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Use of Geographically Referenced Grain Yield Data for Location and Enrollment of Vegetative Buffer Strips in the Conservation Reserve Program

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Abstract. Precision agriculture technologies create new opportunities for producers and public policy makers. This manuscript presents guidelines to help producers in the enrollment of cropland in the USDA Conservation Reserve Program (CRP) as vegetative buffer strips. Society benefits from the prudent adoption and use of precision agriculture practices through stable food prices and improved environmental quality. The study incorporates risk aversion and four land tenure arrangements including owned land, leased land, crop share and cost share. The filter strips are identified using GPS-referenced yield monitor data acquired at harvest for the crop years 1997 to 1999. The analysis shows that risk aversion level and land tenure arrangements must be considered in the decision to enroll filter strips to improve profitability.

Keywords. EV analysis, filter strips, GPS, precision farming, risk analysis, yield monitors.

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Introduction

Agricultural producers continually seek means of enhancing profitability and reducing risk. Enrollment of land which qualifies for Conservation Reserve Program (CRP) payments for areas with low productive capability provides one opportunity for farmers to accomplish these objectives. However, the lack of adequate, detailed data can often prove to be a difficulty in making appropriate management decisions such as what land to enroll in CRP. Fortunately, the availability of production data from yield monitoring and yield mapping affords producers with the historical reference needed to make such decisions under the risky environment they face.

Risk and uncertainty in agriculture is a prevailing phenomenon that receives a great deal of attention from producers and researchers alike, being well represented in the literature (Boisvert and McCarl, 1990; McCarl, 1984; and Kennedy, 1981). Many factors, including weather, disease, weeds, insect infestation, economic conditions, governmental policies and technological innovations, interact to create a very unique operating environment for the agricultural producer. Exposure to risk associated with agricultural production generates considerable thought from producers, with increased attention during times of depressed commodity prices. Analytical studies have evolved in all areas of risk related to agricultural production - marketing, production, financial, legal, and personal. Production risk has been heavily researched (e.g. - Brink and McCarl, 1978; Teague and Lee, 1988; Johnson, 1981; Lin, Dean and Moore, 1974; Pope and Shumway, 1984) and will continue to be researched as it provides a majority of risk implications for farmers.

As producers assess their situations in a more detailed manner, recent innovations within the precision agriculture industry have the potential to make production more profitable, though this hypothesis has very mixed support (e.g. - Lowenberg-DeBoer and Swinton, 1997; Carr et al., 1991; Hammond, 1992; and Wollenhaupt and Wolloski, 1994). Precision agriculture is broadly defined as a compilation of technologies that affords the ability to analyze site-specific information and offer the potential to manage these areas in the same site-specific manner, all in an attempt to meet specified goals. Precision agriculture technology has evolved to include a vast number of practices that offer assistance for producers in making production decisions, including the acquisition of large amounts of site-specific resource

and yield data (Roberts, English, and Mahajanashetti, 2000). Furthermore, the adoption of precision agriculture techniques embodies a continuum of many practices and equipment components including but not limited to yield monitors, variable rate input application (both single and multiple inputs), infrared mapping (monitoring weeds and yield), and grid soil sampling.

The yield monitor is a tool commonly adopted among producers as a base for entry to precision agriculture, in part due to the inclusion of these instruments on harvesting machinery by manufacturers. The use of yield monitors has been on the rise in recent years. Mangold (1997) found that yield monitor use rose from 300 in 1993 in North America to 17,000 in 1997. Similar trends on a state level have been documented for Kentucky (Shearer et al., 1999), Tennessee (English, Roberts and Sleigh, 2000) and Arkansas (Popp and Griffin, 2000). Yield monitors record harvesting crop characteristics, such as yield and moisture, for specific locations within fields. These monitors produce information that can be displayed in a wide array of fashions, including yield maps, revenue maps or profit maps.

Yield maps are generated from yield monitor data depicting visual representation of actual yields reflecting different field characteristics, cropping practices and other factors. Consequently, these maps offer the potential for certain field operations to be altered to suit areas of the field for specific characteristics. Inherent to this process is the ability to analyze economically whether or not to produce in any specific location of a field. Coupled with government program incentives through the Conservation Reserve Program (CRP), this option becomes an alternative that producers consider to better manage less productive land. Recent Natural Research Conservation Service (NRCS) initiatives have promoted the use of CRP filter strips as a means to discourage erosion. Producers can use this as an opportunity to more economically manage field borders by enrolling them in CRP filter strips, which offers payment incentives to landowners for doing such. This process will ultimately have an effect on the overall risk borne by the producer. This research analyzes enrollment implications resulting from varying risk aversion levels that a producer may exhibit. Resulting economically optimal decisions of CRP filter strip enrollment are considered and implications for net returns are analyzed.

