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

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Abstract

One of the main advantages of precision agriculture (PA) is its potential to increase profitability by optimizing the productivity of each section of the field. Incorporating irrigation practices to the PA technology could further increase profitability. However, investing in a complete set of precision agriculture (PA) and/or irrigation equipment represents for the average Kentuckian grain producer a substantial investment that can have a significant impact on the financial risk the he/she faces. An analysis of the consequences of that investment on the farm's cash flow and debt to asset ratio is investigated here.

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.

One other mean to respond to the new challenges faced by producers is the continuous adoption of new and more efficient technologies. 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. A comprehensive literature review on the profitability of PA by Lambert and Lowenberg-DeBoer (2000) shows that 73% of the studies reported found that PA was more profitable than conventional production methods. In addition, PA also has the potential of being more environmental friendly that the conventional production methods.

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 to alleviate one of the biggest concern about the financial risk related to the investment in new technologies is to demonstrate that the investment will not threaten the farm's financial stability.

In effect, cost of adoption and unwillingness to accept greater financial risk rank high among the reasons for non-adoption. Daberkow and McBride found that adopters of PA technology have a significantly higher debt-to-asset ratio, which indicates a willingness to accept greater financial risk. Yet, debt-to-asset ratio alone does not reflect the overall financial risk the farmer is taking while making the investments. Liquidity risk also represents a key component of the financial risk as it measures the producer's ability to meet his/her financial obligations after the investment is made. Ultimately, one of the main concern often expressed by producers is the financial viability of the farm over time. Therefore, consideration of time in the decision-making process becomes a key element. Because the subsurface drip irrigation (SSDI) system is being increasingly successful in Kentucky compared to PA, it was found important to include both technologies in the analysis. In this study, the financial impact of an investment in PA technology and/or irrigation system on risk taking behavior, profitability and production decisions will be evaluated and compared to each other in a multi-period mathematical programming model.

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 and soybean. He/she can choose to either use precision agriculture technology (variable rate application of fertilizer), or irrigation practice. The current study relies upon the discrete stochastic sequential programming (DSSP) model in an expected value variance (E-V) utility framework. This analytical framework is also often described as DSSP/EV model (Apland and Kaiser). The model specification is omitted for the purpose of space but is available upon request.

The choice of the DSSP model was motivated by the need to model a multi-stage (or multi-period) sequential financial decisions. In this type of model, decisions in a later stage is "influenced not only by the occurrence of particular random events in that stage, but also by random outcomes and decisions made in earlier stages" (Apland and Kaiser). In this model, three stages (or period) (N1, N2 and N3) are defined and each period contains ten states of nature represented by ten years (n1 to n10) of expected yield.

The objective function in is modeled using the expected value variance (E-V) analytical framework. The E-V technique used here is known as 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. In this model, the objective function is to maximize ending total net worth in period 3. The model is defined as follow:

<u>Objective functions:</u>

$$\text{Max } \overline{NW3} - \Phi \sigma^2_{NW}$$

Subject to constraints:

(1) $\sum_{E} \sum_{P} \sum_{F} \sum_{D} \text{ACRES}_{EPFDS} + \text{POND}_{S} \leq \text{ACRELIM}_{S} \qquad \forall S$

(2) $$\sum_{S}\sum_{P}\sum_{F}\sum_{D} YLD_{E\,Ni\,D\,S\,P\,F} * ACRES_{D\,S\,P\,F} - SALES_{Ni,\,E} = 0 \quad \forall\, C, N_{i = 1 \text{ to } 3}$$

(3) $$\sum_{D}\sum_{F}\sum_{S}\sum_{P}\sum_{E} IREQ_{I\,F\,P\,D} * ACRES_{E\,F\,D\,P\,S} - IPURCH_{I} = 0 \quad \forall\, I$$

(4) $$(W\_REQ)^* \sum_{D}\sum_{F}\sum_{S}\sum_{P}\sum_{E} ACRES_{E\,D\,S\,P\,F} - W\_AVAL^* \sum_{S} POND_{S} \leq 0 \quad \forall\, IRR$$

(5) $$\sum_{P}\sum_{E} P_{E} * SALES_{E\,Ni} - \sum_{I} IP_{I}\, IPURCH_{I} - Y_{Ni} = 0 \;\forall\, N_{i = 1 \text{ to } 3}$$

