Precision Agriculture, Whole Field Farming and Irrigation Practices: A Production Risk Analysis

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Abstract

One of the potential management practices of precision agriculture (PA) is the capability of varying input application rate across a field. A potential benefit of that practice is the reduction in yield variability. Temporal reduction in yield variability can also be achieved through irrigation practices. Combining both practices should lead to a reduction of the yield risk faced by the farmer. In this study, variable rate application of nutrients will include to nitrogen, potassium and phosphate. Mathematical programming techniques will be used in a standard E-V framework to analyze the ability of PA and/or irrigation to reduce production risk.

Introduction

The farming operation is one that involves a significant level of risk and uncertainty. Finding means and ways to reduce the level of risk farmers are exposed to had long captured the interest of many researcher in various disciplines in agricultural. In spite of those efforts, a 1997 Iowa Farm and Rural Life Poll shows that a large majority of producers (66%) think that risk in farming has been increasing (Paul Lesley). To respond to these increasing challenges, the results of the pool indicate that farmers primarily choose crop insurance, debt reduction, diversification and forward contracts as risk management tools.

Though production practices do not appear to be a primary tool for risk management, Cochrane expresses the believe that the new trend in agricultural research is one "in which the steps in the production process will be fully integrated and the entire process strictly controlled". A increasing control over the production process can be perceived as a mean to manage risk. Today, precision agriculture (PA) is a technology that can enable farmers to increasingly integrate and take control of the production process. The development of that new technology was made possible in the early 80's by the new information technology revolution and the development of the Geographic Information System (GIS). The GIS made it possible to geographically manage different area of the field according to their unique condition and characteristics. The information revolution made it possible to simultaneously process and manage a significant amount of information (multiple layers of soil characteristics maps – moisture, fertility etc -, variable input – fertilizer, lime, chemicals- recommendation, and more). The PA technology was defined by Blackmore et al. (1994), as a comprehensive system designed to optimize agricultural production by carefully tailoring soil and crop management to correspond to the unique condition found in each field while maintaining environmental quality.

In spite of its great potential, there are still a significant number of obstacles impeding the full development of the PA technology and its adoption by a majority of US farmers. Many reasons have been advanced to explain the low rate of PA adoption by US farmers: high cost of adoption (Cook, S.E., Adams, M.L. and R.G.V. Bramley "), low profitability (Lowenberg-DeBoer, Bullock et al.) lack of perceived opportunities delivered by PA (Douglas, Foord and Eidman) unwillingness to replace existing equipment (Khanna, Epouhe and Hornbaker) etc. In order for PA to become a widely adopted technology, it needs to become a mean to answer many of farmers' problems. As pointed by Gagnon and Toulouse the adoption of technology is not a matter of choice, but of survival. Given that PA technology has not yet made itself a necessary instrument that will guaranty the farm survival, need is to determine how to make this great technology a necessary component in the production process. One way to make that possible is to prove PA to be an important risk management tool.

Among the many studies that have focused on the profitability of PA few have devoted attention to its risk reducing capabilities. Johnson et al. (1997) and Oriade et al. (1996) demonstrated that PA had the potential to reduce herbicide applications as well as reductions in leaching and runoff. In addition to those advantages, PA can also enable farmers to reduce their yield variability and therefore, their income variability.

One study by Lowenberg-DeBoer uses the stochastic dominance methodology to show that PA could under certain circumstances reduce temporal yield variability. Another study by Oriade and Popp uses the mathematical programming approach to evaluate the impact of PA on production risk. They found no evidence to support the assumption of PA as being a risk-reducing technology. However, this study was limited by data available and simple method to estimate the additional production cost and yield generated by PA. Production cost and yield were added in fixed proportion on conventional production practices.

There is then, a real need to construct a realistic model that will replicate the production conditions of a typical grain producer. The unique contribution of this study is analysis of the interaction between PA versus conventional production practices and irrigation versus non-irrigated production relative to their impact on profitability and yield risk reduction. In this study, a representative Kentuckian farmer's production conditions will serve as the basis of the analysis.

Model development

In this study a mathematical programming model was used to model the production environment of a hypothetical Henderson County, Kentucky, grain farmer producing corn, soybean and wheat. He/she can choose to either use precision agriculture technology (variable rate application of fertilizer), or conventional technology (uniform rate application of fertilizer), irrigate or not irrigate. It is hypothesized that the ability to variably apply fertilizer and control water application gives the producer much more control over his/her production environment and may represent a powerful mean to manage production risk. It is also assumed that the farmer's objective is to maximize expected utility.