While variable-rate fertilizer application and other precision farming practices are generally tactical, short-run decisions with the ability for alteration after one production season, employing CRP filter strips can be considered more of a strategic decision. CRP enrollment requires a commitment for the strip to be enrolled in the program for at least 10 years. Thus, this is not a decision that is easily reversible. It also represents an area of study that has not been analyzed to a great extent. Generally, precision agriculture studies have focused on decisions and effects that are specific to a production season (e.g. - Fiez, Miller and Pan, 1994; Hayes, Overton and Price, 1994; Mahaman, 1993). As the decision to enroll strips is considered a strategic decision, research for this analysis required a data set for several years. Important to the

discussion for this and other precision agriculture research is the consideration that there should be a sound source of data upon which to base management decisions. It has been observed that yield data collected through yield monitors are sometimes subject to error from various sources, such as operator error or errors due to time lags in yield monitoring practices (Moore, 1988). With the increase in yield monitor use, the size and accuracy of usable datasets for decisions such as these should increase.

While data for analysis increases and there remains an existing growth in the adoption of precision agriculture practices, the importance of research assessing management decisions resulting from these trends increases. The analysis presented here is partially justified in that regard. The overall objective of this research is to assess using CRP filter strips on a diversified crop operation for enhancing profitability and reducing yield risk. It builds on previous research conducted by Stull et al. (2000) assessing impact on net returns from using filter strips identified through the use of GPS yield data. This analysis extends the research through the inclusion of risk analysis, encompassing the consideration of varying land tenure arrangements including scenarios representing producer owned land, leased land, crop sharing and cost sharing. Ibendahl, Trimble and Isaacs (2000) have conducted analysis concerning ability to pay cash rental rates using similar tenure arrangements. It is noteworthy that the procedure used in this study can be applied to analysis for removal of production regardless of CRP payments as the rental strategies (leased land, crop share, cost share) contribute no CRP payment to the farmer in modeling the producer's decision to enroll in filter strips.

Risk analysis in relation to precision agriculture has been studied to a limited extent (Cook and Corner, 1996) and it is intended for this research to contribute to this body of literature. In the same manner, research regarding precision agriculture encompassing varying land tenure arrangements is scarce and warrants analysis. Risk analysis is conducted through mean-variance (EV) analysis, which evaluates decisions based on their expected outcomes E and variances V. In this study, the standard deviation of the net returns for each field, tenure arrangement and risk aversion level is evaluated. This analytical procedure has been consistently used in research, as is shown in the following discussion. The hypothesis underlying this research is that risk aversion levels and varying land tenure arrangements will play a large part in the degree of enrollment in filter strips, with more risk averse individuals choosing to enroll more land in strips.

Consequently, the contributions to the literature from this study are threefold. First, it is intended that the research serve to address a need in a timely fashion to provide the integration of GPS data collection with economic analysis in addressing CRP enrollment. Secondly, an innovative breakeven technique is developed in marginal economic analysis conducted through partial budgeting is coupled with EV risk analysis in utilizing precision agricultural data to evaluate both profitability and risk management potential of alternative production and management practices. Finally, an

application using precision agricultural data to address strategic, long run decisions as opposed to the more common tactical, short run decisions is investigated.

Theoretical Framework

The economic framework for this study primarily involves three elements. First, a production economic product/product model wherein the marginal rate of transformation between enterprises is equated with the ratio of returns for these alternative enterprises is inherently subsumed within the model. Secondly, the procedure was simplified into a breakeven decision criterion. Finally, risk analysis and expected utility maximization is incorporated in the evaluation.

EV analysis has been used heavily in literature using risk modeling (Lambert and McCarl, 1979; Adams, Menkhaus and Woolery, 1980; Dillon, 1992). Boisvert and McCarl (1990) offer a review of this procedure and identify 39 articles that use this approach to analyze mainly production and financial risk, with some dealing with market risk. The procedure was founded on research conducted by Markowitz in 1952 analyzing portfolio selection. Freund, apparently separately, developed analysis using the same principles incorporating risk into modeling procedures. The EV framework is a widely used procedure for analyzing a mix of risky sets. It is strongly considered more of a deductive or analytical tool than an empirical tool (Robison and Barry, 1987). It is founded on the notion that, given any two distributions with equal means, a risk averse individual will prefer the distribution with the smallest variance. In comparison to expected utility (EU) analysis, Meyer (1987) finds that EV analysis is consistent with the EU framework if the cumulative density function (CDF) of the random variables differing only by location and scale. It is thus sufficient when using returns (gross or net) when they are ranked to be linear functions of one another. This being said, the ability to use means and variances to make assessments lends itself to the simplicity and resulting widespread use of EV analysis (Hardaker, Huirne and Anderson, 1997). It is this simplicity coupled with considerations for the type of information obtained for this research that renders the use of EV analysis applicable to this problem.

