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Production Practice Alternatives for Income and Suitable Field Day Risk Management

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ABSTRACT

Production risk includes yield and days suitable for fieldwork variability. Both were modeled using biophysical simulation and a mean-variance, chance-constrained mathematical programming formulation representing a Kentucky corn, soybean, and wheat producer. While crop diversification, planting date, and maturity group can be used to reduce the types of risk considered, interaction between the two influences how production practices are used to manage risk. For the conditions studied, plant population alterations were less effective for risk reduction of either component. The study provides evidence of the importance of the consideration of both elements of production risk in whole farm planning.

Key Words: days suitable for fieldwork, mathematical programming, risk management.

While it has long been established that agricultural producers face a very risky decision-making environment (e.g. Anderson, Dillon, and Hardaker; Hardaker, Huirne, and Anderson; Robison and Barry), the current political and technological environment focuses attention on the need for evaluating and managing agricultural risk. For example, declining government price supports and payments from the FAIR (Federal Agricultural Improvement Reform) Act impact many areas of risk management other than marketing risk alone. Furthermore, the enhanced flexibility of alterations of enterprise mix under the FAIR Act has implications for production management. The increasingly global market structure and heightened competition for agricultural products leads to alterations in output price ratios and greater price volatility which in turn impacts profit maximizing enterprise mix solutions, production practices, and optimal levels of use for production factors. Heightened awareness of weather variability and alterations and tillage techniques in turn expand production risk management beyond the focus solely of yield variability into other areas of production risk consideration such as the uncertainty of days suitable for fieldwork. Additionally, there are numerous means of managing production risk beyond the consideration of enterprise mix alone. Alternative production practices such as planting date and maturity class of cultivar can be used to manage not only yield risk but also to spread out labor requirements in order to address the issue of uncertainty in days suitable for fieldwork.

In light of this multifaceted and complicated arena of risk management, the objectives of this paper are twofold. First, the study aims to provide insight into the use of alternative production practices for risk management associated with yield variability and variability of

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days suitable for fieldwork for a hypothetical Kentucky grain farmer. Second, the study hopes to increase recognition of the potential for alternative production practices (e.g. variety selection, planting date, and row spacing) and management techniques (e.g. site-specific technologies) as economically viable mechanisms for the reduction of various kinds of production risk beyond the standard management consideration of enterprise mix selection. Essential to both of these issues is the awareness of including a plethora of individual components within the major categories of risk (e.g. production risk incorporates much more than just yield variability) and recognition of the importance of evaluation of the interactions between these various sources of risk within and across different categories of sources of risk (i.e. production, marketing, financial, human resource, and institutional).

The study area incorporates the different crops, time periods, and locations analyzed. Corn, soybean, and wheat production are included. Corn, soybean, and wheat are important crops to Kentucky's economy, ranking third, fourth, and fifth, respectively, with $446, $333, and $122 million of total value product for 1997, respectively (Kentucky Agricultural Statistics 1997–1998). Together they make up about 35 percent of the total crop value for 1997. Henderson County—the fifth of 120 counties in overall and crop cash receipts for 1997—was selected as the geographical location for the study. Furthermore, it was the lead county in these categories for Crop Reporting District 2 which represents a primary row crop producing region of the state. In 1997, Henderson ranked second, fourth, and tenth overall among Kentucky counties for soybean, corn, and wheat production, respectively. Historical weather patterns for 1978 through 1998 were incorporated into the analysis. Consequently, a case analysis of a hypothetical crop producer in Kentucky was adopted for this study.

The sections that follow give the background information to establish a framework of study. The analytical procedure is then presented, after which the results are discussed. Finally, the summary and conclusions of the study will be presented.

Background Information

This background information is provided to partially fulfill the objective of heightened awareness of various aspects of sources of risk and opportunities for risk management. It also helps lay a foundation before the development of the model in the analytical procedure. Discussion focuses upon the three areas of risk, days suitable for fieldwork, and mathematical programming of random resource levels.