The current study relies upon the expected utility framework to analyze the production risks included in the objective function. The technique used here is known as expected value variance (E-V) analysis and was first developed by Markowitz for its application in mathematical programming. It allows an analysis of the farmer's profit maximizing production strategies under different risk aversion level. Though highly criticized in the past, it has been shown to be consistent with the expected utility theory (Freund, Meyer, Markowitz, Tobin). Risk is measured in term of variance of crop (or enterprise) net income. If three enterprises fall on the same mean-variance (E-V) frontier, then they are all efficient in an E-V sense, and all three producers could be rational in the sense that they maximize utility. It is accepted that the expected income is a decreasing function of the risk aversion level. That is, the more risk averse the farmer is, the lower his/her expected income will be

The general specification of the model is as followed:

Objective functions:

$$\text{Max } \overline{Y} - \Phi \sigma_Y^2$$

Subject to constraints:

$$(1) \quad \sum_E \sum_P \sum_F \sum_D \text{ACRES}_{EPFDS} + \text{POND}_S \leq \text{ACRELIM}_S \qquad \forall\, S$$

$$(2) \quad \sum_S \sum_P \sum_F \sum_D \text{YLD}_{ENDSPF}\, \text{ACRES}_{DSPF} - \text{SALES}_N = 0 \qquad \forall\, C, N$$

$$(3) \quad \sum_D \sum_F \sum_S \sum_P \text{IREQ}_{IFPP*}\, \text{ACRES}_{EFDPS} - \text{IPURCH}_I = 0 \qquad \forall\, I$$

$$(4) \quad \text{W\_REQ}* \sum_E \sum_P \sum_F \sum_D \text{ACRES}_{EDSPF} - \text{W\_AVAL}* \sum_S \text{POND}_S \leq 0 \qquad \forall\, \text{IRR}$$

$$(5) \quad \sum_P \sum_E \text{P}_E * \text{SALES}_{EN} - \sum_I \text{IP}_I\, \text{IPURCH}_I + \text{Y}_{YR} = 0 \ \forall\, \text{YR}$$

$$(6a) \quad \text{ACRELIM}_{S'} * \text{ACRE}_{DFSP} - \text{ACRELIM}_S * \text{ACRE}_{DFS'P} = 0 \qquad \forall\, P, F, D, S \neq S'$$

$$(6b) \quad \text{ACRELIM}_{S'} * \sum_E \text{ACRE}_{DFSP} - \text{ACRELIM}_S * \sum_E \text{ACRE}_{DFS'P} = 0 \qquad \forall\, P, F, D, S \neq S'$$

$$(7) \quad \sum_N 1/\text{N}\, \text{Y}_N - \overline{Y} = 0$$

where constraints include

(1) land resource availability

(2) sales balance by year and by crop

(3) input purchase balance by input

(4) water resource availability by irrigation level

(5) annual profit balance year

(6a or 6b) ratio constraint to control for non-variable rate management strategy under either conventional (a) or PA variable application (b)

(7) expected profit balance

indices include:

E	represents the different enterprises or crops (corn, wheat and soybean)
P	is the production strategy (irrigated or dry land)
MS	is the input management strategy (single or variable rate application)
S	represents the three soil types (loring, memphis or grenada)
F	is the fertilizer application level (low, high or medium)
D	represents the planting dates (early, normal or late)
I	is the quantity of input applied on the soil
N	number of years
WK	states for week

activities include:

$\overline{Y}$	is the average (across years) expected net returns above variable costs;
Y_N	is the expected net returns above variable cost (across years)
$\text{ACRES}_{E\,D\,S\,P\,F}$	is the number of acres produced for enterprise E on planting date D, soil S under production strategy P at fertilizer level F;
SALES_{N}	is the total farm sale in year N (in bushels);
IPURCH_{I}	is the purchase of input I ;
POND_{S}	is the number of acres that this withdrawn from production and used to build the pond used for irrigation.