The decision to implement filter strips involves analysis that takes into account a varied amount of information. Using historic yield data, producers have the ability to identify areas of the field that would be better managed in filter strips. The decision on how much land to enroll can be affected by the level of risk aversion of the producer. A producer who seeks to minimize risk more than another producer will likely enroll more area into strips than the risk seeker given the constant payment for CRP enrollment versus the yield risk associated with continued production. Using a procedure for identifying continuous filter strips in ArcView GIS, varying risk aversion levels are analyzed under different tenure arrangements to assess the effect of risk aversion on strip enrollment. The identification procedure involves advanced querying in a GIS software package (ArcView GIS) that allows for logical, continuous strips.

The procedure for incorporating risk aversion into this analysis relies upon the seminal work of McCarl and Bessler (1989). The Pratt risk-aversion coefficient is calculated according to varying risk levels. The procedure used generates a risk-adjusted gross revenue that is equal to the mean of the gross revenues minus a normal *Z* value times a standard error (Dillon, 1992). The process basically adjusts gross revenue to varying risk levels, where a highly risk averse scenario would result in a lower gross revenue level acceptable to the individual than compared to a lower risk averse scenario. The Pratt risk-aversion coefficient becomes larger as risk aversion increases, thus penalizing gross revenues more for a higher risk aversion level. The Pratt risk-aversion coefficient is simply calculated with the following formula:

$$\Phi = 2Z_{\alpha} / S_y$$

where F is the risk-aversion coefficient, $Z_{\square}$ is the standardized normal *Z* value of the level of significance, and S_y is the relevant standard deviation. The risk-aversion coefficient will become larger as the risk aversion level rises, thus penalizing gross revenues, which makes likelihood for a cell to be enrolled in a filter strip higher. Risk aversion levels are used representing levels of aversion from risk neutrality to a high-risk aversion level. The resulting formula for adjusting gross revenues follows as:

$$GR_{RiskAdjusted} = \overline{GR} - \Phi\, VAR_{GR}$$

where $GR_{RiskAdjusted}$ represents the adjusted gross revenue, $\overline{GR}$ represents the mean gross revenue, F equals the risk-aversion coefficient calculated from the previous formula, and VAR_{GR} equals the variance of the gross revenues. Gross revenue justification lies in its direct relation to yield, the only stochastic variable, as prices are held constant. This forced marketing management decisions that affect price to be removed from the study to arrive at a base analysis. The adjusted gross revenue is calculated for each cell in the field and is compared to the target breakeven decision criteria level for assessing which cells should be economically enrolled in CRP filter strips, coupled with a procedure that considers logistics and continuity in filter strip enrollment.

Once cells are identified for each risk aversion level and tenure arrangement that meet CRP requirements and breakeven requirements for enrollment in filter strips, these cells are then given a value for the CRP payment that is received. For owned land, the owner/tenant being the same person allows CRP payments to be credited to the producer, while the other tenure arrangements do not allow such since the producer and the owner are two separate entities. Thus, a CRP payment is not received by the producer in the leased, crop share, and cost share scenario, and is consequently not

included. This represents an area that could merit certain policy recommendations in relation to the recipient of payments, thereby inducing strip establishment to a higher extent for land that is not owned by the operator. Upon such calculations, gross revenues are calculated for the period from 1990-1999 for the two possible crop rotations, as discussed below. Standard deviation and values of both mean gross and net returns calculations are then computed to arrive at the net effect of having strips. Resulting assessments are then made considering each field, land tenure arrangement and risk aversion level.

Data and Methodology

To accomplish the aforementioned objectives, a good deal of data is required. Analysis for this research relies on production history for a cooperating producer in Shelby County, Kentucky. Relevant production information includes: 1) GPS yield data on corn, double-cropped soybeans and double-cropped wheat, 2) average yield history for the farm for the years 1990 –1999, 3) variable production costs for each crop, 4) average rental rates for Kentucky cropland 5) relevant CRP payment schedules, 6) respective commodity prices, 7) relevant Loan Deficiency Payments, 8) establishment costs for filter strips, and 9) GPS stream information. These data were evaluated over four land tenure arrangements: owned land, leased land, crop share, and cost share. Under each tenure arrangement, four risk aversion levels (risk neutral as well as low, medium, and high risk aversion) were examined.

