to wealth (Pratt, 1964 and Arrow, 1971) (Griffin, 1996).

Figure 2.1 Risk Loving (A), Risk Neutral (B), and Risk Averse (C) Utility Curves.



Risk and utility theory has strong implications for the producer decision making process. Because farmers are traditionally believed to be risk averse, we assume they are willing to pay to avoid uncertainty. One method by which risk averse producers may transfer their risks is through crop insurance, assuming that the policy is actuarially fair and unsubsidized. As Wu

(1999) and others have shown, risk preferring individuals, however, are likely to purchase subsidized insurance in an effort to capitalize on potential money transfers.

Subsidized policies such as those that have been offered in recent decades are likely to attract higher-risk producers and are characterized by adverse selection and moral hazard, both forms of market distortions. In the case of adverse selection, agents acquire more information about their potential losses than do policy providers. Because policy providers are unable to accurately measure yield risk for individual policy holders, they are forced to set rates according to what they believe is the average level of risk. By doing so, low-risk producers are overcharged, while high-risk producers are undercharged. This skews participation toward risk preferring policy holders and results in increased risk in the insurance pool and larger indemnity payments in the event of yield losses.

As mentioned previously, the cost of monitoring each policy holders actions are prohibitive. As a result, policy providers are unaware if policy holders adjust their level of production risk after they purchase a policy. This problem of moral hazard may result in producers altering behavior in an effort to collect indemnities and, along with adverse selection, result in the failure of insurance contracts. (Goodwin and Smith, 1995)

LITERATURE REVIEW: PART TWO

Literature cited in this section of the review focuses primarily on studies that address the issue of acreage expansion and contraction occurring as a result of crop insurance and/or disaster aid, and the environmental impacts that result from these programs. While significant literature exists on the impacts of crop insurance and disaster aid on crop choice, it will not be addressed specifically.

Unsuccessful attempts at providing multiple-peril crop insurance to U.S. producers date back to the late 1800's. At that time private insurance companies provided for the first time, insurance coverage beyond that of hail and fire insurance. Several efforts were made over the next 20 years to provide price and/or yield risk insurance but all were unsuccessful as payments for losses typically exceeded premiums (Gardner and Kramer, 1986).

The U.S. Government first became involved with crop insurance in 1922 with an investigation into crop insurance and decided to offer insurance in 1939 with the adoption of the Federal Crop Insurance Act of 1938 under President Roosevelt. While the program continued intermittently throughout the first half of the century, indemnities often exceeded premiums forcing the program to rely on government subsidies for financial assistance (Gardner and Kramer, 1986).

During the late 1980's, a few individuals began to realize that by providing a safety net of disaster payments and subsidized crop insurance, government programs may be directly influencing farm production levels and prices. In 1936 the editors of the Christian Science Monitor warned against the dangers of a crop insurance program encouraging production on marginal lands (Goodwin and Smith, 1995). While crop insurance, disaster relief, and the political climate that surrounds them have changed over the last half century, the warning heralded by the editors is still pertinent today.

Numerous government programs exist to manage both price and yield risk, including price controls, crop insurance and others. Some of these government policies and programs are believed to cause distortions in markets as well as farm-level decision making. Plantinga (1996) illustrates this point with a study on the environmental effects of milk price supports. Using county level data for Wisconsin, Plantinga looked at the effects of milk price supports on the conversion of cropland to forest and the potential environmental benefits to be gained if the strike price for supports were raised. Specifically, Plantinga illustrated that reducing the price support for milk in Wisconsin would reduce incentives for profit maximizing producers to operate on marginal lands and would subsequently enhance environmental quality by reducing soil erosion and improving wildlife habitat through afforestation. The study estimates that a five percent reduction in price supports for milk would result in benefits in the form of decreased erosion, increased wildlife habitat, and other environmental quality gains, ranging from 4.1 to 12.3 million dollars in value. A 15% decrease in support would yield benefits ranging from 12 to 35.9 million. Plantinga's study is limited geographically in that he operates under the assumption that land taken out of production would be converted to forestland, as is likely the case in Wisconsin. However, he estimates that if other areas of the country are similar to Wisconsin with regard to the conversion of cropland to forestland, the elimination of price supports could lead to $ 0.5 billion in environmental quality gains. While such a conversion may or may not be likely in other parts of the county, Plantinga's study does prompt us to think about the possibility of regional shifts in agriculture and how these shifts may result in increases in environmental quality in some areas and decreases in others.

Along with direct price supports, crop insurance and disaster relief are also believed to cause distortions in agricultural related markets and farm-level decision making. Distortions can result in impacts at both the intensive and extensive margin. Effects at the intensive margin can result in increases or decreases in inputs such as fertilizers, herbicides, pesticides etc… For examples of literature on impacts at the intensive margin, see Horowitz and Lichtenbeg (1994), and Goodwin Smith and (1996).

Impacts at the extensive margin can come in the form of converting forest or pastureland to cropland as potential increases in returns motivate producers to bring more land into production. Studies on impacts at the extensive margin vary by methodology, study region, and result. Varying estimates exist as to the amount of forest or pastureland that has been brought into production as a result of crop insurance. Table 2.1, taken in part from Soule and Mullarkey's (2000) article on impacts at the extensive margin provides a list of these varying estimates.

Table 1.1 Estimates of acreage expansion due to crop insurance and disaster relief.

Estimate of Acreage Expansion	**Area of Study**	**Type of Analysis**	**Author**
16 million acres remained in production	Great Plains	Empirical econometric analysis	Griffin (1996)
15 million acres in production (45 million CRP when CRP is included)	U.S.	Empirical econometric analysis	Keeton, Skees, and Long (1999)
600,000 acres	U.S.	Simulation model	Young et al. (1999)
Less than 0.1% increase in corn and soybeans acreage.	Corn Belt	Empirical econometric analysis	Goodwin and Vandeveer (2000)

In 1996 Griffin addressed the production impacts of crop insurance and disaster payments on planted acres in the Great Plains using two single equation empirical models with time-series, cross-sectional, county level data. Focusing on six major crops (corn, soybeans, grain sorghum, barley, cotton, and wheat) for the dependent variable, Griffin's study measured the impact that crop insurance participation, risk subsidies, deficiency payments, and disaster payments had on total planted acres for the six crops for the periods 1974-1977 and 1989-1992. Results suggested that roughly 16 million acres were in production that otherwise would not have been without disaster payments, crop insurance, and risk subsidies. To address the environmental impacts of this additional acreage, Griffin estimated the amount of soil erosion that could be attributed to the 16 million acres. In a crude estimate, the study suggested the amount of soil loss that could be attributed to crop insurance and disaster payments to be 61.4 million tons.

Griffin's second model used one continuous time period, 1978-1992, to measure the impact of crop insurance and disaster payments on the amount of acreage devoted to wheat production or to pasture that was converted to wheat production. Results showed that these risk management programs may have provided impetus for the conversion of 2.29 million acres of pasture to wheat.

Keeton et al. (1999) estimated the effects of disaster assistance and crop insurance on land-use patterns for six major crops (corn, wheat, soybeans, grain sorghum, barley, and cotton) in the plains and Midwestern states. More specifically, Keeton et al. wanted to know if government programs were resulting in shifts in production to risky regions of the U.S. Cropping data was taken from 285 Crop Reporting Districts (CRD) for the years 1978-1982 and 1988-1992, along with data on disaster assistance and crop insurance premiums. Changes in land-use patterns were measured by the dependent variable by capturing the change in total cropland for the six crops in each CRD between the two time periods. Statistically significant correlations were found for four of the six independent variables; crop insurance transfers, premium rates, participation, and base acres. Keeton estimated that for every 1-percentage point increase in crop insurance participation, an additional 1.5 million acres are planted to the top six crops in the U.S. Keeton points out that the crop insurance participation rate in 1980 was approximately 10 percent. In 1998, the number rose to roughly 45 percent if CAT is included. As is illustrated in the study, such an increase implies that around 45 million additional acres may be in production as a result of crop insurance when including 30 million CRP acres.

Young, et al. (1999) examined the influence of crop insurance subsidies on the planted acreage of eight major field crops in the U.S. and in each of the seven major production regions. Young measured the extent of market distortion directly attributable to crop insurance subsidies by using acreage and production shifts. Using county-level data, insurance subsidies were converted to commodity-specific "price wedges", a per bushel subsidy for crop insurance. With the POLYSYS-ERS simulation model, Young et al. measured the intra- and inter-regional shifts along with cross-commodity price effects and found that subsidies resulted in a small shift in plantings on a national level and an aggregate increase in plantings of 0.2%. Perhaps more importantly, Young's analysis showed a significant shift in production from the Far West and Southeast to the Plains states. The study is limited in that data was aggregated at the state level, while decisions resulting from crop insurance subsidies are motivated by farm level incentives. Additionally, subsidies are treated as homogenous across production and are incorporated into the study as if they are actual revenue as opposed to additional income. Finally, the study assumes the "price wedge" effect of the subsidy drives short-run supply response. If long-run supply responses are used one of the results would show greater acreage responses.

Goodwin, Vandeveer, and Deal (2001) use a multi-equation structural model of acreage response, insurance participation, CRP enrollment, and input usage. Their analysis is divided into three separate applications; corn and soybean production for the Midwest from 1985-1993, wheat and barley production in the Upper Great Plains, and corn and soybeans for a period after the Federal Agriculture Improvement and Reform (FAIR) act. Results show that participation in crop insurance yields a statistically significant acreage response. Although the response is modest in most cases, a large response was found for wheat in the Northern Great Plains. The authors find that increases in participation resulting from decreases in premiums yield relatively small acreage responses. The study estimates that a 50% decrease in premiums would result in an increase in acreage of .25-3.5%.

Literature that directly addresses the environmental impacts of increases or shifts in production at the extensive margin as a result of crop insurance and disaster relief is far from abundant but is beginning to surface as policy debates on the issue become more prevalent. In 1999, Wu investigated the effect of crop insurance on crop mix and chemical input use in the Central Nebraska Basin. Wu hypothesized that crop insurance was encouraging changes in cropping patterns and application rates of chemical inputs. Using farm level data and a simultaneous equation system, Wu found that farmers with higher soil erosion rates in their corn fields were in fact more likely to purchase corn insurance. Additionally, Wu's results show that purchasers of crop insurance shifted production from hay and pasture to corn and soybeans, resulting in increased soil erosion along with increased applications of nitrogen, phosphorus, and atrazine.

One reason for the lack of research on the environmental impacts of crop insurance and disaster relief may be the lack of a comprehensive environmental quality index. While numerous indexes have been developed to measure soil erosion, wind erosion, and other environmental quality concerns, a comprehensive direct measure of environmental damages that result from agriculture does not exist. It is of course understandable that this is the case. The creation of such index would be a daunting task requiring massive amounts of data. Even with such an index, in an ever-changing physical environment, a static index would be of little use over time. Nonetheless, some individuals such as Ralph Heimlich and others have attempted to create sets of indicators of potential environmental damages.

Using a set of indicators developed by Heimlich and the Economic Research Service (ERS), Heimlich provided information on the "geographic distribution of potential environmental damages from agricultural production" (Heimlich, 1994). Indicators were weighted by affected population and in the case of soil productivity, dryland cash rent per year. In the 1994 paper entitled "Targeting Green Support Payments: The Geographic Interface between Agriculture and the Environment", Heimlich states that we must "explicitly recognize that the environment is fundamentally a spatial phenomenon requiring spatial indicators".

The indicators used for this study, discussed in the next chapter, follow in a similar vein. Environmental indicators are compiled from NRCS databases and are used to give an estimate of potential environmental impacts resulting from changes in production risk.

CHAPTER THREE
DATA AND METHODOLOGY

This study develops a model to estimate the correlation between crop yield risk and the agri-environmental indicators to be described in the independent variables section of this chapter. Two separate regression models are estimated, using a different dependent variable for each. These measures are discussed in detail in the dependent variables section of this chapter.