Risk

The importance of the consideration of risk in the decision-making process in agriculture has been well established (e.g. Anderson, Dillon, and Hardaker; Hardaker, Huirne, and Anderson; Robison and Barry). Additionally, risk has been categorized into many types and sources: production, price or market, institutional, human or personal, and financial (Hardaker, Hurine, and Anderson). Financial risk has been separated from the aggregate effect of the first four categories into what is known as *business risk.* An agricultural producer's decision-making process in a risky environment is complicated by the interactions between the different sources of risk. Additionally, there are many individual causes and types of risk within each of these major categories, as well as multitudes of opportunities for managing these individual types of risk. Consequently, these issues will be briefly examined.

The interaction among the various sources of risk influences the overall exposure to risk as well as the means by which risk is managed. For example, the negative correlation between crop price and yield lessens the variability of gross revenue and demonstrates the overstatement of total risk exposure possible when including only one element for an agricultural producer. Also, diversification across different enterprises is a mechanism for potentially reducing impacts of production risk as well as market risk. The interaction of market risk reduction through hedging and production risk, as well as attitude toward risk, has been analyzed (Lapan and Moschini) as has the potential of weed management under price and yield risk (Pannell). Other price-and-yield risk interaction economic analyses have focused on enterprise mix (Olson *et al.*, Weisensel and Schoney). Research which has combined financial risk in addition to yield risk has often focused on irrigation investment (Vandeveer, Paxton, and Lavergne; Boggess and Amerling). Some studies have focused on interaction of production, financial, and marketing risk with the conclusion that for highly leverage operations, financial risk may be substantial (Wilson and Gundersen).

Production risk is often associated with yield risk resulting from changes in weather patterns. Fluctuations in crop or livestock yields can result from a host of different factors such as alterations in or damage from weather conditions, weeds, insects, disease, soil fertility or feed conversion. However, there are types of production risks beyond that of yield risk. For example, variations in weather not only impact yield but also influence the number of days suitable for fieldwork and therefore affect resource levels. Irrigation requirements are variable and not known with certainty. Consequently, examples of production risk extending into random levels of resource availability, input requirement levels, and quality of factors of production can be found. Closely akin to this issue is the ability to manage production risk through a wide range of alternatives beyond diversification of enterprise mix. While several examples of crop mix as a means of reducing risk can be found (e.g. Dillon, Mjelde, and McCarl; Misra and Spurlock; Teague and Lee; Apland, Barnes, and Justus) a wide variety of production practices for risk reduction have been researched: planting date (e.g. Larson *et al.*; Larson and Mapp; Dillon, Mjelde, and McCarl), variety selection (e.g. Traxler *et al.*, Dillon, Grisley), plant population (e.g. Larson *et al.*; Sweeney, Granade, and Burton; Polito and Voss), irrigation (e.g. Boggess and Ritchie, Boggess and Amerling, Harris and Mapp), pest management (e.g. Hurd; Szmedra, Wetzstein, and McClendon), tillage technique (e.g. Epplin and Al-Sakkaf, Krause and Black, Williams *et al.*), nutrient management (e.g. Mjelde *et al.*, Pingali *et al.*), weed management (e.g. Donald and Prato, Olson and Eidman, Zacharias and Grube) and stubble management (e.g. Oriade, Dillon, and Keisling).

Days Suitable for Fieldwork

The importance of the prediction of days suitable for fieldwork has been recognized in several studies in the early 1980s (e.g. Acharya, Hayes, and Brown; Babeir, Colvin, and Marley; Elliot, Lembke, and Hunt; Whitson, *et al.*). The models developed often used soil moisture content in conjunction with precipitation to predict the suitability of performing fieldwork on a given day. Further development of such models continues with further refinements and application to different areas (e.g. Harrigan, Bickert, and Rozt; Simalenga and Have; Rosenberg, *et al.*; Spurlock, Buehring, and Caillavet).