Yield monitoring practices have been used on the farm since 1996, employing an AgLeader yield monitor. Historical yield data (1997-1999) for three fields were collected based on the yield monitor data and are presented in Table 1. Yield data collected during harvesting was averaged into grid cells representing 25 feet in length and 25 feet in width. These cells represented the average cell yield based on the data that was collected during harvesting within those cells. This data set was used as the basis for the analysis. Using the 10-year average farm-level crop production history (1990-1999) for the producer, also in Table 1, yields were indexed to the yield data information to generate an estimated yield data set to reflect yield risk for each crop in each year and for each field, maintaining spatial yield variability across years. This results from the inability of the data set to estimate temporal yield risk from 1997-1999 GPS data alone. As precision agriculture develops a longer history of use, more years of GPS data will produce a data set that has this capability.

Variable production costs for the three commodities were collected for the producer. These costs were based on 1999 production and are consistent with Farm Financial Standards Council (FFSC) standards used by the University of Kentucky Farm Business Management program, resulting in variable costs of $149.68/acre for corn, $137.43/acre for wheat, and $113.64/acre for soybeans. An average cropland rental rate of $63.10/acre for Kentucky producers for the years 1996-1998 was used

(Kentucky Economic Subject Matter Outlooks). An average annual CRP payment of $71.00 was used, relevant to the fields being analyzed, as collected from the Natural Resource Conservation Service (NRCS). Five-year average commodity prices were calculated for relevant prices as received by this and similar producers. Loan Deficiency Payments (LDP) were collected from the Farm Service Agency integrated into these averages in applicable years to arrive at a final average price received by the producer; this resulted in $2.72/bu. for corn, $3.43/bu. for wheat, and $6.67/bu. for soybeans.

Establishment costs for filter strips were based on actual costs experienced by the cooperating producer for filter strips that had been previously established. These costs included fescue seed costs of $20.77/acre, drilling costs of $14.00/acre and a measurement cost of $3.00/acre, and were spread over a 10-year life for the strip, consistent with NRCS expectations. Investment costs relevant to these establishment costs were calculated using a average yearly investment calculation at an 8% interest rate, resulting in a $1.51/acre cost per year. Maintenance costs of $5.00 per acre for the filter strips were used as determined by the NRCS. Filter strip requirements were used as follows: (1) the maximum distance from the top of the stream bank is 150 feet, (2) a minimum enrollment of 40 feet in width, and (3) the preclusion of trees from enrollment in the strips. To determine areas eligible for strip enrollment, GPS stream data collected from the Environmental Systems Research Institute (ESRI) was used in ArcView GIS. The stream data along with the yield monitor data allowed queries to be performed that selected areas of the field that were physically within geographic CRP requirements for filter strip enrollment.

The various land tenure arrangements required separate breakeven calculations. Owned land incorporated variable costs, CRP payments to the owner/producer, and establishment costs for the strips. Breakeven calculations for the other arrangements (leased land, crop share, cost share) were based mainly on variable costs as the tenant does not receive CRP payments for enrollment, nor do they incur any establishment charge as this is the sole responsibility of the landowner. The tenant avoids rental payment on land that essentially yields below breakeven. This is consistent with current arrangements for the operation being analyzed and other Kentucky operations as well, as noted by Ibendahl, Trimble and Isaacs. The leased land arrangement incorporated an average rental rate of $63.10 per acre. The crop share arrangement required the tenant receive 75% of production, with rent being paid as a quarter share of yield given to the landowner and no sharing of production costs except the landowner's full responsibility for lime costs. The cost share arrangement required the tenant to bear two-thirds of the fertilizer, seed, and chemical costs (and the entirety of all other production costs except lime) and receive two-thirds of the yield. The landowner pays the remaining one-third of the fertilizer, chemical and seed costs and all the lime costs and receives one-third of the yield as a land rental payment.

The breakeven average annual gross revenues for each scenario were as follows: owned land ($261.08/acre)[1], leased land ($221.64/acre), crop share ($184.03/acre), and cost share ($160.60/acre). These criteria were based on average production costs for each year and compared to average gross revenues for each cell. Using these calculations, filter strips were identified that would be optimally enrolled in the CRP program rather then continued in crop production. Essential to identifying the strips was economic evaluation that incorporated risk analysis. Gross revenues were adjusted for risk using the EV analysis and the previously mentioned risk aversion coefficient procedure used by McCarl and Bessler (1989). Using these risk aversion coefficients[2], gross returns were adjusted for each cell resulting in a risk adjusted gross revenue compared to the breakeven gross revenue to identify areas that are more economically enrolled in CRP filter strips. Combining this information with the physical information in the form of field data and stream data, resulting filter strips were identified. Specifically, cells were identified through ArcView spatial analysis that fell within filter strip guidelines and met economic criteria for enrollment (i.e. possessed a gross revenue less than the breakeven gross revenue). If a cell was not within the specified distance from the stream (150 feet), it was not queried against the breakeven criteria because it could not be enrolled due to filter strip guidelines. Additionally, continuity of strips was incorporated in the programming procedure to ensure contiguous filter strips. Results of this procedure formed the basis for the filter strips used under each land tenure arrangement.