Coefficients include:

Φ	is the Pratt risk-aversion coefficient
IP_{I}	is the price of input I
P_{E}	is the price of crop E in dollar per bushel including related costs
ACRELIM	is the total number of acres available to the farmer (1350 acres)
W_REQ	is the per acre water required for irrigation (271540 gallons)
W_AVAL	is the water available in the pond to irrigate the field (45618720 gals)
$FLDDAY_{WY}$	is the variable field days at different levels of certainty;
$YLD_{N D S P F}$	is the expected yield during year N for enterprise E at planting date D, under production strategy P, on soil type F (in bushels per acre);
$IREQ_{I F P MS P}$	is the input I required per plant population P (in unit per acre);

Data and Production Methods

The results and scope of this study are limited to Henderson County, KY. Henderson County was chosen because it is a major agricultural county in the state. The County ranks second for the production of corn and soybean in Kentucky.

The data required in the development of the model include: (1) yield, (2) soil types, (3) irrigation requirements, (4) input requirements and prices, (5) crop prices and (6) land available for production.

(1) Yield data

Crops yields were obtain using CropMan (Crop Management), a biophysical model which is an adaptation of EPIC (Erosion-Productivity Impact Calculator), to farm management. CropMan adds to EPIC a window interface, economic data and production practice environment familiar to economists. Simulation models are capable of simulating crop variables and management practices as plant population, planting and harvesting dates, maturity groups, irrigation, drainage systems, tillage, irrigation methods, etc. Compared to other crop growth models, EPIC has the capability to simulate yield data when fertilizer levels are varied. The model was then calibrated to fit Henderson County production conditions: historical weather data, soil characteristics, fertilizer and chemical levels as well as sowing dates. Typical recommendations for planting dates, types, quantity, time and frequency of chemical and fertilizer application were obtained from scientists in the agronomic department.

The model generates expected yields for corn, single cropped soybean and wheat for varying fertilizer levels (nitrogen, phosphorus and potash), planting date and irrigated or dry land conditions. Three fertilizer levels were used to generate three series of yield data on each type of soil. The medium level corresponds to the exact recommendations obtained for agronomist and was increased or decreased by 35% to obtain high and low levels of fertilizer application. The fertilizers varied were urea, phosphorous and potassium for corn and wheat and potassium and phosphorous for soybean. Planting dates were references as early, normal and late and were respectively March 10, March 25 and April 8 for corn; April 5, April 19 and May 2 for soybean and October 14, October 28 and November 12 for wheat. It is important to notice that only the simulation data on corn responded to planting date, fertilizer and irrigation application. The simulations on soybean did not respond at all to variations in fertilizer level producing then the same yield at all fertilizer application level.

(2) Soil data

The number and types of soil chosen were based on expert opinions from Dr. Tom Muller a soil scientist at the University of Kentucky and based on the Henderson County soil survey. According to Dr. Muller soil test show that a typical farm in Kentucky usually has three to four different soil types. Soils types are usually found by association. Two of the most extensive associations in Henderson County are the Loring-Grenada and Memphis-Wakeland associations. The two associations make up for more than 35% of the county surface but a much larger percentage of the agricultural land as they are mainly used for agriculture. The Loring-Grenada association is made of brown and well-drained soils and is well suited for farming. Memphis which also represents 10% of the association is also a well-drained and brown soil. "Loring soils make up to 35 percent of this association, Grenada soils 20 percent, Memphis soils 15 percent and other soils make up the rest" (Henderson County soil survey). The Memphis-Wakeland association is made of brown, strongly sloping to steep, dominantly well-drained and silty soils. Memphis makes up to more than 60% of that association. For the purpose of this study, Memphis, Grenada and Loring series are the three soil types that are utilized. In the Grenada series, the Grenada silt loam 2 to 6 percent slopes is the most dominant. It is a soil with a moderately high moisture, low organic matter but that responds well to lime and fertilizer. The most dominant soil type in the Loring series is the Loring silty clay 6 to 12 percent slopes eroded. Though sloppy and eroded, this soil is an important agricultural soil in the county. It is moderate in natural fertility and is strongly acid, but the response of crops to fertilizer and lime is good. Yields on that soil are better than average if the soil is limed and fertilized. Finally, in the Memphis series, the Memphis silt loam 2 to 6 percent slope is the most dominant. This is a deep well-drained soil with a high moisture supplying capacity. Natural fertility is moderate but crop respond well to lime and fertilizer on that soil of which most of the acreage is cultivated

(3) Irrigation data

A surface irrigation method was used in the study. It is assumed that the water need for irrigation is always available. There is no water shortage for irrigation purposes. Center-pivot irrigation method and automatic irrigation options were chosen in CropMan. Choosing those options resulted in an average of 15 acre-inch of irrigated water on all crops. However, Dr. Steve Wokman, from the Biosystems and Agricultural Engineering department at the University of Kentucky and specialist in irrigation systems estimated that a 10 acres-inch of irrigated water is sufficient for Kentucky conditions. This estimation was used to determine the given number of acres that would be withdrawn from production to build a pond each time irrigated production strategy is chosen as a production strategy. It was estimated that 0.12 acre of land would be necessary to build a 14 feet deep pond would in order to irrigate one acre of land. These estimations include 50% for water loss and evapo-transpiration.