While economic analyses involving suitable field time constraints and the risky environment of a whole farm planting model have been limited, two studies have been conducted in recent years. Misra and Spurlock used a Target MOTAD model for analyzing the fluctuations across years of both yield and lint price of cotton while incorporating changes in available suitable fieldwork time across periods and years. They used GOSSYM/COMAX under varied planting dates, varieties, and nitrogen fertilizer rates in determining the importance of including suitable fieldwork risk considerations in whole farm planning and the potential of a combination of alternative management practices for risk reduction. Etyang *et al.* conducted an economic assessment of modeling random resources of suitable field time under both discrete stochastic programming and chance constrained linear programming. A focus on a hypothetical Indiana corn and soybean farm with both conventional till and no-till conditions reveals that it is essential to investigate closely the development of the decision rules for estimating suitable fieldwork time resources.

Mathematical Programming of Risk

The incorporation of risk into mathematical programming, while multifaceted, has been discussed (Hardaker, Huirne, and Anderson; Boisvert and McCarl). For the problem at hand, however, the issue of appropriately modeling risk associated with the right-hand side is the issue of relevance. One mechanism for modeling right-hand side uncertainty is stochastic programming with recourse to the discrete stochastic programming procedure developed by Cocks. While widely used (e.g. Rae, Apland and Kaiser, Leatham and Baker, Etyang *et al.*) the models become extremely large when incorporating numerous random variables, thereby complicating the modeling procedure (Etyang *et al.*, Misra and Spurlock). While Paris (1979) has developed a technique for the modeling of right-hand side risk in a mathematical programming formulation, questions of the implications of duality have been debated (Dubman, Gunter, and Miller; Paris, 1989). The chance-constrained formulation developed by Charnes and Cooper is a fairly well-known technique which has been used in some studies (e.g. Boisvert and Jensen; Danok, McCarl, and White). Nonetheless, the technique has not been especially widely used and lacks theoretical underpinning regarding decision-making analysis but displays the distinct advantage of simplicity. Because of the simplicity and intuitive appeal behind this technique, it is chosen for the problem at hand as discussed in the next section.

Analytical Procedure

The theoretical and methodological framework for conducting the study relies upon the decision-making environment facing the Henderson County grain producer. It is assumed that the goal of the producer is to maximize expected utility and that this can be adequately represented in a mean-variance framework. Consequently, the producer's decisions are motivated by economics which in turn are driven by the underlying production function. Therefore, the discussion of the analytical procedure will focus on two issues: the underlying production environment and the economic model.

The Underlying Production Environment

The production decisions focus on corn, soybeans, and wheat and the four enterprises of corn, full-season soybeans, wheat, and double-cropped soybeans with wheat. Crops were produced no-till under dryland conditions. A wide range of planting dates for all the crops was incorporated into the analysis as reflected in Kentucky Agricultural Statistics. However, in order to investigate the trends towards earlier planting dates, the ranges were moved earlier by one to two weeks. Additionally, alternative plant populations and maturity classes were examined for corn and soybean. Expert opinions of agricultural producers, Kentucky Cooperative Extension Service Specialists, and others were sought to determine the agronomic experimental design.

Corn planting took place in weekly intervals from March 29 through May 24 for nine planting dates. Corn included early, medium, and late maturity classes as well as low, medium, and high plant populations of 20,000, 24,000, and 28,000 plants per acre, respectively. Corn yields are simulated using the CORNF model by Stapper and Arkin.

Soybean planting dates were in nine weekly intervals from April 26 through June 21. Three general, overall representative varieties of Maturity Group III, IV, and V (MG III, MG IV, MG V) soybean were included. Additionally, six plant and row spacing combinations were incorporated for alternative plant population alternatives. These included soybean row spacing of nine inches (with two and three plants per foot), 19-inch rows (with four and six plants per foot) and 30-inch rows (with six and nine plants per foot). The SOYGRO (Wilkerson *et al.*) model was used to simulate soybean yields.

The wheat planting dates were from September 27 to November 22 in nine weekly intervals. Wheat was drilled with a single cultivar and plant population assumed. While wheat is almost always double-cropped with some other crop, often soybean, the option of single-crop wheat was simulated. When wheat is double-cropped it is assumed to be double-cropped with soybean which is planted ten days after wheat harvest. The double-cropped soybean plant and row spacing as well as maturity groups parallel those used for the full season soybean experimental design. The CERES model (Ritchie and Otter) model was used for simulating wheat yields and was integrated with the SOYGRO model for the simulation of double-cropped wheat and soybean. This allows the consideration of soil moisture impacts to be duly reflected in generating yield estimations.