Results

The results from this analysis are presented in Tables 2, 3, and 4 for fields A, B, and C respectively. The tables depict impacts to total net returns for each field when using strips under each land tenure arrangement and for various risk aversion levels. The standard deviation, minimum, and maximum values give an idea of the economic effect from each scenario. The filter strip enrollment is a percentage enrolled of the total area eligible for enrollment. Comparing just across tenure arrangements, net returns for owned land is higher than the other tenure arrangements, with the difference in net returns in comparison to any other strategy conceptually being the opportunity cost of owning land when comparing tenure arrangements. Leased land consistently had higher net returns than crop share and cost share scenarios. This suggests its use in comparison to the other strategies as a preferred tenure arrangement for these fields for the producer given a $63.10/acre rental rate. This is in part due to the ability of the operator to receive more return in good years in comparison to the other strategies. Consistent with expectations, for each field and land tenure arrangement, mean net returns and standard deviations decreased as risk aversion increased. Basically, as a producer becomes more risk averse, the individual will sacrifice returns in order to mitigate risk, which can be measured through the standard deviation.

As the producer becomes more risk averse, cropping practices will be altered in order to minimize the standard deviation. The results show that filter strips are a means to accomplish this objective. Filter strip enrollment as a percentage of the area eligible for enrollment always increased in every scenario for each field. Therefore, the expected result that filter strips reduce exposure to risk is evident in the findings.

Comparing the owned land arrangement to the other arrangements, filter strip enrollment is always higher as a percentage. This results from the fact that the landowner and tenant in the owned land case is ultimately the same individual, allowing CRP payments to be paid to the tenant and thus being considered in the breakeven analysis. That being said, the owned land scenario offers the greatest potential to mitigate risk through CRP filter strips because the constant, zero variability incentive payment is made to the producer. While leased land would be considered to have higher risk than the crop share and cost share which inherently include risk sharing, the results show that enrollment under leased land to be lower, suggesting a more limited profitability potential of CRP enrollment for this tenure arrangement. These results are reflected by the relatively higher mean net returns for leased land as compared to the crop share and cost share arrangements for the conditions analyzed.

The leased land arrangement triggers the lowest enrollment in every case except for the high-risk level in field B, wherein the enrollment of 70% is only slightly higher than the 69% for the cost share scenario. It does however respond to risk levels to a greater extent versus crop share and cost share scenarios, though enrollment is rarely higher for leased land. This suggests that filter strips do not offer as high degree of

profitability, but is more responsive in terms of risk mitigation under the leased land arrangement as compared to the other land acquisition arrangements. This, in part, can be attributed to the fact that under a lease arrangement, 'rental' rates are constant and are not yield dependent as the 'rental' rates are for crop share and cost share arrangements.

Comparing enrollment across fields, the percentage enrolled for field A is always higher than fields B and C. This is consistent with findings in previous unpublished research that triggered 100% enrollment in filter strips for field A when the other fields did not do so. Therefore, it can be assumed that the yields for field A in the areas that are eligible for enrollment are consistently lower than those for fields B and C. The resulting conclusion would be that field A represents the best field for filter strip enrollment to minimize yield risk and enhance profitability. Reasoning would suggest that the area for enrollment in field A is characteristically defined by factors consistent with poor producing land.

Enrollment comparisons between crop share and cost share scenarios shows little difference in percentage enrolled. Both have similar trends in the degree of filter strip enrollment, with 8 of the 12 different scenarios (3 fields x 4 risk levels) triggering enrollment within 2 percentage points of each other. There exists no general trend for which one is higher than the other in terms of enrollment percentage. This being said, it can only be stated that these two arrangements are similar in their responses to filter strip enrollment.

A graphical depiction of filter strip enrollment percentage is presented in Figure 1. Again, it is evident that in comparison to the other two fields, field A represents the best candidate for this type of decision. The enrollment trend for each cropping arrangement is higher in field A than both fields B and field C, further supporting the notion that the area eligible for enrollment in field A is more suitable for filter strip than the other two fields. The notion that crop share and cost share arrangements have similar effects on stripping levels is also supported. These two trend lines nearly overlay each other for each field. While the enrollment trend and lines for fields A and B almost mirror each other, the line for field C increases to a greater extent as risk aversion level initially increases, suggesting that field C has some areas of production that are marginally more productive than fields A and B, but eventually are enrolled at higher levels of risk aversion.