Though the center-pivot irrigation system was selected in the simulation model it is not the most widely used system in Kentucky partly because of the high front cost it requires. Irrigation on grain is in fact rarely used in Kentucky. When irrigation is used on grain, it would tend to be the “T” type of irrigation system which requires a lower level of investment. However, this type of irrigation system was not available as an option in CropMan. As a result, the cost structure incorporated in the model was based on the center pivot irrigation cost structure. Not that sloppy type of agricultural soil existing in

Kentucky does not permit the use of furrow irrigation system. Most agricultural soil have a 2 to 12% slope. Irrigated yield for PA management practice was not considered.

(4) Input requirements and prices

The input requirements are the variable production cost for each crops (corn, soybean and wheat) and production strategy (dry or irrigated land, variable or uniform rate fertilizer application). The primary data for dry land uniform rate irrigation were obtained from Budgets developed by Murali Kanakasabai and that fit Henderson County production conditions. Additional variable costs generated by the usage of PA technology were obtained from a PA budget developed by Gandonou et al. Finally, additional variable production costs generated by irrigation were obtained form the University of Arkansas estimated production costs using center-pivot irrigation system.

5) crop prices

Annual Kentucky crop prices were obtained nass/usda database on the Web.

(6) land data

It will be assumed that they are found in the field in about the same proportion as they exist in the county. The typical grain farmer field is then assumed to be a combination of three soils in the following proportion: 40% Grenada soil, 35% Loring and 25% Memphis.

Results analysis

The results herein presented are provisional and further analysis and model development need to be conducted. They are summarized and presented in four different categories in the four tables below: model summary statistics, management strategies, agronomic results and a more detailed summary of the management strategies adopted in percentage form. Three different sets of runs of the model are made. In the first run, the producer can only produce using precision agriculture technology with or without irrigation. In the second run he/she can also irrigate or not irrigate but can only uniformly apply fertilizers. Finally, in the last run, all options are allowed. This presentation allows to compare the risk management power of each production possibility as the producer becomes more and more risk averse and also what would be the ultimate choice when all choices are available. It also permits to compare the profitability of each production possibility. Results here will be discussed table for each table.

From table 1, it can be observed that mean profit decreases and coefficient of variation (CV) increases as risk-aversion level increases. It appears contrary to what would have been expected, that the adoption of PA gives the higher CV but also the higher maximum profit. It also gives the lower profit level with the higher variance. These results can be observed at all risk aversion levels.

In table 2, when PA is offered as the only alternative, soybean is produced under both irrigated and dry land production method. Corn is only irrigated. However, as risk aversion level increases, the farmer produces only dry soybean and irrigated corn. However, as risk aversion increases, he/she reduces the land in production. If the number of soybean acreage produced under dry conditions increases, the production of soybean under irrigated management stops. The least productive soil, Memphis is no longer cultivated. When PA is not an option, soybean is produced on dry land and under low fertilizer application and corn is irrigated. The low fertilizer rate application for soybean is due to the fact that the soybean yield result is not respondent to a variation in fertilization rate. Here also, as risk aversion increases, the management strategy changes and the producer tends to significantly reduce the amount of land in production. While the acreage allocated to soybean remains constant, the allocated to irrigated corn decreases.

In table 3, PA clearly gives the higher average yields per acre than uniform rate application. Therefore, it seems that the lower profitability of PA results in the fact that the additional cost does not cover the slight gain in yield. This results may confirm some of the previous finding showing PA not to be profitable. However, given that the producer using PA is able to withdraw low fertility soils out of production the technology retains some of its appeal since it can allow the producer to improve the management of those soils. Such opportunities are not reflected in the model.