The biophysical simulation models relied upon daily weather data from Henderson for 1978 through 1998 which, because of the overlap of winter wheat, provided 20 seasons of estimated yield data. The exception on weather data was the need for solar radiation which required the use of Evansville, Indiana as a location. Extensive validation of yield responses to varying management practices was not possible because of insufficient data, which is the reason the biophysical simulation models are used. However, some validation was performed by reliance upon previous studies' validation of all models concerned as well as comparison of overall yield levels and responsiveness of yields to alterations and to production practices. This entailed examination of Kentucky Agricultural Statistics for various years, comparison to Ohio Valley region of Kentucky Farm Business Management Association results (Morgan, Gibson) and discussions with experts. Overall, the yield responses seem to be reasonable.

The Economic Model

A mathematical programming model was employed to embody the decision-making framework facing a hypothetical Kentucky crop producer on a loamy soil in Henderson County, located in the Ohio Valley region of Kentucky. The Ohio Valley region is a major corn and soybean producing area of the state.

A quadratic programming model was employed within a expected value-variance (E-V) framework to incorporate profit and risk considerations for various lease types. The conditions under which the use of E-V is consistent with expected utility theory must include one of the following: (1) normal distribution (Freund), (2) if the distributions of net returns associated with the decision variable differ only by location and scale (Meyer), or (3) if the utility can be approximated by a quadratic function (Markowitz). For this study yield is the only random component of net returns; therefore normality of yields is expected to be a sufficient condition for normality of returns. Testing with Kolmogorov-Smirnov statistics did reject the normality assumption at the five percent level of significance for some of these yields. While other test procedures have been suggested for investigating Meyer's criterion (Dillon), they become cumbersome with numerous variables. Therefore, E-V was considered an acceptable method.

The specification of the E-V model is:

$$\max \bar{y} - \Phi\sigma_y^2$$

subject to:

$$(1)\quad \sum_E \sum_V \sum_P \sum_S X_{E,V,P,S} \leq 1350$$

$$(2)\quad \sum_E \sum_V \sum_P \sum_S LAB_{E,S,WK} X_{E,V,P,S} \leq FLDDAY_{WK} \quad \forall\, WK$$

$$(3)\quad \sum_E \sum_V \sum_P \sum_S EXPYLD_{C,E,V,P,S,YR} X_{E,V,P,S} - SALES_{C,YR} = 0 \quad \forall\, C,YR$$

$$(4)\quad \sum_E \sum_V \sum_P \sum_S REQ_{I,P*} X_{E,V,P,S} - PURCH_I = 0 \quad \forall\, I$$

$$(5)\quad \sum_I IP_I PURCH_I - \sum_C P_C^* SALES_{C,YR} + Y_{YR} = 0 \quad \forall\, YR$$

$$(6)\quad \sum_{YR} \frac{1}{N} Y_{YR} - \bar{Y} = 0$$

$$(7)\quad \sum_E \sum_V \sum_P \sum_S ROTATE_{R,E} X_{E,V,P,S} \leq 625 \quad \forall\, R$$

where activities include:

$\bar{Y}$ = expected net returns above variable cost (mean across years)

Y_{YR} = net returns above variable cost by year (net returns)

$X_{E\,V,P,S}$ = production of enterprise E of variety V with a plant population P under sowing date S in acres
$SALES_{C,YR}$ = bushels of crop C, sold by year
$PURCH_I$ = purchases of input I

constraints include:

(1) Land resource limitation
(2) Labor resource limitations by week
(3) Sales balance by crop and year
(4) Input purchases by input
(5) Profit balance by year
(6) Expected profit balance
(7) Rotation limitations

coefficients include:

Φ = Pratt risk-aversion coefficient
P_C = Price of crop C in dollars per bushel
IP_I = Price of input I
$EXPYLD_{C,E,V,P,S,YR}$ = Expected yield of crop C for enterprise E of variety V planted in population P planted on sowing date S in bushels per acre for year YR
$REQ_{I,P}$ = Requirement of input I for production in row and plant spacing P in units per acre
$LAB_{E,S,WK}$ = Labor requirements for production of enterprise E planted on sowing date S in week WK in hours per acre
$FLDDAY_{WK}$ = vailable field days per week at varying levels of certainty
$ROTATE_{R,E}$ = Rotation categorization matrix by enterprise E to include corn if R = 1 and other crops if R = 2

indices include:

C = Crop
E = Enterprise
V = Variety (MG III, IV, and V for soybeans or EARLY, MEDIUM, and LATE for corn)
P = Plant population
S = Sowing date
I = Input
WK = Week
YR = Year
R = Rotation category

The objective function maximizes the certainty equivalent of net returns which is net returns above variable costs (hereafter referred to as simply *net returns*) less the product of Pratt risk-aversion function coefficient and the variance of net returns (σ_y^2). The Pratt risk-aversion function coefficient is a measure of a hypothetical producer's aversion to risk. This coefficient is calculated using the method described by McCarl and Bessler, wherein a producer is said to maximize the lower limit from a confidence interval of normally distributed net returns. The resultant general formula for calculating the risk aversion parameter is:

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

where Φ = risk-aversion coefficient, Z_α = the standardized normal Z value of α level of significance, and S_y = the relevant standard deviation the risk-neutral profit maximizing base case for each.

The data required to specify the production decision model are (1) available land, (2) available field days, (3) labor requirements, (4) input requirements and prices, (5) crop prices, and (6) yields. The hypothetical farm is assumed to be a commercial size grain operation with 1350 acres. This is derived by rounding the average number of tillable acres for an Ohio Valley grain farm of 1346 up to 1350 (Morgan).

The number of days a week suitable for fieldwork was estimated using historical weather data and soil water simulation under a modified procedure discussed by Dillon, Mjelde, and McCarl. A 50-percent likelihood of a given number of days suitable for fieldwork occurring in any particular week was then specified as the labor constraint for the base case. Experiments of 60-percent, 70-percent, and 80-percent probabilities of available days were also examined. Available field time is calculated by multiplying the average number of workable field days a week by 12 working hours a day for 2.56 persons, the average number of persons working on Ohio Valley grain farm (Morgan). The weekly number of days the tractor could work was calculated using a field days criteria function. The criteria used to identify a nonworking day are the following: (1) if it rained three consecutive days the third day along with the following day is not considered a field day, (2) if the soil moisture of the top 3.9 inches (10 cm) is 80 percent or greater of water storage capacity on a given day that day is not considered a field day, and (3) if it rained 0.15 inches (0.38 cm) or more on a given day that day is not considered a field day. The soil moisture portion of the biophysical model is used to derive soil moisture. The vector of the field days available appeared as the weekly right-hand side values in the mathematical programming model; the average weekly days available for Henderson was 5.2 with a standard deviation of 2.6.

The chance-constrained formulation of the uncertain right-hand side of days suitable for fieldwork used herein is the well-known technique developed by Charnes and Cooper. Some applications of the technique to agriculture are seen in the literature (e.g. Boisvert, Boisvert and Jensen, Danok *et al.*) and the technique is much simpler to use than stochastic programming with recourse (Etyang *et al.*). Consequently, the labor constraints, in general mathematical programming notation are:

$$P\left(\sum_{J} a_{iJ}X_J \le b_i\right) \ge \alpha$$

This in turn may be reduced to:

$$\sum a_{iJ}X_J \le b_{i,\alpha}$$

where $b_{i,\alpha}$ is the b_i associated with a probability α of occurring. This more general form is used because the days per week suitable for fieldwork is not normally distributed based upon Kolmogorov-Smirnov statistics. Consequently, the normally distributed $\overline{b}_i - Z_\alpha\sigma_{bi}$ was not used but rather actual sample distribution calculations for α ranging from 50 to 80 percent likely.