To estimate the correlation between yield risk and the environmental variables, data from various sources are used. The National Agricultural Statistics Service (NASS) provided crop yield data by county for the years 1956-2000. 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 ERS.

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. Individuals at the Environmental Working Group and elsewhere have proposed 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 discussed in the independent variables section of this chapter.

Dependent Variables

Two dependent variables are 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 for both the Model 1 and Model 2 variables. The dependent variable of Model 2, is the coefficient of variation for the total normalized percent deviation from the trend yield in a county. To arrive at the Model 2 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 Model 1 yield variation variable is derived in the same manner but only uses 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;

$$\text{Normalized Deviant} = \Sigma\ (AY/TY_{tc}) * CS_{tc} + \ldots\ (AY/TY_{t6}) * CS_{t6} \qquad 3.1$$

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. Geographic Information Systems (GIS) coverages for Model 1 and Model 2 are provided in Appendix 3.1.

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 3.1 shows the five agri-environmental indicators along with their data sources, years of record, spatial scale, and crop coverage. Detailed information on each explanatory variable follows the table. Maps for each explanatory variable can be found in Appendix 3.2-Explanatory Variable Maps.

Table 3.1- Explanatory Variables

Variable Name	Sources of Data	Years of Record	Spatial Scale	Crop Coverage
Soil Erosion-Water	National Resources Inventory	1997	8-Digit Hydrologic Unit	Cultivated Cropland
Soil Erosion-Wind	National Resources Inventory	1997	8-Digit Hydrologic Unit	Cultivated Cropland
Potential Nitrogen Fertilizer Loss	National Resources Inventory	1992	8-Digit Hydrologic Unit	Corn, Soybean, Wheat, Cotton, Barley, Sorghum, Rice
Pesticide Leaching Potential and Pesticide Runoff Potential	National Resources Inventory	1992	8-Digit Hydrologic Unit	Barley, corn, cotton, oats, peanuts, potatoes, rice, sorghum, soybeans, sugar beets, sunflowers, tobacco, wheat

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 (e_wind) 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.

Because risk data was calculated using FIPS codes while environmental variables were created using 8-digit hydrologic units (HUCs), GIS and the statistical software SAS were used to convert watershed or hydrologic units into weighted FIPS or county units. The polygons representing counties and watersheds were united using the union tool in the Arcview GIS software. Next the area of the individual union polygons of county and watershed areas were calculated using an Arcview script. Using SAS the area of union polygons with identical FIPS and HUCs designations were summed. Next, the areas of unionized polygons were summed by identical FIPS designation to determine the area of the FIPS unit. Finally, environmental indicators assigned to HUC units were transferred to FIPS units by summing the HUC values weighted by unionized FIPS-HUC polygon area as a ratio of total FIPS area for each FIPS unit (See Eq. 3.1).

$$X_{FIPS} = \sum_{FIPS-HUC} X_{HUC} * (Area_{FIPS-HUC} / Area_{FIPS}) \qquad 3.1$$

Where X is the environmental variable of interest.

Farm Resource Regions

Hydrologic units in the study area were aggregated into nine ERS Farm Resource Regions (Agri-Environmental Policy at the Crossroads, 2001). Farm resource 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, Northern Great Plains, Heartland, Northern Crescent, Fruitful Rim, Prairie Gateway, Mississippi Portal Southern Seaboard, and Eastern Uplands. A map of each of the regions is found in Appendix 3.4- ERS Farm Resource Regions. (Water Quality and Ag., 1997)

Theoretical Model

The proposed model tests the hypothesis that shifts and expansions in production into relatively more risky regions of the country are resulting in changes in soil erosion and chemical use. An Ordinary Least Squares (OLS) model is developed to test the relationship between yield risk and the environment. The model uses the yield risk variable as the dependent variable. The modeled equation (Equation 3.2) is:

$$Y_i = \sum_{r=1}^{R} [b_r D_{ir} + \sum_{j=1}^{K} \alpha_{rj} X_{ij} D_{ir}] \qquad 3.2$$

where Y_i represents the yield risk variable for each $_i$ FIPS unit in the study and X_i represents the explanatory (environmental) variables. R represents the number of regions 1 through 9 and K represents the environmental variables 1 through 6. D_{ir} = 1 if Region = r and is 0 otherwise. The modeled data is cross sectional, but is not time series (i.e., is grouped). As described previously in the dependent variables section, yield variation data was compiled across years to give a single yield risk value estimate for each county.

The structure of Equation 3.2 follows that of a fixed effects model. In a fixed effects model the intercept varies across the N cross-sectional units, or regions. As there are 9 separate regions used in the model, N-1 dummies are used. The dummy variable coefficients are used to measure shifts in the regression line arising from unknown variables (Kennedy, 1998). Differences in intercept are differences in mean crop yield variation by region.

While designed like a fixed effects model, Equation 3.2 is not a fixed model because the data are not time series. Furthermore, Equation 3.2 allows for shifts in slope, something not common in a fixed effects model. However, one characteristic of a fixed effects model utilized. Specifically, it is assumed that the errors for each cross section are well behaved (i.e., $\sigma^2_{r=1} = \ldots = \sigma^2_{r=1}$). If so then this model is efficiently estimated by OLS. This is a strong assumption for grouped data, but one that is maintained throughout this investigation. Again, Equation 3.2 is special in that it captures differences in the independent variables by region. Specifically, Equation 3.1 allows changes in both the intercept and slope terms by region. The design of Equation 3.1 is a block diagonal matrix (Equation 3.2) such that Y = xb where:

$$X = \begin{bmatrix} x_{(i,k)\, j=1} & 0 \ldots & 0 \\ 0 & x_{(i,k)\, j=2} & 0 \\ 0 & 0 & x_{(i,k)\, j=3} \end{bmatrix} \qquad \begin{array}{l} k = 1 \ldots K = 7 \\ i = 1 \ldots I = \#\text{ of counties in region} \\ j = 1 \ldots J = 9 \text{ regions} \end{array} \qquad 3.3$$

The block diagonal matrix is (J∗I)∗(J∗K) where J is 9 (the number of regions), and K is 7 (the number of parameters plus the region dummy variable). Thus this model estimates J∗K parameter values (i.e., b is (J∗K)∗1) to explain the variation in the vector Y that is dimension (J∗K)∗1). Note that all K regional dummy variables are included in this model, hence estimation does not include an intercept. Specifically (Equation 3.4);

$$\sum_{j=i} CD_{ij} \quad = \quad 1 \qquad \text{for all K} = 1...(J*I) \qquad 3.4$$

The intercept, if included, would be perfectly correlated with the included country dummy variables and estimation of equation 3.2 would fail due to *X* being non-singular.

Autocorrelated errors were tested for using the Durban Watson test. The test revealed that autoregressive error terms existed in all regions of the data except the Basin and Range. Because autoregressive error terms violate an assumption of linear regression the data was corrected for autocorrelation using first differencing. If autocorrelation goes uncorrected, the residual variance is likely to underestimate the true variance. Additionally, variances and standard errors of the OLS estimators are likely to underestimate the true variances and standard errors. As a result, t and F tests of significance would no longer be valid and would provide misleading conclusions regarding the significance of the estimated regression coefficients (Kennedy, 1998).

Heteroskedasticity was also found in all regions of the data other than the Basin and Range. This implication is that one or more of the independent variables varies in magnitude in direct proportion to the residuals. This violates the assumption of homoskedastic variance of residuals. Heteroskedasticity was corrected by using weighted least squares where the weight was determined using a variant of White's procedure. The consequences of not correcting heteroskedasticity are the same as those for not correcting autocorrelation.

The Barra-Jarque test was run to test for normality. Normality assumes that ε_i is normally distributed, meaning that for each value of X, the disturbance is normally distributed around zero. The test revealed that ε_i was not normally distributed about the mean. A DF Betas test was run to determine influential observation and outliers. Problem observations were then removed from the data set in an effort to correct infinite error variance. Although non-normality still exists in the data, in most cases removing influential observations and outliers resulted in a more normal distribution of errors.

Given Equations 3.2 and 3.3 the model estimated in this study is (Equation 3.5):

$$\begin{aligned}
\text{Risk1} = \; & b_{11}R1_i + b_{12}N_i * R1_i + b_{13}\text{Wind }E_i * R1_i + b_{14}\text{Water }E_i * R1_i + b_{15}PR_i * R1_i + b_{16}PL_i * R1_i + b_{17}AC_i * R1_i \; + \\
& b_{21}R2_i + b_{22}N_i * R2_i + b_{23}\text{Wind }E_i * R2_i + b_{24}\text{Water }E_i * R2_i + b_{25}PR_i * R2_i + b_{26}PL_i * R2_i + b_{27}AC_i * R2_i \; + \\
& b_{31}R3_i + b_{32}N_i * R3_i + b_{33}\text{Wind }E_i * R3_i + b_{34}\text{Water }E_i * R3_i + b_{35}PR_i * R3_i + b_{36}PL_i * R3_i + b_{37}AC_i * R3_i \; + \\
& b_{41}R4_i + b_{42}N_i * R4_i + b_{43}\text{Wind }E_i * R4_i + b_{44}\text{Water }E_i * R4_i + b_{45}PR_i * R4_i + b_{46}PL_i * R4_i + b_{47}AC_i * R4_i \; + \\
& b_{51}R5_i + b_{52}N_i * R5_i + b_{53}\text{Wind }E_i * R5_i + b_{54}\text{Water }E_i * R5_i + b_{55}PR_i * R5_i + b_{56}PL_i * R5_i + b_{57}AC_i * R5_i \; + \\
& b_{61}R6_i + b_{62}N_i * R6_i + b_{63}\text{Wind }E_i * R6_i + b_{64}\text{Water }E_i * R6_i + b_{65}PR_i * R6_i + b_{66}PL_i * R6_i + b_{67}AC_i * R6_i \; + \\
& b_{71}R7_i + b_{72}N_i * R7_i + b_{73}\text{Wind }E_i * R7_i + b_{74}\text{Water }E_i * R7_i + b_{75}PR_i * R7_i + b_{76}PL_i * R7_i + b_{77}AC_i * R7_i \; + \\
& b_{81}R8_i + b_{82}N_i * R8_i + b_{83}\text{Wind }E_i * R8_i + b_{84}\text{Water }E_i * R8_i + b_{85}PR_i * R8_i + b_{86}PL_i * R8_i + b_{87}AC_i * R8_i \; + \\
& b_{91}R9_i + b_{92}N_i * R9_i + b_{93}\text{Wind }E_i * R9_i + b_{94}\text{Water }E_i * R9_i + b_{95}PR_i * R9_i + b_{96}PL_i * R9_i + b_{97}AC_i * R9_i
\end{aligned} \tag{3.5}$$

In Equation 3.5 Risk1 is crop yield variation by FIPS. N is Potential Nitrogen Fertilizer Loss from Farm Fields, Wind E is Average Annual Soil Erosion by Wind on Cultivated Cropland as a Proportion of the Tolerable Rate (T), Water E is Average Annual Soil Erosion by Water on Cultivated Cropland as a Proportion of the Tolerable Rate, PR is Pesticide Runoff Potential, PL is Pesticide Leaching Potential, and AC is the acreage control variable described earlier. Again, R1 through R9 are dummy variables for each of the 9 regions included for estimation.

CHAPTER FOUR
EMPICIRAL ANALYSIS

The results reported in this chapter are from the estimation of model 1 described in Chapter 3 (Figure 3.?). With respect to model results, greatest emphasis will be placed on Model 1, as it is believed to provide a more accurate measure of yield risk that better matches crop insurance subsidies. However, both models yield similar results. The chapter is divided into three sections. The first provides an overview of the estimation results and the acreage and weighted mean values for each of the variables by region for Model 1. Section two is a detailed analysis of the parameter estimates for all nine regions in the study and addresses the impacts of increases in production within a particular region. The third section discusses the elasticity values for Model 1 and the potential inter-regional impacts of production at the extensive margin.