Finally, table 4 shows that in all two cares, the farmer does not plant late. The producer in almost all cases plants his/her crops early in the season to get higher yields. In all cases, wheat never comes into production

Conclusion

It would be premature to gives any definitive conclusion at this stage. However, these preliminary results show that farmers adopting PA would remove the least productive of there land in order to manage production risk. The producer that uses PA also varies fertilizer level in order to maximize profit. It also clearly appears that early planting would be one of the most adopted production strategy. According to the EV-Frontier graph whole field production strategy is the most dominant one.

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Table 1. Summary Statistics

Whole Field Farming										
	Risk Aversion Level									
Statistics	***50***	***55***	***60***	***65***	***70***	***75***	***80***	***85***	***90***	***95***
MEAN	261134	261134	261134	256936	252388	233378	197709	171642	149043	128531
OBJ	261134	236162	211190	186488	162464	138027	118648	103889	90318	76792
MAXPROF	396726	396726	396726	387931	379645	348407	289790	246954	214836	191578
MINPROF	3735	3735	3735	8336	13512	15775	20020	23122	25811	28252
VAR	9224776074	9224776074	9224776074	8674605056	8147913099	6733894670	4466736964	3128577313	2186152123	1505853522
STD	96046	96046	96046	93138	90266	82060	66834	55934	46756	38805
CV	37	37	37	36	36	35	34	33	31	30
Precision Agriculture										
	Risk Aversion Level									
Statistics	***50***	***55***	***60***	***65***	***70***	***75***	***80***	***85***	***90***	***95***
MEAN	254694	254131	250777	243516	242896	203330	176987	155518	139834	124943
OBJ	254694	225756	198201	172818	147441	126024	109970	97389	85597	71875
MAXPROF	405933	402624	392749	375397	374285	303371	256850	228746	210299	191776
MINPROF	-27189	-22954	-14523	-5253	-5083	5749	12568	17761	21554	23204
VAR	10771358933	10481989094	9710892845	8705395646	8649079361	5459518029	3786308184	2684147672	2019056035	1544550920
STD	103785	102382	98544	93303	93000	73889	61533	51809	44934	39301
CV	41	40	39	38	38	36	35	33	32	31
All Combinations										
	Risk Aversion Level									
Statistics	***50***	***55***	***60***	***65***	***70***	***75***	***80***	***85***	***90***	***95***
MEAN	265008	265008	261271	259392	252519	242334	205889	179255	156164	134943
OBJ	265008	238486	214189	190733	167762	144059	124046	108728	94550	80249
MAXPROF	413719	413719	396977	392842	379780	362559	300936	255903	227594	202964
MINPROF	-12319	-12319	3671	5681	13503	14751	19218	22482	25312	27795
VAR	10405564593	10405564593	9235966087	8979172299	8156461968	7371198443	4910927241	3458780773	2436078146	1690674910
STD	102008	102008	96104	94758	90313	85856	70078	58811	49357	41118
CV	38	38	37	37	36	35	34	33	32	30

Table 2. Management Practices in acre

Whole Field Farming													
				Risk Aversion Level									
Acres*			***Mgt****	***50***	***55***	***60***	***65***	***70***	***75***	***80***	***85***	***90***	***95***
soy_PA			DRY	235	235	405	675	675	675	675	675	675	675
soy_PA			IRR	440	440	270							
corn_PA			IRR	675	675	675	675	672	475	346	244	170	117
Precision Agriculture				***Risk Aversion Level***									
Acres*	**prod.**	**soil**	***Mgt****	***50***	***55***	***60***	***65***	***70***	***75***	***80***	***85***	***90***	***95***
soy_PA	DRY	Memphis	LOW			170	170	170	170	170	170	170	170
soy_PA	DRY	Loring	LOW				270	270	270	270	270	270	270
soy_PA	DRY	Grenada	LOW	235	235	235	235	235	235	235	235	235	235
soy_PA	IRR	Memphis	LOW	170	170								
soy_PA	IRR	Loring	LOW	270	270	270							
corn_PA	IRR	Memphis	HIGH	170	170	170	170	170	170	170	170	170	117
corn_PA	IRR	Loring	MED		270	270	270	267	69.8				
corn_PA	IRR	Loring	HIGH	270									
corn_PA	IRR	Grenada	MED	235	235	235	235	235	235	176	74.5		
All Combinations				***Risk Aversion Level***									
Acres			***Mgt****	***50***	***55***	***60***	***65***	***70***	***75***	***80***	***85***	***90***	***95***
soy_WF			DRY	157	157	664	675	675	675	675	675	675	675
soy_PA			DRY	172	172								
soy_PA			IRR	338	338	3							
corn_WF			IRR	675	675	675	664	664	602	376	212	69	