The labor requirements per week, input prices, and input requirements per acre were taken from representative Tennessee no-till enterprise budgets (Gerloff and Maxey). Labor requirements were adjusted to weekly data and shifted by planting date. Statistical computation of simulated harvest dates allowed for adjustment of harvest time by maturity class. The 1993–1997 Kentucky average season prices for crops were used with $2.79/bu for corn, $6.70/bu for soybeans, and $3.48/bu for wheat (Kentucky Agricultural Statistics 1997–1998).

Results and Discussion

The base case scenario was analyzed for the 50-percent likelihood of days suitable for fieldwork under risk-neutral and risk-averse scenarios. The risk-aversion parameter based on McCarl and Bessler approach was selected by increasing the Z score from 50 percent for the risk-neutral situation in five percent increments up to the 90-percent probability level. The standard deviations from the optimal solution for the risk-neutral base case used as the representative standard deviations in the McCarl and Bessler formula. Following the base-case scenario, aversion to uncertain production plan implementation due to a lack of suitable field days was examined. Specifically, days suitable for fieldwork which were 60 percent, 70 percent, and 80 percent probable were incorporated in the model and the solution results analyzed.

Base Case Scenario Results

The results for net returns and production strategies selected for the base case are shown in Table 1. Discussion of risk-averse results are narrowed to focus on the 60-percent, 75-percent, and 85-percent risk significance level to simplify presentation and concentrate on those levels of risk aversion which caused changes in production strategies worthy of noting. The risk-neutral optimal solution provided mean net returns above selected costs of $294,393 and a coefficient of variation (c.v.) of 23.59 percent. The minimum net return was $145,272. The production strategies that lead to these economic results were a half and half crop mix of full-season soybean and corn. Soybean was planted in a two-week period from April 26 through May 3. While the MG IV was used for the vast majority of the soybean acreage, there was a slight use of MG III

Table 1. Base Case (50% Likelihood of Days Suitable for Fieldwork) Net Returns and Production Strategy Results by Risk Attitude

Section I. Net Returns above Specified Costs

	Risk Significance Level[a]			
Component	50%	60%	75%	85%
Mean ($)	294393.10	288768.47	287603.97	255775.86
Std. Dev. ($)	69440.51	59681.68	58746.41	47220.28
C.V. (%)	23.59	20.67	20.43	18.46
Min ($)	145272.07	175225.47	186315.93	172726.27
Max ($)	425711.67	413396.60	411043.95	351612.69
Percent of Profit Max (%)	100.00	98.09	97.69	86.88

Section II. Production Strategies Results in Acres

			Risk Significance Level[a]			
Crop	Planting Date	Maturity Class	50%	60%	75%	85%
Soybean	April 26	MG3	25.60	512.00	510.16	373.75
Soybean	April 26	MG4	512.00	25.60	0.00	0.00
Soybean	May 3	MG3	0.00	13.92	0.00	0.00
Soybean	May 3	MG4	137.40	0.00	0.00	0.00
Soybean	May 10	MG3	0.00	42.23	15.02	0.00
Soybean	June 21	MG3	0.00	0.00	0.00	155.66
Soybean	June 21	MG4	0.00	81.25	149.82	0.00
Corn	March 29	MED	0.00	0.00	0.00	88.96
Corn	April 5	LATE	261.46	0.00	0.00	0.00
Corn	April 12	LATE	0.00	261.46	261.46	204.23
Corn	April 19	LATE	413.54	0.00	0.00	22.05
Corn	May 10	EARLY	0.00	0.00	0.00	118.75
Corn	May 24	LATE	0.00	413.54	413.54	241.00
Wheat	Sept 27		0.00	0.00	0.00	145.59
Soybean Mean Yield (bu/ac)			46.14	45.29	45.03	44.80
Wheat Mean Yield (bu/ac)			0.00	0.00	0.00	57.25
Corn Mean Yield (bu/ac)			125.71	124.76	124.76	117.73

[a] The risk level represents the certainty of receiving or exceeding a maximized lower level confidence limit on net returns. Assuming a normal distribution of net returns, a 50-percent certainty exists at risk neutrality that the actual net returns will be at or higher than the expected net returns. With risk aversion, a higher percentage of certainty in net returns is required; therefore, a certainty parameter larger than 50 percent is necessary. McCarl and Bessler provided details.