Summary and Conclusions

This study includes the development of a breakeven procedure that melds EV risk analysis with marginal economic analysis of a product-product model conducted through partial budgeting. Profitability and risk management potential of CRP enrollment under alternative land tenure arrangements and attitudes towards risk are

investigated. The use the GPS yield maps was instrumental in providing a basis for comparison to the breakeven decision criteria developed.

The degree of filter strip enrollment is affected by the degree of risk aversion exhibited by a producer. Consistent with expectation, filter strip enrollment increases with the degree of risk aversion as variability is lowered as areas eligible are actually enrolled in CRP. This suggests that filter strips are a means that producers can use to lower exposure to risk, as well as enhance profitability.

The varying land tenure arrangements showed expected responses to the degree of filter strip enrollment. Owned land consistently showed the highest enrollment as CRP payments made to the producer/owner make this decision more than just a breakeven decision as with the other cropping arrangements. The leased land arrangement offers the least response to risk mitigation in comparison to the other cropping arrangements.

When comparing tenure arrangements, expectation would be that the leased land requires more risk be borne by the producer than crop sharing or cost sharing because rental rates are fixed. The results show that for these fields, the leased land arrangement consistently exhibited the lowest degree of filter strip enrollment, with cost sharing showing the highest enrollment. Thus, filter strips are less profitable for leased land but do offer greater risk response over varying risk aversion levels. This would also suggest leased land as the preferred cropping arrangement when considering these fields for the conditions analyzed. A further discussion can be developed concerning government payments to tenants under rental arrangements. The results show that rental arrangements versus owned land does not result in the same percentage of filter strip enrollment. Arguments concerning the right of the tenant to receive the CRP payment for filter strip enrollment can be justified in that regard. This has potential for policy recommendations for CRP payments to tenants to induce these producers to enroll in filter strips. Further research may identify the level of payment to each involved party, but it is evident that a payment to the tenant would increase enrollment percentage from a tenant perspective.

In consideration of the fields, there does exist a response to filter strip enrollment relative to field characteristics (i.e., field A possesses stronger characteristics that trigger enrollment in CRP filter strips). The characteristics of fields of productivity as related to such factors as fertility, slope and soil type may be indicative of areas that are suitable for filter strip enrollment. Further analysis in this area would strengthen the results from this research. Additional research concerning environmental implications would also add merit to this study. Additional data in the form of accurate GPS yield monitor information would extend and solidify these findings. Further research may also warrant inclusion of other crops under the same analysis.

In conclusion, filter strips do offer the potential for increasing profitability and reducing yield risk. Analysis for each field and cropping arrangement is warranted to ensure optimal enrollment in filter strips. With the increasing concern for exposure to risk by producers and researchers alike, the process of filter strip enrollment is suggested as a means to mitigate risk. Filter strip enrollment decisions should include consideration for rental strategy and risk preferences. Using GPS yield monitor information has shown to provide data for accurate decision-making and give value to strategic decision-making based on GPS data. Still yet, more studies investigating precision agriculture practices are warranted due to the continued evolution of practices and increase in data available. The results of this research may be very useful in a period where agricultural production has become increasingly riskier with lower commodity prices and increased concern with environmental regulations. Results of this study demonstrate both land tenure arrangement and risk preference should be considered in the decision of CRP enrollment. Additionally, the incorporation of risk is important in conducting precision agriculture research.

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Footnotes

[1] While expectations for breakeven requirements might initially suggest owned land should be lower, it is important to remember that CRP payments are included along with establishment costs for owned land and not the other tenure arrangements due to separability between the producer and owner.

[2] The respective risk-aversion coefficients were calculated at the 50%, 55%, 60%, and 65% level for the following owned land gross returns per acre risk neutral standard deviations: field A ($83.71), field B ($71.06), and field C ($69.09).

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Table 1. Yield Averages for Cooperating Farm.

Section I. Individual Field Averages Based on Yield Monitor Data						
Field #	Total Area (Ac)	Eligible Area (Ac)	Yields (bu./acre)			
			'97 Wheat	'97 Soybeans	'98 Corn	'99 Wheat
A	31.5	0.92	21.06	14.58	128.60	65.90
B	28.4	3.46	28.13	13.53	127.43	66.96
C	85.4	3.98	37.42	15.76	127.27	58.07

Section II. Historical Farm Average Yields				
	Growing Season	Yields (bu./acre)		
		Corn	Wheat	Soybeans
	1990	89.0	36.0	32.0
	1991	105.0	19.0	28.0
	1992	179.6	32.0	41.9
	1993	153.0	58.4	30.8
	1994	112.0	69.0	24.0
	1995	127.0	46.0	29.6
	1996	101.3	51.0	35.7
	1997	76.0	42.7	20.1
	1998	129.0	54.0	28.0
	1999	93.0	68.0	5.0

Table 2. Net Returns for Field A Under Varying Tenure Arrangements and Risk Aversion Levels.