Results are derived for the nine ERS Farm Resource Regions described in Chapter Three. However, most of the discussion will focus on three regions in particular; the Northern Great Plains, the Heartland, and the Prairie Gateway. These three regions make up over 80% of the acreage devoted to the six crops used in the study. Little emphasis is placed on the Fruitful Rim, Basin and Range, and Eastern Uplands regions, as they make up a small portion of the acreage devoted to the six crops used in the study.

Table 4.1 summarizes the estimated relationship between yield risk and the explanatory variables for the nine regions. The left-hand column reports the percentage of acres devoted to the crops used in the study. The regression results reveal that the Heartland, Prairie Gateway, and Northern Great Plains regions show a positive correlation between yield risk and erosion. Positive correlations between yield risk and erosion suggest that as yield risk increases within each region, soil erosion from wind and water is likely to increase as well.

The estimated relationship between yield risk and chemicals (i.e. Nitrogen Fertilizer Loss, Pesticide Runoff and Pesticide Leaching) are less clear. While the relationship between yield risk and chemical loss does not conform to expectations in some regions, it is believed that the model may not be properly designed to capture the relationship between chemical use and yield risk. Specifically, the model does not take into account the type of crop being produced.

As chemical use can be closely tied with a particular crop, for example nitrogen fertilizer and corn, a control for the type of crop produced may yield more meaningful results.

The negative relationship between the acreage control variable and yield variation is of the expected sign. The negative correlation simply reflects the reality that cropping is more intense in areas with lower yield variability (i.e., a higher proportion of the surface is planted to these crops in low risk areas).

It should be noted that an increase in crop acreage does not cause a decrease in yield variability. This study is not designed to show causality. Similarly, a positive correlation between wind erosion and yield variability cannot be interpreted to mean that increases in yield variability cause increases in wind erosion. Rather, the evidence strongly suggests that a statistically significant correlation exists between wind erosion and areas that have greater yield risk. As soil erosion from wind increases, an increase in yield risk, within that particular region, is also present.

The analysis of variance, having corrected the data for infinite error variance and non-spherical errors, reveals a coefficient of determination (Adj R-sq) of 0.91. This suggests that 91% of the variance in the dependent variable is being explained by the independent variables. The probability of F (Pr > F) is .0001, which suggests that at least one of the independent variables aids understanding of yield variance with 99% confidence.

Table 4.1 Included Variables, Regions, Acreage Percent, Average Variation in Crop Yield, and Sign of Parameter Coefficients for Models 1.

Model 1	% Acres	Regional Variation	Nitrogen	Wind Erosion	Water Erosion	Pest-Runoff	Pest-Leaching	Acreage Control
Heartland	40.6	0.094	.	POS	POS	NEG	.	NEG
Prairie Gateway	26.4	0.163	NEG	POS	.	.	NEG	NEG
N. Great Plains	13.6	0.136	NEG	.	POS	.	NEG	NEG
Northern Crescent	6.3	0.143	NEG	NEG	NEG	NEG	.	NEG
Mississippi Portal	5.8	0.088	.	.	.	.	.	.
Southern Seaboard	3.3	0.148	NEG	.	.	.	NEG	NEG

Missing observation denote parameter estimates that are not statistically different from 0 at α=0.05.

Regional mean values weighted to control for regional differences in acreage, are reported in Table 4.2. The variance of crop yield variation ($\hat{\beta}$) is used as a measure of the dispersion of the sampling distribution of $\hat{\beta}$ by region. Weighted mean values for the explanatory variables reveal high levels of actual and potential environmental damage in several regions of importance. Among these are nitrogen loss from farm fields in the Heartland and Mississippi Portal, and wind erosion above the tolerable rate (T) in the Prairie Gateway and water erosion above the tolerable rate (T) in the Heartland.

Table 4.2 Regional Mean Values Weighted by Acres for Model 1.

Region	Acreage in Millions	% of Total Acreage	Weighted Mean-Model 1	Weighted Variance-Model 1	Nitrogen	Wind Erosion	Water Erosion	Pest Runoff	Pest Leaching
Basin and Range	2.1	1.09	0.09	0.000	3.27	0.86	1.10	2.00	2.22
Northern Great Plains	26.2	13.58	0.11	0.019	4.38	3.51	0.32	1.83	1.05
Heartland	78.3	40.6	0.06	0.010	23.87	0.53	0.91	2.94	1.64
Northern Crescent	12.2	6.30	0.09	0.019	0.88	0.09	0.05	0.43	0.62
Fruitful Rim	2.8	1.45	0.10	0.003	9.09	8.42	0.67	1.59	2.16
Prairie Gateway	50.8	26.38	0.10	0.022	7.45	3.26	0.57	2.03	1.95
Mississippi Portal	11	5.76	0.07	0.002	18.17	0	1.07	2.92	2.93
Southern Seaboard	6.3	3.28	0.05	0.016	2.08	0	0.18	1.17	2.15
Eastern Uplands	2.7	1.42	0.11	0.003	0.65	0	0.13	1.08	1.11

Intra-regional analysis

It is important to note that while the results are discussed by region the model was run using the entire data set (See Equation 3.?). Region one, Basin and Range, makes up a 1.9% of the acreage in the study area and observations only come from Montana and Colorado. The weighted variance for this region, 0.00099, is the lowest in the study area (Table 4.2). The mean value of yield risk variation in the region is 0.09. The Basin and Range has the largest share of nonfamily farms and the smallest share of U.S. cropland. The area produces primarily cattle, (not included in this study) wheat, and sorghum, and accounts for 4% of U.S. farms, cropland, and value of production. No statistically significant correlations are found between yield risk and the explanatory variables (Table 4.3).

Table 4.3 Parameter Estimates: Region One- Basin and Range.

Parameter Estimates				
Variable	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Region 1	0.08218	0.01381	8.95	<.0001
Nitrogen-Leach/Runoff	-0.00069686	0.00591	-0.12	0.9062
Erosion-Air	-0.00227	0.00216	-1.05	0.2919
Erosion-Water	0.00465	0.01457	0.32	0.7495
Pesticide-Runoff	0.00494	0.01450	0.34	0.7334
Pesticide-Leach	-0.00137	0.00801	-0.17	0.8646
Acreage Control	-0.00032364	0.00158	-0.20	0.8379

The Northern Great Plains, Region 2, shows statistically significant correlations for nitrogen leaching and runoff, erosion by water, and pesticide leaching, along with the acreage control variable and the intercept (Table 4.4). A positive correlation exists between yield risk and soil erosion by water. Although a direct causal relationship may not be inferred, the results strongly suggest that as yield risk in the Northern Great Plains increases, increased soil erosion by water is likely. This is especially concerning given that the Northern Great Plains make up nearly 14% of the acreage in the study area, approximately 26 million acres. The Northern Great Plains has a weighted variance of 0.019 and a weighted mean value of yield risk variation of 0.11, the highest in the study (Table 4.2). The area with the largest farms and the smallest population, the Northern Great Plains make up 5% of farms, 6% of the value of production, and 17% of the cropland in the U.S. The area produces primarily wheat, cattle, and sheep.

Table 4.4 Parameter Estimates: Region Two- Northern Great Plains.

Parameter Estimates				
Variable	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Region 2	0.13628	0.01101	12.38	<.0001
Nitrogen-Leach/Runoff	-0.00287	0.00078350	-3.67	0.0003
Erosion-Air	-0.00151	0.00125	-1.21	0.2273
Erosion-Water	0.03402	0.01710	1.99	0.0468
Pesticide-Runoff	0.00293	0.00369	0.79	0.4277
Pesticide-Leach	-0.01346	0.00439	-3.07	0.0022
Acreage Control	-0.00039011	0.00021564	-1.81	0.0706

The Heartland makes up the region of the U.S. with the most farms (22%), the highest value of production, (23%), and the most cropland (27%). For Model 1 the Heartland has the lowest weighted mean value of yield risk variation (0.06) in the study outside of the Southern Seaboard, and has a weighted variance of 0.01 (Table 4.2). The region produces primarily cash grain and cattle farms and is found to have statistically significant correlations between yield risk and all independent variables except pesticide leaching and nitrogen leaching and runoff (Table 4.5). Positive correlations are found for soil erosion by wind and water, along with the acreage control and the intercept. A positive correlation between wind erosion and yield risk is particularly important since the Heartland makes up the highest percentage of acreage in the study at 40% or 78 million acres. Once again, a direct causal relationship cannot be inferred but as yield risk increases in the Heartland, it is likely that soil erosion above the tolerable rate (T) will also increase. If producers respond to subsidies that pay more to those in higher risk regions by increasing production, as previous research has shown, increases in acreage are likely to result in increased soil erosion above the tolerable rate.

Table 4.5 Parameter Estimates: Region Three- Heartland

Parameter Estimates				
Variable	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Region 3	0.09434	0.01280	7.37	<.0001
Nitrogen-Leach/Runoff	-0.0004503	0.00020247	-0.22	0.8240
Erosion-Air	0.00271	0.00160	1.70	0.0895
Erosion-Water	0.00669	0.00345	1.94	0.0526
Pesticide-Runoff	-0.01044	0.0475	-2.20	0.0279
Pesticide-Leach	-0.00095501	0.00147	-0.65	0.5149
Acreage Control	-0.00023366	0.00008200	-2.85	0.0044

Region four, called the Northern Crescent, includes portions of Minnesota, Wisconsin, Michigan, a small section of Ohio, and most of Pennsylvania. The Northern Crescent makes up 6.3% of the total acreage in the study with 12 million acres. The region has weighted mean value of yield risk variation of 0.09 and a weighted variance of 0.019 (Table 4.2). Much of the Northern Crescent is not included in the study area, as it does not produce a significant amount of the six crops used in the study. The Northern Crescent as a whole is the most populous region in the country and makes up 15% of farms, 15% of the value of production, and 9% of the cropland. Dairy, general crops, and cash grain farms are prevalent in this area of the country. Although all independent variables except pesticide leaching are significant for the region, none are positively correlated with yield risk (Table 4.6).

Table 4.6 Parameter Estimate: Region Four- Northern Crescent.

Parameter Estimates				
Variable	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Region 4	0.14296	0.00535	26.73	<.0001
Nitrogen-Leach/Runoff	-0.00118	0.00011255	-10.52	<.0001
Erosion-Air	-0.00305	0.00088349	-3.46	0.006
Erosion-Water	-0.00645	0.00168	-3.85	0.0001
Pesticide-Runoff	-0.01927	0.00209	-9.20	<.0001
Pesticide-Leach	0.00094139	0.00152	-0.62	0.5353
Acreage Control	-0.00000524	0.00000005	-9.13	<.0001

The Fruitful Rim makes up a relatively small portion of the study area with observations found in parts of Texas, Georgia, Alabama, and South Carolina. The majority of the Fruitful Rim is located outside of the study area in California, Florida, and the Northwestern U.S. The region makes up 1.4% of the study area with 2.8 million acres devoted to the crops used in the study. Statistically significant correlations are found for nitrogen runoff and leaching, as well as soil erosion by water (Table 4.7). Soil erosion above the tolerable rate (T) is positively correlated in this, suggesting that as risk increases, actual soil erosion also increases. Because most observations in the Fruitful Rim are located on the coast, soil erosion by water is not unexpected.

Table 4.7 Parameter Estimate: Region Five- Fruitful Rim.