(6a) $$ACRELIM_{S'} * ACRES_{D\,E\,F\,S\,P} - ACRELIM_{S} * ACRE_{D\,E\,F\,S'\,P} = 0 \quad \forall\, P, F, D, S \neq S'$$

(6b) $$ACRELIM_{S'} * \sum_{F} ACRES_{D\,E\,F\,S\,P} - ACRELIM_{S} * \sum_{F} ACRE_{D\,E\,F\,S'\,P} = 0 \quad \forall\, P, F, D, S \neq S'$$

(7) $$\sum_{N} (1/N1*N2*N3)\, Y_{N1\,N2\,N3} - \overline{NW3} = 0$$

(8) NW1 = EASSET1 - EDEBT1 ∀ N1

(9) EASSET1 = basset + CBAL1 - bcbal - DEP1 + invk_pa*BUY_PA + invk_ir*BUY_IR ∀ N1

(10) EDEBT1 = bdebt + invk_pa*BUY_PA + invk_ir*BUY_IR - KPAID1 ∀ N1

(11) CBAL1 = PROFIT1 + bcbal - KPAID1 - (lr_int*(bdebt + invk_ir*BUY_IR + invk_pa*BUY_PA)) - sr_int*BOR1 ∀ N1

(12) BOR1 = invk_ir*BUY_IR + invk_pa*BUY_PA + $\sum_{I} IP_{I}\, IPURCH_{I}$ + min_cash – BCBAL ∀ N1

(13) KPAID1 = (bdebt/lbdebt) + ((invk_ir/lirr)*BUY_IR) + ((invk_pa/lpa)*BUY_PA) ∀ N1

(14) DEP1 = ((invk_pa/ulife_pa)*BUY_PA) + ((invk_ir/ulife_irr)*BUY_IR) ∀ N1

(15) NW2 = EASSET2(N1,N2) - EDEBT2(N1,N2) ∀ N1, N2

(16) EASSET2 = EASSET1 + CBAL2 - CBAL1 - DEP2 ∀ N1, N2

(17) EDEBT2 = EDEBT1 - KPAID2 ∀ N1, N2

(18) CBAL2 = CBAL1 - KPAID2 - lr_int*EDEBT2 – sr_int*BOR2 + PROFIT2 ∀ N1, N2

(19) BOR2 = $\sum_{I} IP_{I}\, IPURCH_{I}$ - CBAL1 + min_cash - BOR2 ∀ N1, N2

(20) KPAID2 = (bdebt/lbdebt) + ((invk_ir/lirr)*BUY_IR) + ((invk_pa/lpa)*BUY_PA) $\forall$ N1, N2

(21) DEP2 = ((invk_pa/ulife_pa)*BUY_PA) + ((invk_ir/ulife_irr)*BUY_IR) $\forall$ N1, N2

(22) NW3 = EASSET3 - EDEBT3 $\forall$ N1, N2, N3

(23) EASSET3) =EASSET2 + CBAL3 - CBAL2 - DEP3 $\forall$ N1, N2, N3

(24) EDEBT3 = EDEBT2 - KPAID3 $\forall$ N1, N2N3

(25) CBAL3 = CBAL2 - KPAID3 - lr_int*EDEBT3 – sr_int*BOR3 + PROFIT3 $\forall$ N1, N2, N3

(26) BOR3 = $\sum_I$ IP_I $IPURCH_I$)) - CBAL2 + min_cash $\forall$ N1, N2, N3

(27) KPAI3 = (bdebt/lbdebt) + ((invk_ir/lirr)*BUY_IR) + ((invk_pa/lpa)*BUY_PA) $\forall$ N1, N2, N3

(28) DEP3 = ((invk_pa/ulife_pa)*BUY_PA) + ((invk_ir/ulife_irr)*BUY_IR) $\forall$ N1, N2, N3

where constraints include

(1) land resource availability

(2) sales balance for periods 1 to 3 by year and by crop

(3) input purchase balance by input

(4) water resource availability by irrigation level

(5) annual profit balance year in period 1, 2 and 3

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

(7) expected ending net worth balance

(8), (15), (22) net worth respectively for periods 1, 2 and 3 by year

(9), (16), (23) ending asset respectively for periods 1, 2 and 3 by year

(10), (17), (24) ending debt respectively for periods 1, 2 and 3 by year

(11, (18), (25) cash balance respectively for periods 1, 2 and 3 by year

(12), (19), (26) total investment capital borrowed respectively for periods 1, 2 and 3 by year

(13), (20), (27) principal paid on investment capital borrowed respectively for periods 1, 2 and 3 by year