	Total Annual Net Returns ($)				
	Mean	**Standard Deviation**	**Minimum[1]**	**Maximum[2]**	**Filter Strip Enrollment (%)[3]**
Owned Land					
Risk Neutral	$2,399.23	$2,589.07	-$1,532.90	$9,272.26	78%
Low Risk	$2,398.35	$2,577.18	-$1,524.13	$9,238.95	94%
Medium Risk	$2,397.96	$2,576.28	-$1,524.12	$9,235.81	95%
High Risk	$2,395.11	$2,572.79	-$1,525.43	$9,222.73	100%
Leased Land					
Risk Neutral	$1,379.61	$2,625.60	-$2,573.14	$8,347.93	35%
Low Risk	$1,378.29	$2,598.48	-$2,560.85	$8,276.71	66%
Medium Risk	$1,371.98	$2,582.39	-$2,554.22	$8,227.39	86%
High Risk	$1,369.69	$2,578.77	-$2,553.32	$8,215.24	91%
Crop Share					
Risk Neutral	$540.62	$1,993.22	-$2,471.20	$5,656.96	66%
Low Risk	$539.57	$1,985.30	-$2,467.65	$5,635.20	78%
Medium Risk	$538.02	$1,978.17	-$2,461.57	$5,614.93	91%
High Risk	$537.46	$1,976.95	-$2,461.48	$5,610.73	94%
Cost Share					
Risk Neutral	$581.57	$1,749.08	-$2,106.85	$5,143.96	55%
Low Risk	$577.58	$1,740.64	-$2,098.60	$5,105.17	80%
Medium Risk	$573.38	$1,738.58	-$2,096.16	$5,095.18	86%
High Risk	$555.71	$1,736.76	-$2,094.95	$5,085.56	92%

[1] All minimum net returns were experienced in 1999 with a rotation using wheat/soybeans that year.

[2] All maximum net returns were experienced in 1992 with a rotation using corn that year.

[3] Enrollment percentage is percentage of eligible area that can be enrolled for each scenario.

Table 3. Net Returns for Field B Under Varying Tenure Arrangements and Risk Aversion Levels.

	Total Annual Net Returns ($)				
	Mean	**Standard Deviation**	**Minimum[1]**	**Maximum[2]**	**Filter Strip Enrollment (%)[3]**
Owned Land					
Risk Neutral	$2,134.70	$2,096.04	-$671.66	$7,865.80	34%
Low Risk	$1,915.45	$1,989.35	-$748.76	$7,363.30	66%
Medium Risk	$1,878.67	$1,980.71	-$770.68	$7,300.94	71%
High Risk	$1,782.02	$1,961.48	-$827.96	$7,144.86	82%
Leased Land					
Risk Neutral	$1,380.19	$2,159.85	-$1,517.85	$7,285.07	10%
Low Risk	$1,004.63	$2,035.08	-$1,721.07	$6,575.38	51%
Medium Risk	$881.82	$1,993.40	-$1,790.23	$6,341.28	64%
High Risk	$826.62	$1,982.99	-$1,825.66	$6,255.40	70%
Crop Share					
Risk Neutral	$460.31	$1,594.48	-$1,682.40	$4,822.34	20%
Low Risk	$215.06	$1,515.27	-$1,817.60	$4,364.08	56%
Medium Risk	$139.30	$1,491.72	-$1,858.90	$4,224.51	66%
High Risk	$113.84	$1,486.84	-$1,875.65	$4,184.74	70%
Cost Share					
Risk Neutral	$488.83	$1,414.98	-$1,413.30	$4,360.23	21%
Low Risk	$284.53	$1,348.98	-$1,524.53	$3,978.33	55%
Medium Risk	$212.25	$1,327.65	-$1,567.48	$3,848.00	66%
High Risk	$192.65	$1,323.92	-$1,578.97	$3,817.97	69%

[1] All minimum net returns were experienced in 1991 with a rotation using wheat/soybeans that year.

[2] All maximum net returns were experienced in 1992 with a rotation using corn that year.

[3] Enrollment percentage is percentage of eligible area that can be enrolled for each scenario.

Table 4. Net Returns for Field C Under Varying Tenure Arrangements and Risk Aversion Levels.