* soy_PA = number of acres produced under PA technology

* corn_ = number of acres produced under uniform rate application (whole field) management

** Dry = production under a dry land system

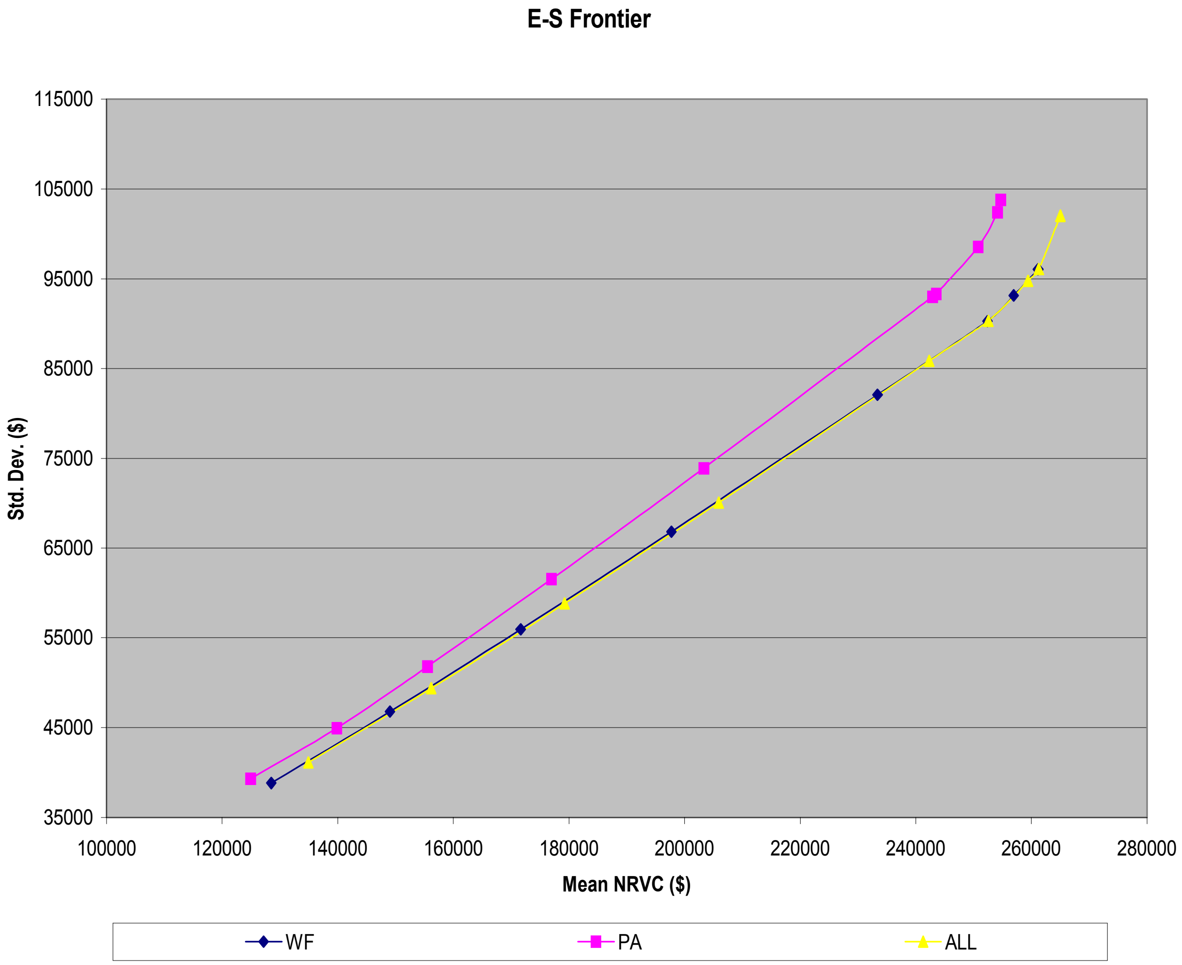
** Irr = production under an irrigated land system