Parameter Estimates				
Variable	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Region 5	0.11094	0.00961	12.37	<.0001
Nitrogen-Leach/Runoff	-0.00061883	0.00097021	-0.64	0.5237
Erosion-Air	-0.00059877	0.00070047	0.85	0.3928
Erosion-Water	0.01484	0.00655	2.27	0.0234
Pesticide-Runoff	-0.00167	0.00427	-0.39	0.6957
Pesticide-Leach	0.00191	0.00529	0.36	0.7185
Acreage Control	-0.00102	0.00033231	-3.08	0.0021

Region six, the Prairie Gateway, makes up 13% of farms, 12% of the value of production, 17% of cropland, and consists of several states in the study region including Kansas, Oklahoma, and parts of Texas, Colorado, and Nebraska. The second largest region in the study, the Prairie Gateway makes up 26% of the acreage in the study with approximately 51 million acres. The region has a weighted mean value of yield risk variation of 0.1 and a weighted variance of 0.24 (Table 4.2). The Prairie Gateway produces primarily wheat, oat, barley, rice and cotton along with cattle and sorghum. Statistically significant correlations were found for all independent variables except erosion by water and pesticide runoff (Table 4.8). A positive correlation exists between yield risk and soil erosion by air. Because the Prairie Gateway is such a large region, a positive correlation between yield risk and soil erosion by wind is especially significant.

Table 4.8 Parameter Estimate: Region Six- Prairie Gateway.

Parameter Estimates				
Variable	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Region 6	0.16328	0.00513	31.81	<.0001
Nitrogen-Leach/Runoff	-0.00133	0.00033192	-4.00	<.0001
Erosion-Air	0.00191	0.00022624	8.43	<.0001
Erosion-Water	-0.00567	0.00407	-1.40	0.1632
Pesticide-Runoff	-0.00353	0.00234	-1.51	0.1361
Pesticide-Leach	-0.01250	0.00170	-7.37	<.0001
Acreage Control	-0.0004828	0.000075	-6.40	<.0001

The Mississippi Portal is made up of areas bordering the Mississippi River Valley from Tennessee to the Louisiana Delta. The Mississippi Portal makes up 5.7% of the total acreage in the study with 11 million acres devoted to the six crops in the study. The region has a weighted mean value of yield risk variation of 0.07 and a weighted variance of 0.0025 (Table 4.2). Because of missing data, the independent variable soil erosion by air was not regressed for this region. No statistical significance is found in the region, apart from the intercept.(Table 4.9)

Table 4.9 Parameter Estimates: Region Seven- Mississippi Portal.

Parameter Estimates				
Variable	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Region 7	0.08875	0.02076	4.27	<.0001
Nitrogen-Leach/Runoff	-0.00045750	0.00075941	-0.60	0.5469
Erosion-Air	-	-	-	-
Erosion-Water	-0.00143	0.00578	-0.25	0.8045
Pesticide-Runoff	-0.00417	0.00894	-0.47	0.6413
Pesticide-Leach	0.00168	0.00975	0.17	0.8630
Acreage Control	-0.000109	0.000312	-0.35	0.7258

Region eight, the Southern Seaboard, is made up of a mix of small and large farms that produce general field crops as well as cattle and poultry. The Southern Seaboard makes up 3.3% of the total acreage in the study with 6 million acres devoted to the six crops in the study. The region has a weighted mean value of yield risk variation of 0.05 and a weighted variance of 0.0169 (Table 4.2). No statistically significant positive correlations exist in the region (Table 4.10). Nitrogen and Pesticide Leaching were found to be negatively correlated with the yield risk.

Table 4.10 Parameter Estimates: Region Eight- Southern Seaboard.

Parameter Estimates				
Variable	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Region 8	0.14805	0.00908	16.30	<.0001
Nitrogen-Leach/Runoff	-0.00206	0.00068172	-3.02	0.0025
Erosion-Air	-0.02189	0.01503	-1.46	0.1455
Erosion-Water	-0.0008	0.00244	-0.33	0.7431
Pesticide-Runoff	0.00335	0.00562	0.60	0.5513
Pesticide-Leach	-0.01587	0.00431	-3.69	0.0002
Acreage Control	-0.0000065	0.0000041	-1.56	0.1199

The Eastern Uplands, Region 9, consists of mostly small farms and produces primarily part-time cattle, tobacco, and poultry. Crops used in this study are not heavily produced in this region. The Eastern Uplands make up 1.4% of the total acreage in the study with 2.7 million acres devoted to the six crops in the study. The region has a weighted mean value of yield risk variation of 0.11 and a weighted variance of 0.0036 (Table 4.2). Statistically significant positive correlations are found between yield risk and soil erosion by air and water (Table 4.11). Thus, as yield risk increases, an increase in soil erosion is also likely.

Table 4.11 Parameter Estimates: Region Nine- Eastern Uplands.

Parameter Estimates				
Variable	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Region 9	0.09133	0.00650	14.04	<.0001
Nitrogen-Leach/Runoff	-0.00245	0.00074982	-3.27	0.0011
Erosion-Air	0.71659	0.15508	4.62	<.0001
Erosion-Water	0.00888	0.00276	3.21	0.0013
Pesticide-Runoff	-0.00077867	0.00325	-0.24	0.8104
Pesticide-Leach	-0.00483	0.00199	-2.43	0.0152
Acreage Control	0.00053	0.000381	1.39	0.1640

Inter-Regional Analysis:

While expansions and shifts in production, and the subsequent environmental impacts of those shifts, are essentially the results of farm-level incentives, policy decisions are made at the national level. For this reason it is necessary to investigate shifts in production occurring between regions. Additionally, Heimlich (1994) and others have demonstrated that the environmental impacts of agricultural can vary greatly across space. If this is the case, the ability to determine the relative environmental impacts across regions is necessary. The inter-regional analysis is once again broken down by the nine ERS Farm Resource Regions, with special emphasis placed on the Northern Great Plains, Heartland, Prairie Gateway, Mississippi Portal, Southern Seaboard, and Eastern Uplands regions.

Table 4.12 shows elasticity values using parameter estimates from Model 1 (Tables 4.3 through 4.11) for each of the six explanatory variables. For example, if $Y = b_0 + b_1 X_1$ is the estimated model, then the elasticity for X, can be determined using Equation 4.1.

$$\varepsilon_1 = (\partial Y / \partial X_1) * (\overline{X}_1 / \overline{Y}) = b_1(\overline{X} / \overline{Y}) \qquad 4.1$$

The elasticity (ε_1), calculated according to Equation 4.1, measures the responsiveness of Y to X at the mean value of Y and X (mean values for each variable are reported in Table 4.2). Because the mean is a cross-section specific measure, ε is similar to an arc elasticity common in economic literature, where ε_I measures the percent change in crop yield variability for a percent change in one of the independent variables. For example, a one-unit increase in wind erosion in the Heartland is associated with a 0.026 unit increase in yield variability (Table 4.12). Positive elasticity values for erosion exist in the Heartland, Prairie Gateway and Northern Great Plains. Of the two erosion measures, higher elasticity values are associated with soil erosion by water. In the Heartland a one unit change in water erosion is associated with a 0.11 unit increase in yield variability. A one-unit change in water erosion in the Northern Great Plains is associated with a 0.102 unit increase in yield variability. Elasticities for chemicals and the acreage control variable are negative throughout. Zero is used when the coefficient is not statistically different than zero.

Table 4.12 Elasticity Values- Model 1.

Model 1	**Elasticity Values by Parameter Estimate**					
Region	**Nitrogen**	**Wind Erosion**	**Water Erosion**	**Pesticide Runoff**	**Pesticide Leaching**	**Percent Crop Acres**
Basin and Range	0	0	0	0	0	0
Northern Great Plains	-0.11	0	0.10	0	-0.13	-0.09
Heartland	0	0.02	0.11	-0.55	0	-0.23
Northern Crescent	-0.01	-0.00	-0.00	-0.09	0	-0.55
Fruitful Rim	0	0	0.09	0	0	-0.27
Prairie Gateway	-0.09	0.05	0	0	-0.23	-0.18
Mississippi Portal	0	0	0	0	0	0
Southern Seaboard	-0.08	0	0	0	-0.69	0
Eastern Uplands	-0.01	0	0.01	0	-0.05	0

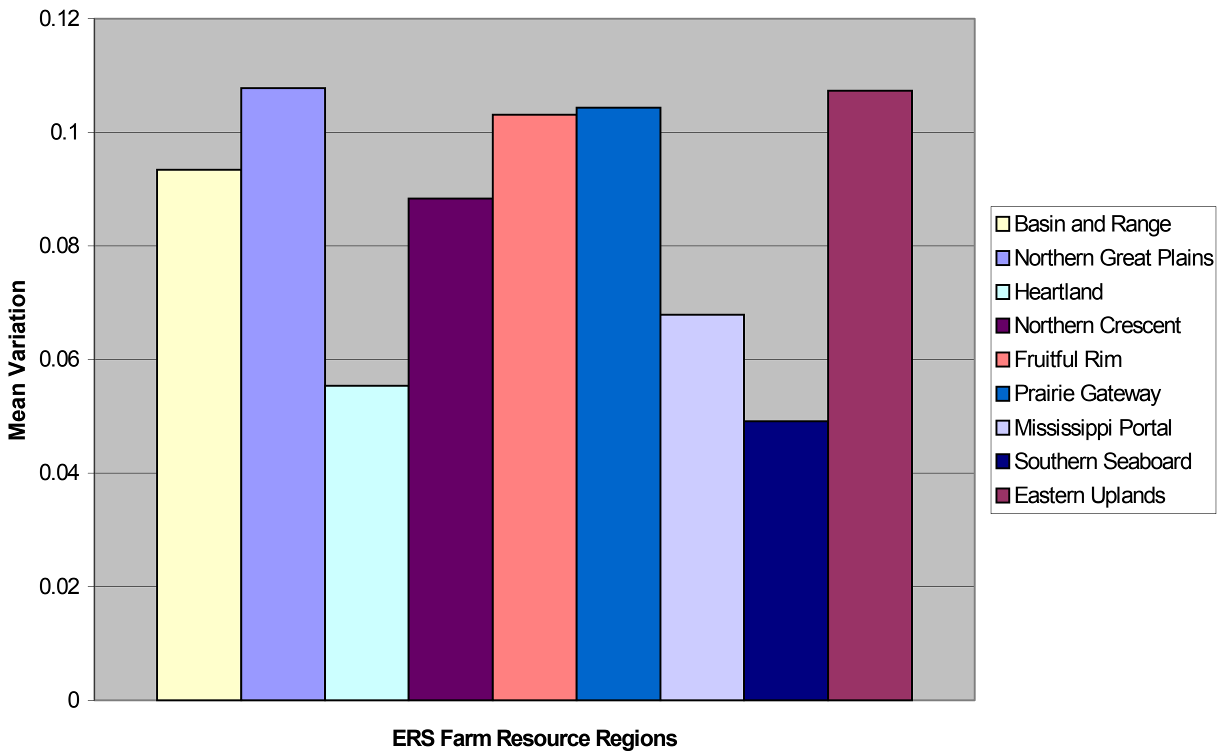
Intercept values for the nine regions are found in Table 4.13. Each of the regional parameter estimates are statistically different from 0 with 95% confidence. Statistical differences between regional intercepts are discussed later in this chapter.