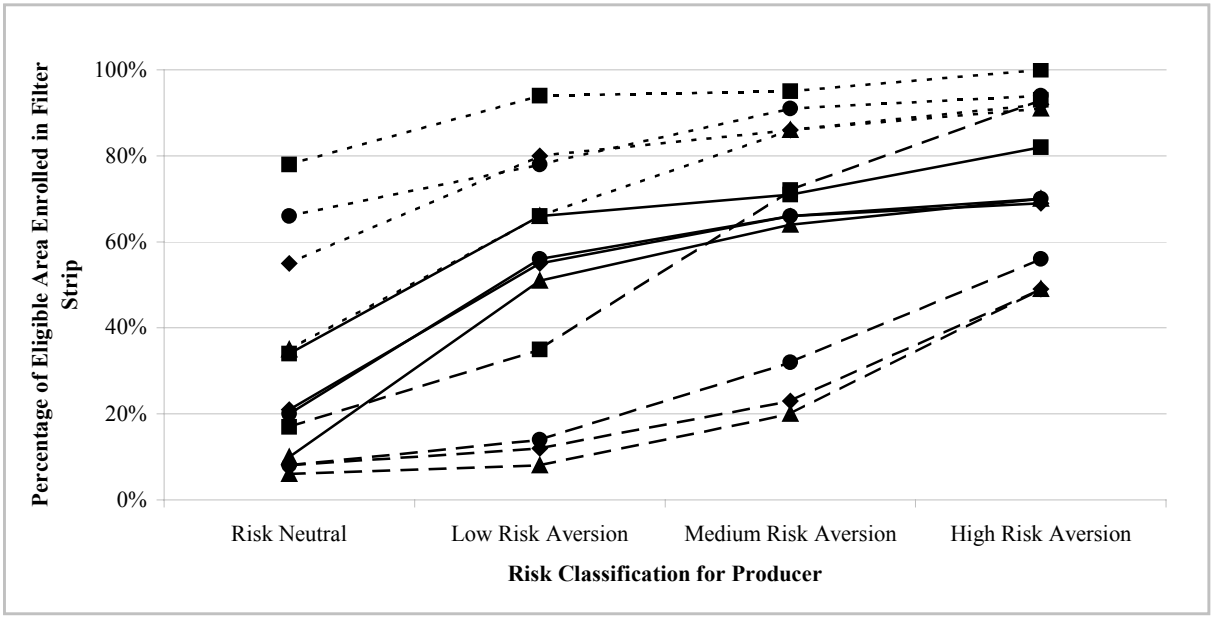
	Total Annual Net Returns ($)				
	Mean	**Standard Deviation**	**Minimum[1]**	**Maximum[2]**	**Filter Strip Enrollment (%)[3]**
Owned Land					
Risk Neutral	$9,235.69	$5,849.16	$1,100.92	$24,664.71	17%
Low Risk	$9,098.40	$5,806.20	$1,030.98	$24,413.29	35%
Medium Risk	$8,771.20	$5,712.93	$859.01	$23,586.16	72%
High Risk	$8,565.23	$5,651.02	$745.39	$23,483.12	93%
Leased Land					
Risk Neutral	$6,604.04	$5,869.18	-$1,564.97	$22,075.77	6%
Low Risk	$6,582.71	$5,863.92	-$1,575.90	$22,039.31	8%
Medium Risk	$6,474.83	$5,841.88	-$1,648.42	$21,881.66	20%
High Risk	$6,141.19	$5,768.30	-$1,854.70	$21,362.18	49%
Crop Share					
Risk Neutral	$3,427.03	$4,399.24	-$2,694.53	$15,023.25	8%
Low Risk	$3,382.45	$4,389.28	-$2,723.51	$14,953.24	14%
Medium Risk	$3,240.65	$4,357.41	-$2,810.98	$14,729.18	32%
High Risk	$3,033.43	$4,313.23	-$2,946.98	$14,415.57	56%
Cost Share					
Risk Neutral	$3,354.36	$3,912.25	-$2,089.33	$13,666.60	8%
Low Risk	$3,327.48	$3,906.57	-$2,108.14	$13,626.29	12%
Medium Risk	$3,252.52	$3,890.87	-$2,154.92	$13,514.34	23%
High Risk	$3,057.54	$3,849.15	-$2,281.88	$13,218.27	49%

[1] All minimum net returns were experienced in 1991 with a rotation using wheat/soybeans that year.

[2] All maximum net returns were experienced in 1992 with a rotation using corn that year.

[3] Enrollment percentage is percentage of eligible area that can be enrolled for each scenario.

Figure 1. Percentage Enrollment for Filter Strips According to Risk Classification



Land Tenure Arrangements:

■ Owned Land ▲ Leased Land ● Crop Share ◆ Cost Share

Fields:

Field A —— Field B ------- Field C - - - - -