(14), (21), (28) total investment depreciation respectively for periods 1, 2 and 3 by year

indices include:

E represents the different enterprises or crops (corn 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

Ni number of years; N1 = N2 = N3 = 10

activities include:

$\overline{NW3}$ is the average (across years) expected net worth in ending period 3;

Y_{Ni} is the expected net returns above variable cost (across years) for period i

$ACRES_{E\,D\,S\,P\,F}$ 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_{NDSPF}	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);
$IREQ_{IFPMSP}$	is the input I required per plant population P (in unit per acre)
M	is a scalar = 10000

Accounting variables include:

NW1, NW2, NW3	net worth respectively for periods 1, 2 and 3
EASSET1, EASSET2, EASSET2	ending assets respectively for periods 1, 2 and 3
EDEBT1, EDEBT2, EDEBT3	ending debt respectively for periods 1, 2 and 3
CBAL1, CBAL2, CBAL3	cash balance respectively for periods 1, 2 and 3
BOR1, BOR2, BOR3	capital borrowed respectively for periods 1, 2 and 3
KPAID1, KPAID2, KPAID3	debt principal payment respectively for periods 1, 2 and 3
DEP1, DEP2, DEP3	total depreciation respectively for periods 1, 2 and 3

Scalars include:

basset	is the beginning asset value and is set at $1,525,000
bdebt	is the beginning debt value and is set at $499,000
bcbal	is the beginning cash balance value at $129,254

invk_pa	is the total capital amount invested in precision agriculture equipment ($31,535)
invk_ir	is the per acre capital amount invested in irrigation equipment ($569)
lr_int	is the long term interest rate for investment capital borrow (8%)
sr_int	is the term operating capital borrow and entirely reimbursed at the end of the year (6.5%)
lbdebt	is the repayment period of the beginning debt (20 years)
lpa	is the repayment period of the precision agriculture equipment (5 years)
lirr	is the repayment period of the irrigation equipment (10 years)
ulife_pa	is the useful life of the precision agriculture equipment (8 years)
ulife_irr	is the useful life of the irrigation equipment (20 years)

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, (6) land available for production and (7) accounting data.

(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 and single cropped soybean 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 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. 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

<u>(3) Irrigation data</u>

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. 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 and soybean) 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

Commodity prices are respectively $5.86 for soybean and $2.38 for corn. The commodity price data is the average seasonal commodity prices for the state of Kentucky. Price included in the model represents the five years average seasonal prices from 1997 to 2001 (Kentucky Agricultural Statistics 1997-2001). These prices also included hauling cost.

(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.

(7) accounting data

Beginning debt and asset, cash balance, minimum cash requirement values were obtained from the 1999 annual financial survey developed by the University of Kentucky cooperative extension service.

Results and Conclusion.

Because the current paper primarily concentrates on the definition and description of the model used, the results presented in the following three tables will only be briefly summarized. This deliberate choice was motivated by the space limitation but also by the early stage of the model development, and the subsequent preliminary results presented.

To analyze the impact of PA and/or irrigation equipment purchase on the farm financial situation, three scenario were analyzed. In the first scenario, the farmer is "forced" to invest in PA equipment without the option to irrigate. In the second scenario, he/she has to invest in irrigation technology but not in PA. Finally, in the last scenario, the producer invests in both technologies. The results show that the producer's net worth is the highest in the third scenario and lowest in the first on. Investment in PA, irrigation and PA and irrigation respectively yields a mean profit of $146,743, $157,743 and $240,134. This result implies that the more the producer invest in more productive technologies, the higher is his/her

On the debt level, the more the farmer invests, the higher is the debt level. However, given that investment in new technologies happens to be profitable, the debt to asset ratio actually tends to decrease from period to period in all scenario. Furthermore, the debt to asset ratio is at its lowest when the farmer invest simultaneously in PA and irrigation technology. Risk averse farmers tend to have a higher debt to asset ratio compared to risk neutral farmers given that their expected mean profit is lower for the same level of investment and debt cause by the investments.

On the production side, the production strategy remains identical for all risk level in the PA investment case. However, in the irrigation scenario, the level of irrigated acreage increases with the risk aversion level; the higher risk averse producer, will tend to irrigate an increasing portion of hi/her land.

Though much need to be done to improve this model, it appease according to these preliminary results that investment in PA and/or irrigation tends to improve the farm's financial situation.

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Table1. Investment in PA equipment only.