Table 4.13 Intercept Values- Model 1

Region	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Basin and Range	0.08218	0.01381	8.95	<.0001
Northern Great Plains	0.13628	0.01101	12.38	<.0001
Heartland	0.09434	0.0128	7.37	<.0001
Northern Crescent	0.14296	0.00535	26.73	<.0001
Fruitful Rim	0.11094	0.00961	12.37	<.0001
Prairie Gateway	0.16328	0.00513	31.81	<.0001
Mississippi Portal	0.08875	0.02076	4.27	<.0001
Southern Seaboard	0.14805	0.00908	16.3	<.0001
Eastern Uplands	0.09133	0.0065	14.04	<.0001

Figure 4.1, found at the end of this chapter, shows the mean value of yield variation by region weighted by total acres in each county used in the study. Results show that counties in the Northern Great Plains have the highest overall mean value of variation followed closely by the Eastern Uplands and the Prairie Gateway. While the Eastern Uplands stretches from Pennsylvania down to Georgia and also includes a smaller section in western Arkansas, southern Missouri, and eastern Oklahoma, it is primarily the portion of this region west of the Mississippi River that is included in the study. The area east of the Mississippi River is devoted in large part to crops not included in the study. If Griffin (1996), Keeton (1999), and others are correct, it is likely that the greatest expansions in production are occurring in these regions. Regions of comparatively lower yield variation include the Heartland, Mississippi Portal, and the Southern Seaboard. One common misconception may be that acreage shrinkage is likely to occur in areas with low yield variation. On the contrary, Keeton (1999) and others have shown that acreage expansions are simply occurring at slower rates in these regions of the country when compared to areas in the Plains states where yield variation is higher.

Figure 4.1 Mean Variation for Model 1 by ERS Farm Resource Region.



Figures 4.2 through 4.6 examine the relationship between yield risk and the agri-environmental indicators assuming that all parameter values are fixed at their regional mean. Figure 4.2, found at the end of this chapter, shows the relationship between yield variation and soil erosion by water. A statistically significant positive relationship exists between water erosion and yield variation in the Northern Great Plains, Heartland, and Eastern Uplands. This relationship suggests that if producers in regions with high levels of yield risk, like the Northern Great Plains, respond to subsidies more strongly than producers in less risky regions of production, an increase in soil erosion from water is likely. Elasticity values found in Table 4.12 reveal that a one-unit increase in soil erosion in the Northern Great Plains is associated with a 0.102 unit increase in yield variability. The elasticity value in the Heartland is slightly higher at 0.111. An F test on the regional intercepts for Model 1 reveals that mean yield variation is statistically different at a 99% confidence level between the Northern Great Plains and the Heartland. The slopes for the two regions showing positive correlation between yield variation and water erosion are not statistically different from one another at the 99% confidence level.

This suggests that the rate of change in variation as water erosion increases is the same between the Heartland and Northern Great Plains. However, the difference in slope between the Northern Great Plains and the Heartland is statistically significant at an 88% confidence level.

Figure 4.2 Yield Variation and Soil Erosion by Water.

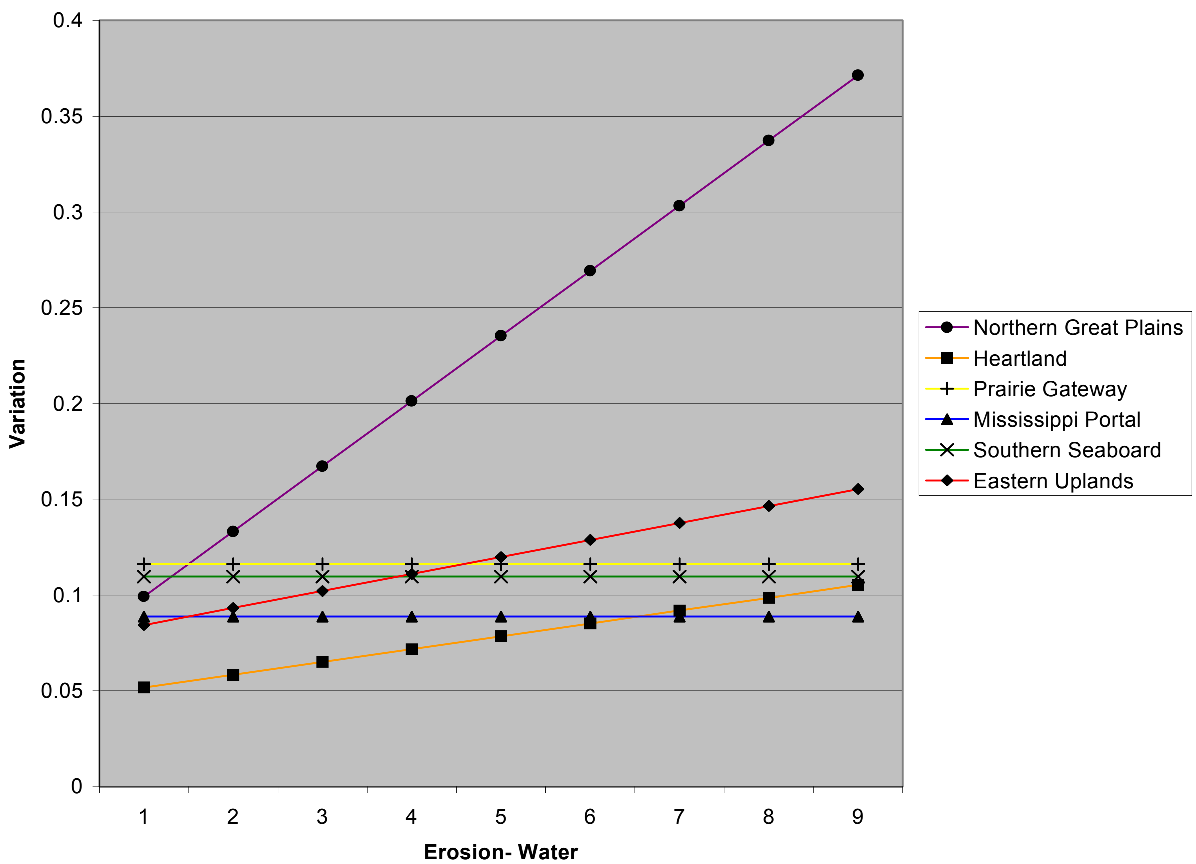
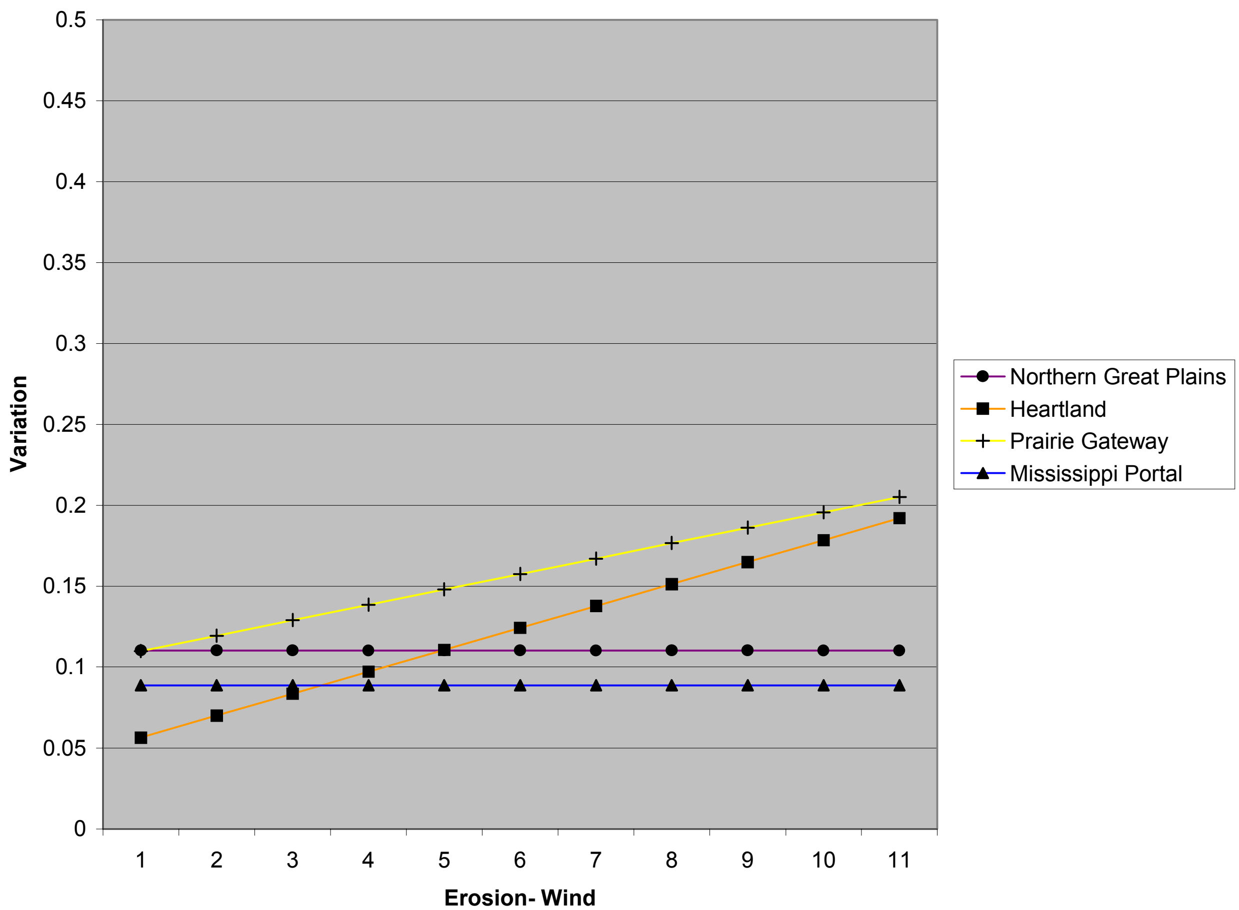


Figure 4.3, found at the end of this chapter, shows the relationship between yield variation and soil erosion by wind. A statistically significant positive relationship exists for the Prairie Gateway and Heartland regions. The Prairie Gateway in particular shows a high level of yield variation (Fig.4.1- Appendix 4.1) suggesting that acreage expansions are likely in this area as producers in this region respond to incentives from risk management programs and expand production onto the extensive margin. Elasticity values for the Prairie Gateway and Heartland are 0.06 and 0.03, respectively. Therefore, a one-unit change in wind erosion in the Prairie

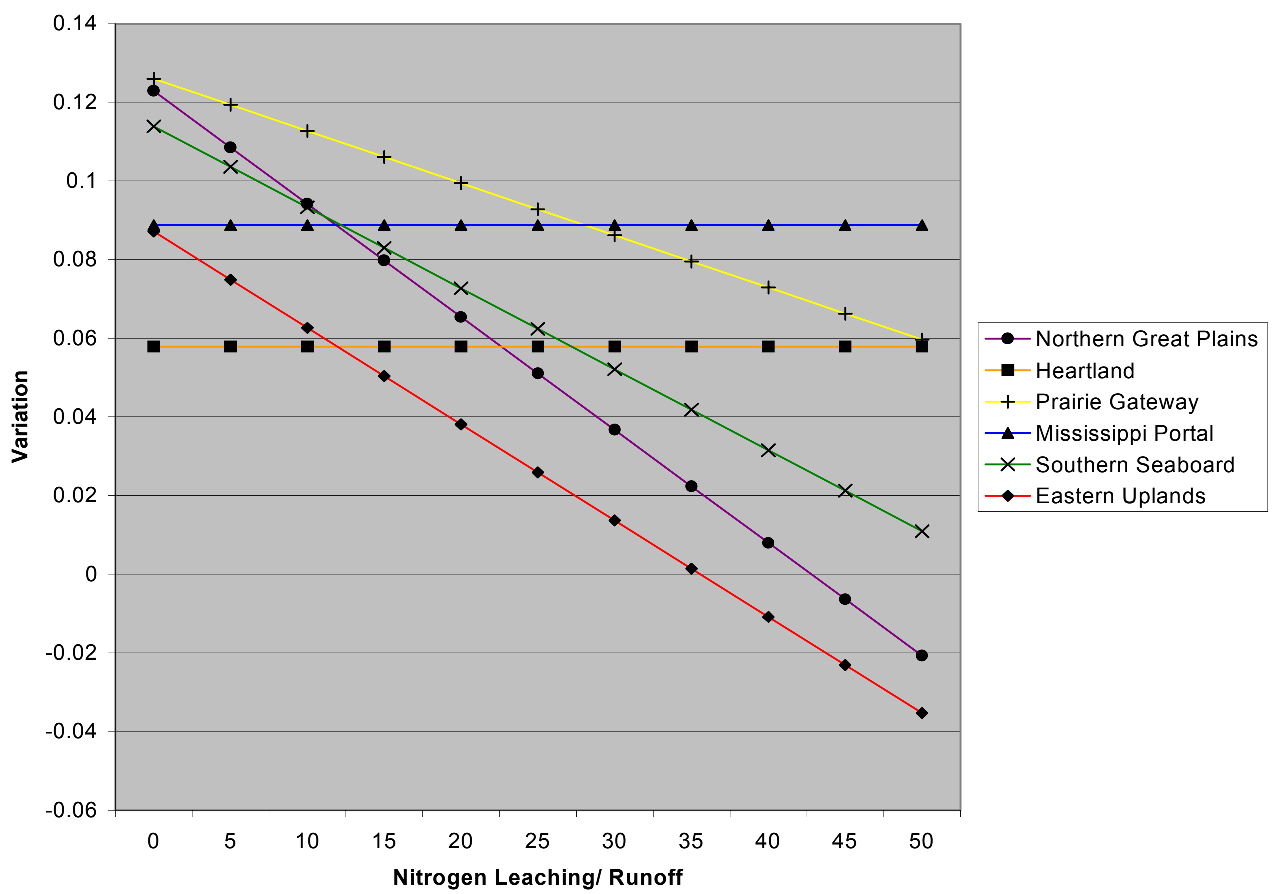
Gateway is associated with a 0.06 unit increase in yield variability. An F test on the regional intercept estimates reveals that mean yield variation is statistically different at the 99% confidence level between the Prairie Gateway and the Heartland. Slope values for the two regions, however, are not statistically different from one another suggesting that the rate of change in variation as wind erosion increases is the same between the Prairie Gateway and the Heartland.