Table 3. Average Yield in bu/acre

Whole Field Farming		***Risk Aversion Level***										
Yield	***Management***	***50***	***55***	***60***	***65***	***70***	***75***	***80***	***85***	***90***	***95***	**MEAN (BU/AC)**
soy_yld_PA	DRY	47	47	43	37	37	37	37	37	37	37	**39**
soy_yld_PA	IRR	47	47	43	37	37	37	37	37	37	37	**39**
crn_yld_PA	DRY	211	208	207	207	208	212	217	225	235	235	**217**
crn_yld_PA	IRR	211	208	207	207	208	212	217	225	235	235	**217**
Precision Agriculture		***Risk Aversion Level***										
Yield	***Management***	***50***	***55***	***60***	***65***	***70***	***75***	***80***	***85***	***90***	***95***	**MEAN (BU/AC)**
soy_yld_WF	DRY	37	37	37	37	37	37	37	37	37	37	**37**
soy_yld_WF	IRR	37	37	37	37	37	37	37	37	37	37	**37**
crn_yld_WF	DRY	213	213	213	208	201	201	201	201	201	201	**205**
crn_yld_WF	IRR	213	213	213	208	201	201	201	201	201	201	**205**
All Combinations		***Risk Aversion Level***										
Yield	***Management***	***50***	***55***	***60***	***65***	***70***	***75***	***80***	***85***	***90***	***95***	**MEAN (BU/AC)**
soy_yld_WF	DRY	37	37	37	37	37	37	37	37	37	37	**37**
soy_yld_WF	IRR	37	37	37	37	37	37	37	37	37	37	**37**
crn_yld_WF	DRY	213	213	213	211	201	201	201	201	201		**206**
crn_yld_WF	IRR	213	213	213	211	201	201	201	201	201		**206**
soy_yld_PA	DRY	47	47	58								**51**
soy_yld_PA	IRR	47	47	58								**51**
crn_yld_PA	DRY				235	235	235	235	235	235	235	**235**
crn_yld_PA	IRR				235	235	235	235	235	235	235	**235**

Table 4. Results in percentage of acres prodeced.

Precision Agriculture											
Risk Aversion Level	Soil	***50***	***55***	***60***	***65***	***70***	***75***	***80***	***85***	***90***	***95***
soy_PA	Memphis	25	25	25	25	25	25	25	25	25	25
soy_PA	Loring	40	40	40	40	40	40	40	40	40	40
soy_PA	Grenada	35	35	35	35	35	35	35	35	35	35
soy_PA	LOW	100	100	100	100	100	100	100	100	100	100
soy_PA	early	100	100	100	100	100	100	100	100	100	100
corn_PA	Memphis	25	25	25	25	25	36	49	70	100	100
corn_PA	Loring	40	40	40	40	40	15				
corn_PA	Grenada	35	35	35	35	35	49	51	30		
corn_PA	MED	35	75	75	75	75	64	51	30		
corn_PA	HIGH	65	25	25	25	25	36	49	70	100	100
corn_PA	early	65	60	100	100	100	100	100	100	100	100
corn_PA	norm	35	40								
Whole Field Farming											
Risk Aversion Level		***50***	***55***	***60***	***65***	***70***	***75***	***80***	***85***	***90***	***95***
soy_WF	LOW	100	100	100	100	100	100	100	100	100	100
soy_WF	early	100	100	100	100	100	100	100	100	100	100
corn_WF	MED				43	100	100	100	100	100	100
corn_WF	HIGH	100	100	100	57						
corn_WF	early	100	100	100	100	100	100	100	100	100	100
All Combinations											
Risk Aversion Level		***50***	***55***	***60***	***65***	***70***	***75***	***80***	***85***	***90***	***95***
soy_WF	LOW	100	100	100	100	100	100	100	100	100	100
soy_WF	early	100	100	100	100	100	100	100	100	100	100
soy_PA	Memphis	26	26	100							
soy_PA	Loring	41	41								
soy_PA	Grenada	34	34								
soy_PA	LOW	100	100	100							
soy_PA	early	100	100	100							
corn_WF	MED				13	100	100	100	100	100	
corn_WF	HIGH	100	100	100	87						
corn_WF	early	100	100	100	100	100	100	100	100	100	
corn_PA	Memphis				100	100	100	100	100	100	100
corn_PA	HIGH				100	100	100	100	100	100	100


E-S Frontier
115000
105000
95000
85000
75000
65000
55000
45000
35000
Std. Dev. ($)
100000
120000
140000
160000
180000
200000
220000
240000
260000
280000
Mean NRVC ($)
WF
PA
ALL