Precision Agriculture, no irrigation

	Risk Aversion Levels				
	1	**2**	**3**	**4**	**5**
Objective function					
Ending net worth in period 3	$1,358,641	$1,350,625	$1,342,038	$1,337,624.81	$1,333,778
Coefficient of variation	0.0251	0.0191	0.0161	0.0151	0.0145
Standard deviation	$34,055.85	$25,854.50	$21,570.16	$20,191.31	$19,390.72
Mean net worth in period 1	$1,131,849	$1,131,335	$1,131,096	$1,131,005.03	$1,130,942
Mean net worth in period 2	$1,244,229	$1,243,201	$1,239,840	$1,237,503.91	$1,235,720
Mean profit across periods	$146,743	$146,229	$145,989	$145,898.54	$145,835
Accounting variables					
Beginning cash balance	$129,254	$129,254	$129,254	$129,254	$129,254
Ending cash balance in period 1	$207,788	$207,274	$207,034	$206,943.90	$206,880
Ending cash balance in period 2	$292,853	$291,825	$288,463	$286,127.66	$284,344
Ending cash balance in period 3	$379,949	$371,934	$363,346	$358,933.44	$355,087
Beginning debt	$499,000	$499,000	$499,000	$499,000.00	$499,000
Ending debt in period 1	$499,278	$499,278	$499,278	$499,278.00	$499,278
Ending debt in period 2	$468,021	$468,021	$468,021	$468,021.00	$468,021
Ending debt in period 3	$436,764	$436,764	$436,764	$436,764.00	$436,764
Beginning asset	$1,525,000	$1,525,000	$1,525,000	$1,525,000.00	$1,525,000
Ending assets in period 1	$1,631,127	$1,630,613	$1,630,374	$1,630,283.03	$1,630,220
Ending assets in period 2	$1,712,250	$1,711,222	$1,707,861	$1,705,524.91	$1,703,741
Ending assets in period 3	$1,795,405	$1,787,389	$1,778,802	$1,774,388.81	$1,770,542
Beginning debt to asset ratio	0.3272	0.3272	0.3272	0.3272	0.3272
Debt-to-Asset Ratio in period 1	0.3061	0.3062	0.3062	0.3063	0.3063
Debt-to-Asset Ratio in period 2	0.2733	0.2735	0.2740	0.2744	0.2747
Debt-to-Asset Ratio in period 3	0.2433	0.2444	0.2455	0.2461	0.2467
Production Strategies (acres)					
Soybean on Memphis soil	170	170	170	170	170
Soybean on Loring soil	270	270	270	270	270
Soybean on Grenada soil	235	235	235	235	235
Corn on Memphis soil	170	170	170	170	170
Corn on Loring soil	270	270	270	270	270
Corn on Grenada soil	235	235	235	235	235

Table 2. **Investment in PA and irrigation equipment**

Precision Agriculture and irrigation

	Risk Aversion Levels				
	1	2	3	4	5
Objective function					
Ending net worth in period 3	$1,634,077	$1,629,208	$1,621,943	$1,612,517	$1,605,560
Coefficient of variation	0.0194	0.0150	0.0131	0.0114	0.0105
Standard deviation	$31,685	$24,497	$21,189	$18,339	$16,795
Mean net worth in period 1	$1,220,503	$1,219,598	$1,219,598	$1,219,300	$1,219,201
Mean net worth in period 2	$1,426,274	$1,424,203	$1,424,203	$1,423,608	$1,423,409
Mean profit across periods	$240,134	$238,968	$238,968	$238,671	$238,571
Accounting variables					
Beginning cash balance	$129,254	$129,254	$129,254	$129,254	$129,254
Ending cash balance in period 1	$296,442	$295,537	$295,537	$295,239	$295,140
Ending cash balance in period 2	$474,898	$472,827	$472,827	$472,232	$472,033
Ending cash balance in period 3	$655,385	$650,517	$643,252	$633,825	$626,869
Beginning debt	$499,000	$499,000	$499,000	$499,000	$499,000
Ending debt in period 1	$499,278	$499,278	$499,278	$499,278	$499,278
Ending debt in period 2	$468,021	$468,021	$468,021	$468,021	$468,021
Ending debt in period 3	$436,764	$436,764	$436,764	$436,764	$436,764
Beginning asset	$1,525,000	$1,525,000	$1,525,000	$1,525,000	$1,525,000
Ending assets in period 1	$1,719,781	$1,718,876	$1,718,876	$1,718,578	$1,718,479
Ending assets in period 2	$1,894,295	$1,892,224	$1,892,224	$1,891,629	$1,891,430
Ending assets in period 3	$2,070,841	$2,065,972	$2,058,707	$2,049,281	$2,042,324
Beginning debt to asset ratio	0.3272	0.3272	0.3272	0.3272	0.3272
Debt-to-Asset Ratio in period 1	0.2903	0.2905	0.2905	0.2905	0.2905
Debt-to-Asset Ratio in period 2	0.2471	0.2473	0.2473	0.2474	0.2474
Debt-to-Asset Ratio in period 3	0.2109	0.2114	0.2122	0.2131	0.2139
Production Strategies (acres)					
Soybean on dry Grenada soil	228.40	228.40	228.40	228.40	228.40
Soybean on irrigated Memphis soil	170.00	170.00	170.00	170.00	170.00
Soybean on irrigated Loring soil	270.00	270.00	270.00	270.00	270.00
Corn on irrigated Memphis soil	170.00	170.00	170.00	170.00	170.00
Corn on irrgated Loring soil		270.00	270.00	270.00	270.00
Corn on irrgated Loring soil	270.00				
Corn on irrigated Grenada soil	228.40	228.40	228.40	228.40	228.40