Figure 4.3 Yield Variation and Soil Erosion by Wind.



The relationship between yield variation and nitrogen runoff and leaching, (Fig. 4.4) is negative for all areas included in the study except the Heartland and Mississippi Portal, where no statistically significant relationship is found. This variable did not conform entirely to expectations, as it was thought that a positive relationship would likely exist in some regions of the country. As explained previously, one possible explanation for the lack of positive correlation between yield risk and nitrogen and pesticides may be the design of the model. The model may not be designed to properly capture the relationship between chemical use and yield risk. More specifically, the model does not take into account the type of crop being produced. As chemical use can be closely tied with a particular crop, a control for the type of crop produced may yield more meaningful results.

Figure 4.4 Yield Variation and Nitrogen Runoff/Leaching.



A negative relationship exists between yield variation and pesticide leaching in all regions except the Northern Great Plains and the Mississippi Portal, where no statistical significance exists (Fig. 4.5). Similarly a negative relationship is found between yield variation and pesticide runoff (Fig. 4.6) in the Northern Great Plains. No statistically significant relationship exists for the remaining regions. Regional intercept values for pesticide leaching are quite varied, reaching from a high of approximately 0.14 in the Prairie Gateway and Southern Seaboard to a low of approximately 0.7 in the Heartland.

Figure 4.5 Yield Variation and Pesticide Leaching.

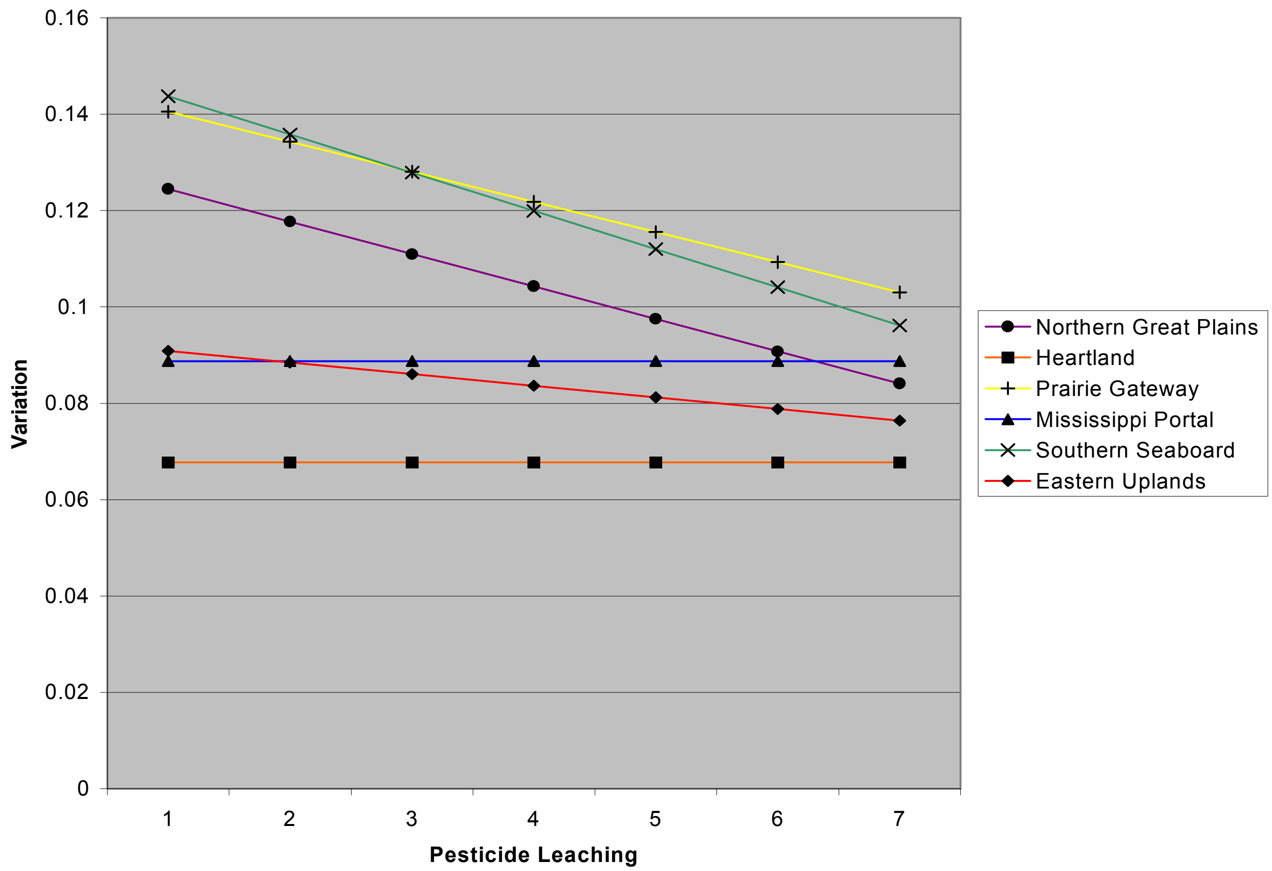
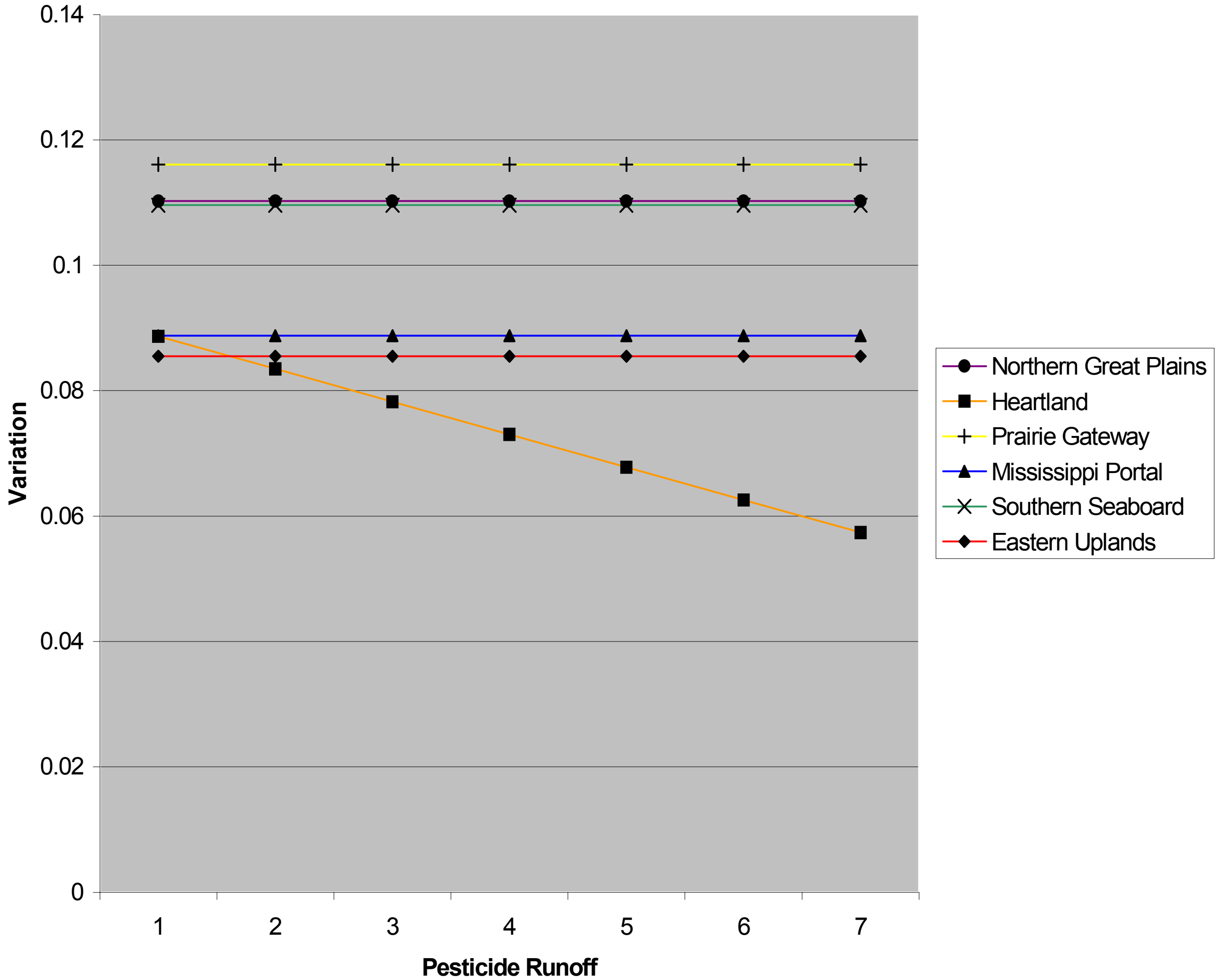


Figure 4.6 Yield Variation and Pesticide Runoff.



CHAPTER FIVE
CONCLUSION

Investigating the relationship between yield risk and the environment brings to light several potentially relevant policy issues. This thesis 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. Wu's 1999 study uses farm-level data to show that purchasers of crop insurance shifted production from hay and pasture to corn and soybeans. This shift resulted in increased soil erosion, along with increased applications of nitrogen, phosphorus, and atrazine.

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 been proposed by individuals at the Environmental Working Group and 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. An Ordinary Least Squares (OLS) model is developed to test this relationship.

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 green support payments.

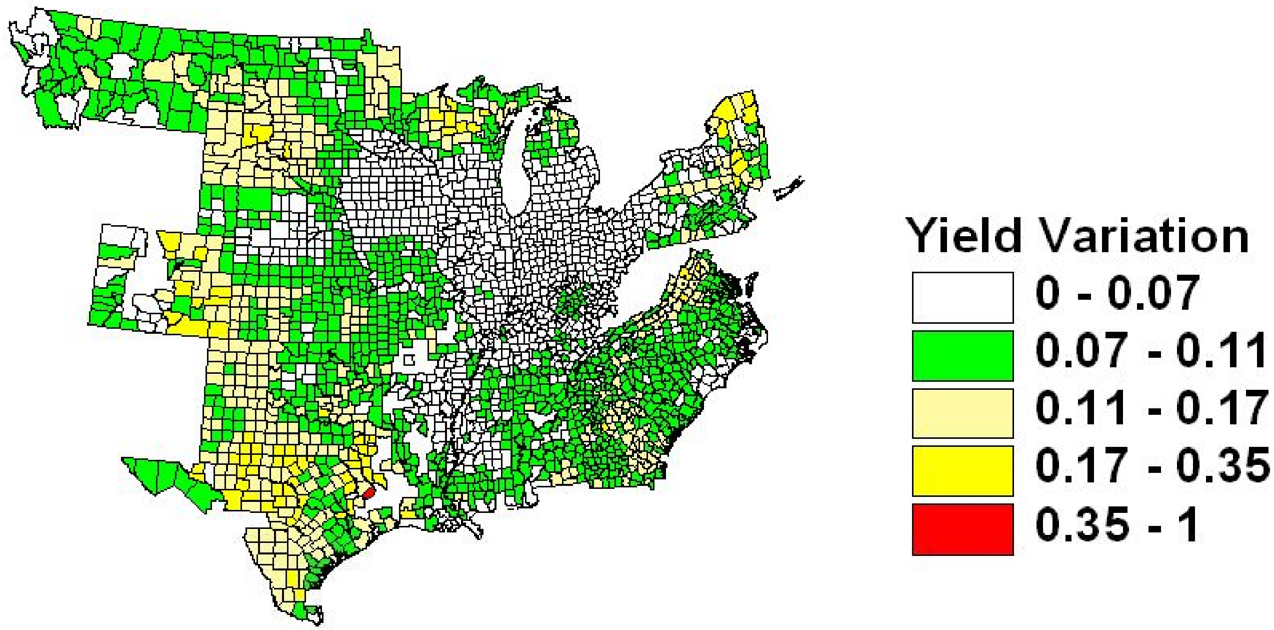
The results of this study suggest that as farmers take advantage of subsidies that pay more to those who produce in higher risk regions, increases in soil erosion from water are likely in the Heartland and Northern Great Plains. As these two regions make up over half of the U.S. acreage devoted to the 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.

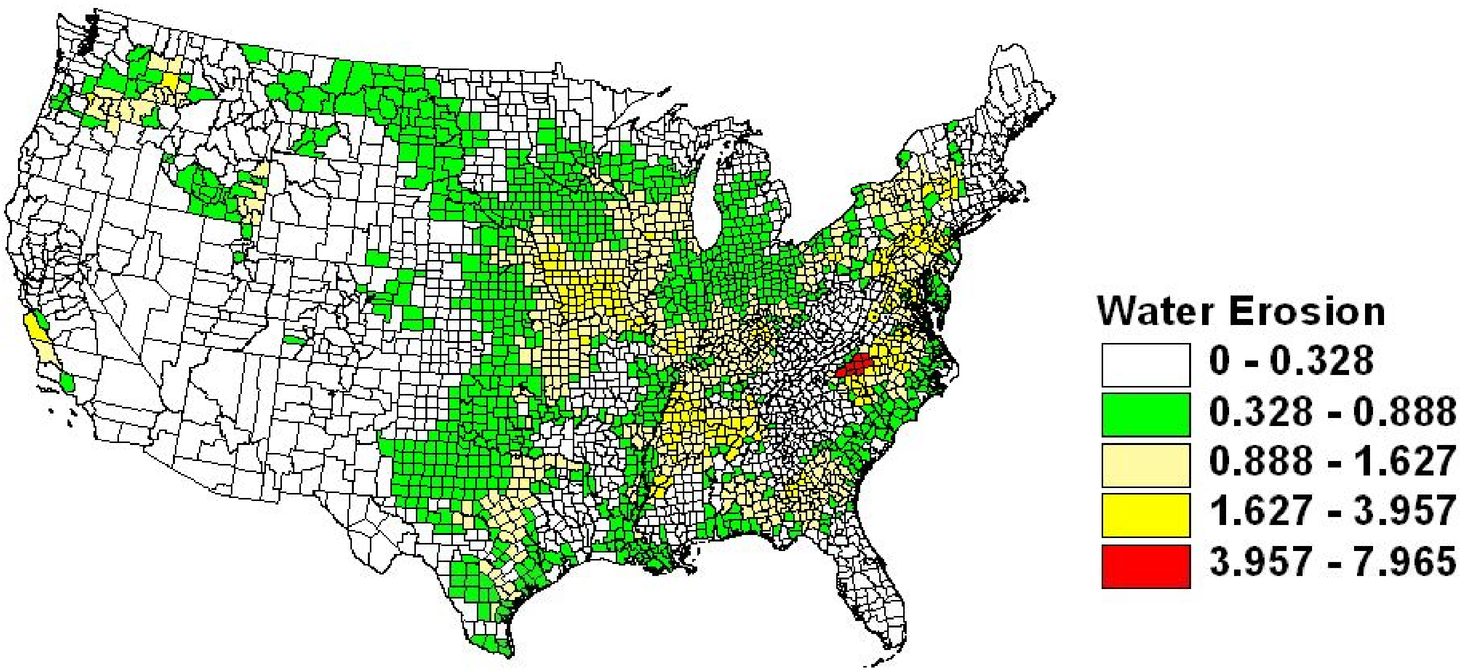
Results of the regression between yield risk and chemicals (i.e. Nitrogen Fertilizer Loss, Pesticide Runoff and Pesticide Leaching) are less clear. While the relationship between yield risk and chemical loss does not conform to expectations in some regions, it is believed that the model may not be designed to properly capture the relationship between chemical use and yield risk. More specifically, the model does not take into account the type of crop being produced. As chemical use can be closely tied with a particular crop, for example nitrogen fertilizer and corn, a control for the type of crop produced may yield more meaningful results. The addition of a control variable for crop type would likely be an excellent addition to future research.

There are several additional limitations to this study. The study area is limited geographically in that for the most part, the western and northeastern U.S. is not included in the analysis. Additionally, only six major row crops are included in the study. The study could be improved by expanding the research area to all areas of the U.S. as well as incorporating additional crops. While such a study would be far more complex, it may allow for a more complete picture in terms of national environmental impacts, and subsequently allow for greater national-level policy analysis. The study is also limited by a lack of data in several areas. No direct measure of farm level risk is available at this time. If such a measure were available indirect valuation methods such as the yield variation measure employed here would not be necessary. Additionally, while the development of agri-environmental indicators has significantly improved in recent years, much work is still needed to accurately assess environmental impacts of agricultural production.

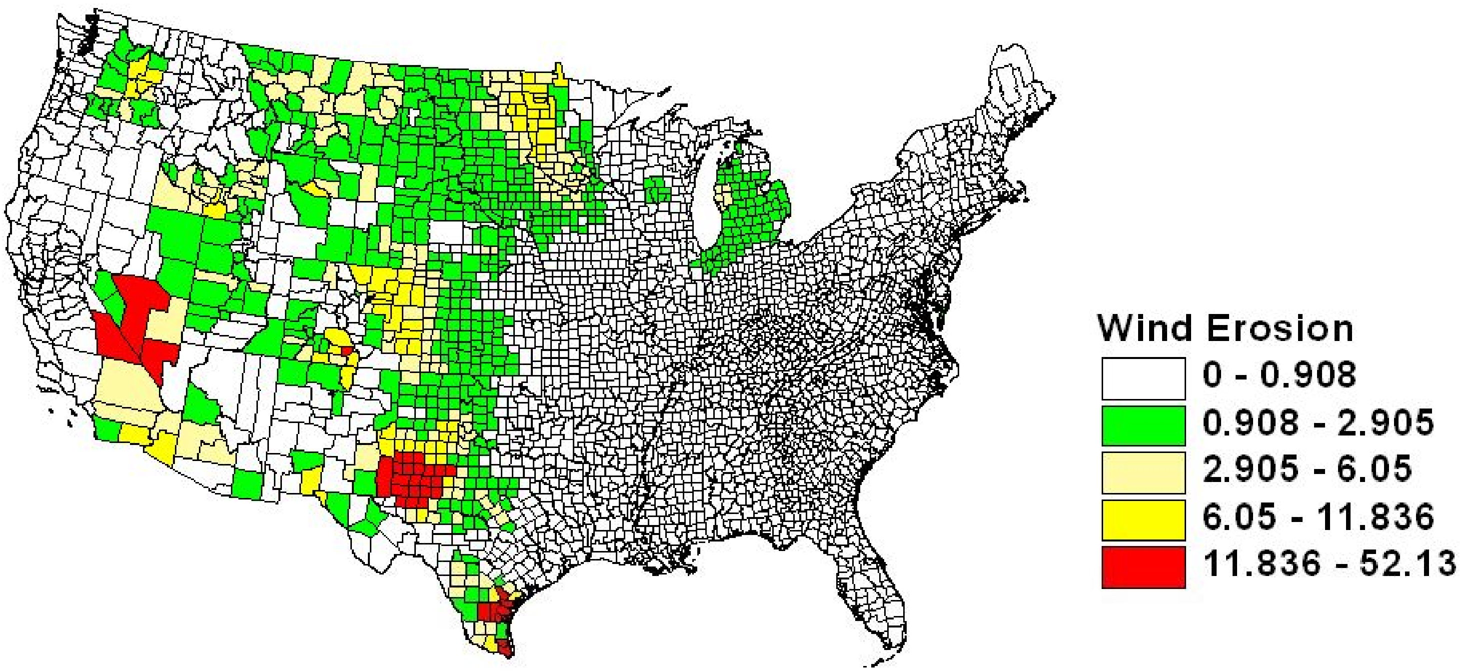
Appendix A: A.1. Yield Variation Model 1



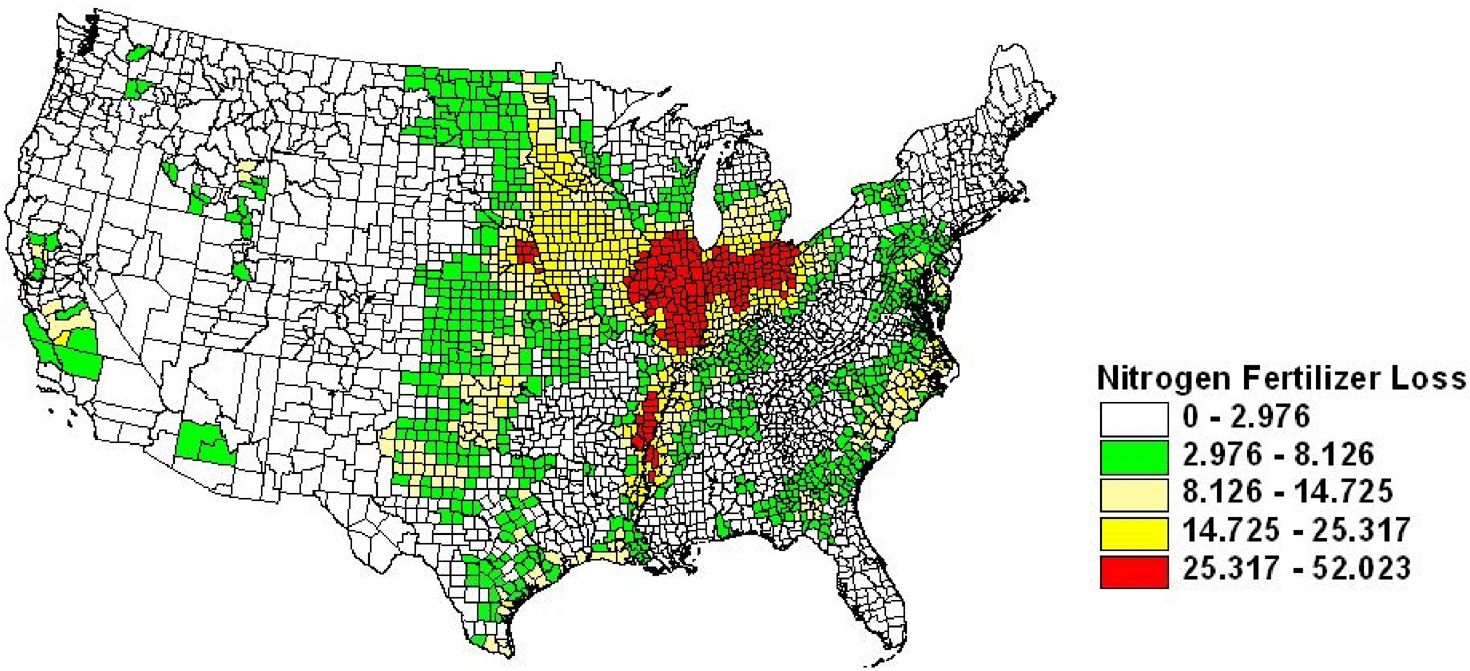
Appendix A: A.2. Average Annual Soil Erosion By Water