Table 3. **Investment in irrigation equipment only**

Irrigation, no Precision Agriculture

	Risk Aversion Levels				
	1	2	3	4	5
Objective function					
Ending net worth in period 3	$1,408,045	$1,399,599	$1,387,622	$1,381,538	$1,377,153
Coefficient of variation	0.0236	0.0183	0.0142	0.0128	0.0121
Standard deviation	$33,283	$25,557	$19,746	$17,671	$16,634
Mean net worth in period 1	$1,150,567	$1,145,784	$1,136,827	$1,131,887	$1,128,819
Mean net worth in period 2	$1,278,472	$1,274,908	$1,264,393	$1,258,447	$1,254,983
Mean profit across periods	$157,835	$165,389	$176,784	$183,630	$187,884
Accounting variables					
Beginning cash balance	$129,254	$129,254	$129,254	$129,254	$129,254
Ending cash balance in period 1	$228,509	$220,621	$206,541	$198,635	$193,724
Ending cash balance in period 2	$331,101	$321,327	$300,567	$288,689	$281,538
Ending cash balance in period 3	$435,363	$417,601	$390,256	$375,273	$365,358
Beginning debt	$499,000	$499,000	$499,000	$499,000	$499,000
Ending debt in period 1	$480,569	$536,461	$628,669	$682,065	$715,240
Ending debt in period 2	$454,895	$504,576	$586,539	$634,002	$663,491
Ending debt in period 3	$429,220	$472,692	$544,409	$585,939	$611,742
Beginning asset	$1,525,000	$1,525,000	$1,525,000	$1,525,000	$1,525,000
Ending assets in period 1	$1,631,136	$1,682,245	$1,765,496	$1,813,952	$1,844,059
Ending assets in period 2	$1,733,366	$1,779,484	$1,850,932	$1,892,449	$1,918,474
Ending assets in period 3	$1,837,265	$1,872,290	$1,932,031	$1,967,477	$1,988,895
Beginning debt to asset ratio	0.3272	0.3272	0.3272	0.3272	0.3272
Debt-to-Asset Ratio in period 1	0.2946	0.3189	0.3561	0.3760	0.3879
Debt-to-Asset Ratio in period 2	0.2624	0.2836	0.3169	0.3350	0.3458
Debt-to-Asset Ratio in period 3	0.2336	0.2525	0.2818	0.2978	0.3076
Production Strategies (acres)					
Soybean on dry Memphis soil	169.99	169.91	169.77	169.70	169.65
Soybean on dry Loring soil	269.98	269.85	269.64	269.52	269.44
Soybean on dry Grenada soil	234.99	234.87	234.69	234.58	234.51
Corn on dry Memphis soil	168.39	154.56	131.75	118.54	110.34
Corn on dry Loring soil	267.44	245.48	209.25	188.28	175.24
Corn on dry Grenada soil	232.77	213.66	182.13	163.87	152.53
Corn on irrigated Memphis soil	1.60	15.35	38.02	51.15	59.31
Corn on irrgated Loring soil	2.55	24.37	60.39	81.24	94.20
Corn on irrigated Grenada soil	2.22	21.21	52.56	70.71	81.99