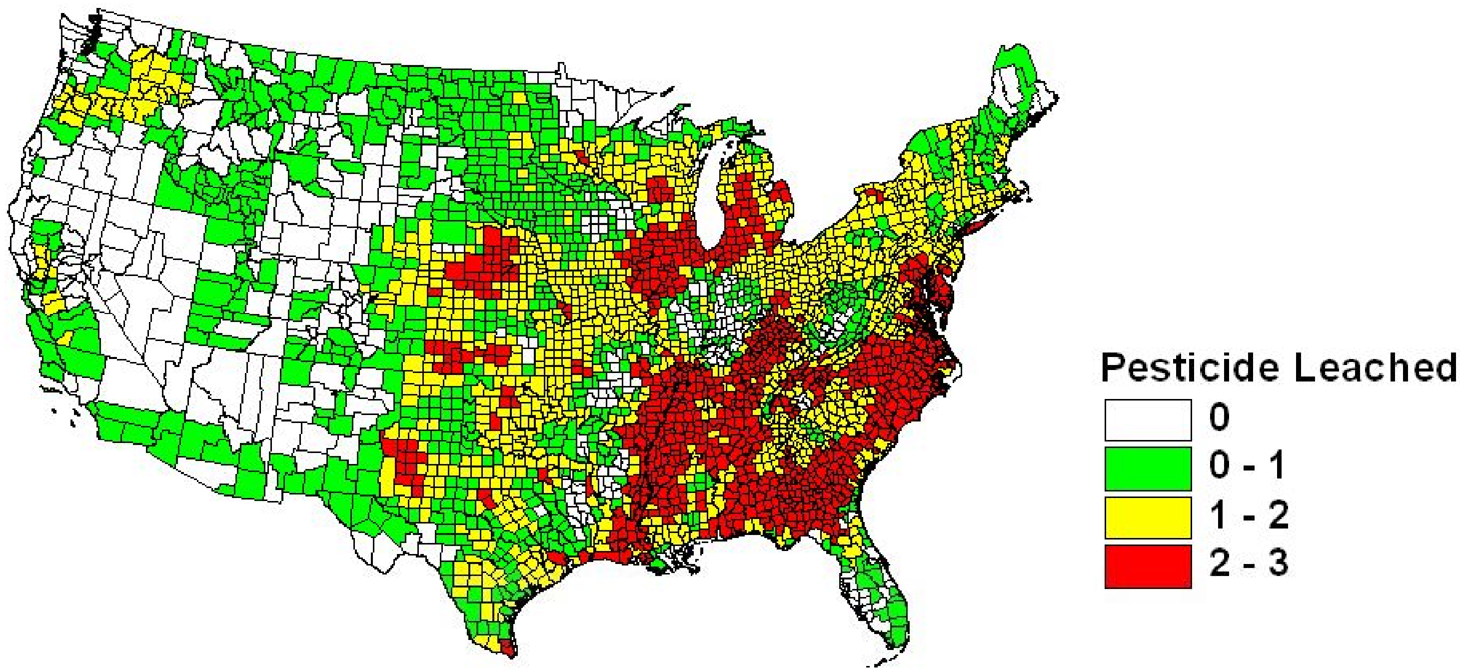
Appendix A: A.3. Average Annual Soil Erosion By Wind



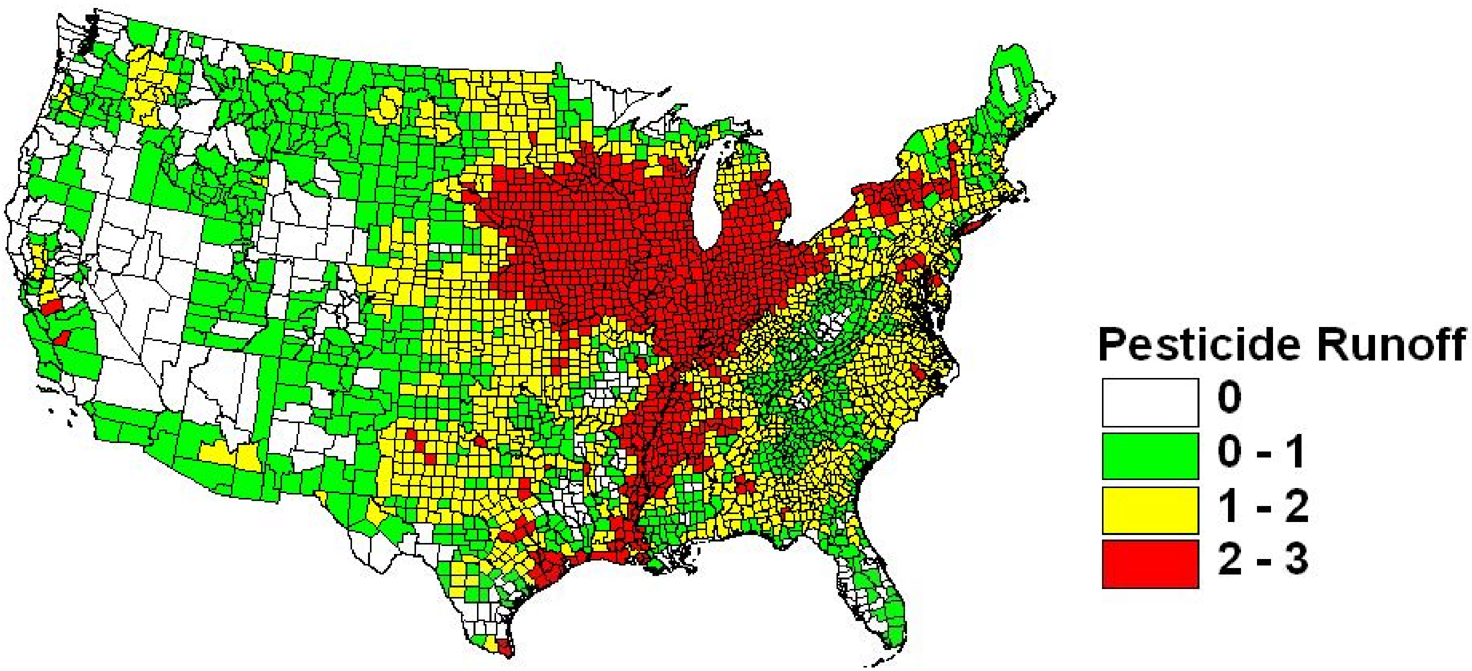
Appendix A: A.4. Potential Nitrogen Fertilizer Loss from Farm Fields



Appendix A: A.5. Pesticide Leaching Potential by Watershed

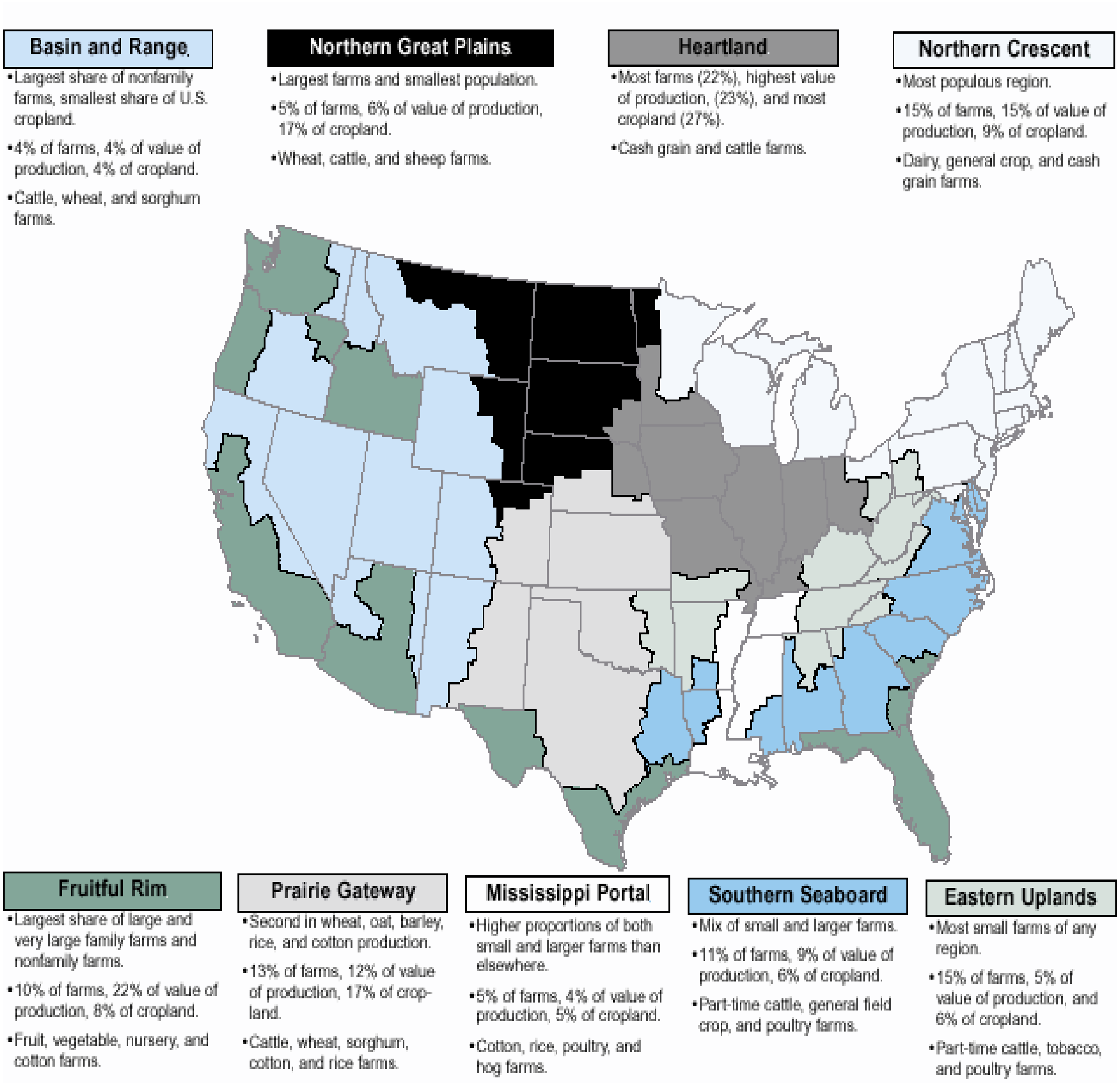


Appendix A: A.6. Pesticide Runoff Potential by Watershed



Appendix A: A.7. 8-Digit Hydrologic Units

Appendix A: A.8: ERS Farm Resource Regions



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