soybean on April 26. Since the April 26 planting used both MG III and MG IV soybean, this indicates the need to spread harvesting requirements across critical time periods. Corn was planted over a three-week period prior to soybean on April 4 and April 19. The late maturity class of corn was used. Plant population was not varied under any base-case scenario or suitable field day experiment. Specifically, the production of soybean always used a nine-inch row spacing with two plants per foot. Corn production always focused upon the low plant population of 20,000 plants per acre. The mean soybean yield was 46 bushels per acre and the mean corn yield for the strategies was 126 bushels per acre. Examination of summary descriptive statistics for actual commercial grain producers in the Ohio Valley Kentucky Farm Business Management Program indicated that the crop mix percentage, net returns above selected costs, and yield averages were reasonably representative (Gibson, Morgan).

Initial risk aversion results in a decline of almost two percent in net returns to a level of $288,768 in order to achieve a risk reduction in c.v. to 20.67 percent from 23.59 percent. Additionally, there is over a 20-percent increase in the minimum level of net returns to $175,225. The production strategies which allow for this reduction in production risk were later planting of both soybean and corn and a greater reliance on MG III soybean. Specifically, the April 26 planted soybean represented the substantial portion of soybean acreage switch from a reliance of 95 percent MG IV soybean to only five percent in MG IV and 95 percent in MG III. Additionally, the May 10 and June 21 plantings of soybean are incorporated. The use of earlier maturing soybean under earlier planted conditions is consistent with observations of trends in actual production scenarios given the farmers' desire to avoid summer drought stress in order to reduce risk. The decision to plant April 12 and May 24 corn reflects a one- and two-week delay in planting that crop in order to reduce risk.

Additional reduction in risk is possible through further concentration on later planting dates and diversity of soybean maturity group. Substantial reduction of risk to a c.v. of 18.46 percent is possible at the 85 percent risk significance level, but results in a substantial reduction in net returns to 87 percent of the base-case risk-neutral scenario. This results in an additional decrease in the minimum net returns to a level $172,726. However, it is interesting to note the production decisions embodied in this risk-reduction strategy. A transfer of soybean acreage to full season wheat production and earlier planting dates and alternative maturity classes for corn production. The optimal solution in this situation calls for 146 acres of winter wheat planted September 27. While Kentucky grain producers are unlikely to concentrate on single cropped wheat, the model takes advantage of diversifying this earliest wheat planting date given its negative correlation with both soybean (−0.25 with April 26, MG III and −0.22 with June 21, MG III) especially and to a lesser degree corn yield (e.g. March 29 medium maturity class corn with a −0.08 correlation). Furthermore, the soybean production uses strictly the MG III cultivar and the two most extreme planting dates. The previously unused medium maturity class of corn enters the solution of the March 29 planting date and the previously unused early maturity class of corn enters the solution under a May 10 planting. Nonetheless, mean corn yield declines by about seven or eight bushels per acre to a level of 118 bushels per acre, resulting in the ability to substantially reduce risk while continuing to use all 1350 acres, but this causes substantially reduced net returns.

Days Suitable for Fieldwork Experiment

The chance-constrained right-hand-side resource allotments for days suitable for fieldwork are altered to reflect the producer's desire to plant for greater certainty of the ability to actually implement the production decisions and their corresponding field operations. Consequently, beyond the base-case scenario of incorporating 50-percent probable base suitable for fieldwork, the experiment examines the alterations in economic components and optimal production decisions resulting from days suitable for fieldwork which are 60-percent, 70-percent, and 80-percent probable. The results for the 60-percent likelihood of days suitable for fieldwork were identical to the base-case scenario because, as discussed earlier, the distribution of days suitable for fieldwork were not normal. Recall that the actual percentile distributions for each weekly field time constraint are used. Therefore, if seven suitable days were estimated in 12 of the 20 states of nature then seven days is 60 percent likely and used in both the 50-percent likelihood and 60-percent likelihood resource allotment. While the right-hand-side vectors for suitable field days were not equivalent across all weeks for both the 50-percent and 60-percent likelihood, the critical time periods were identical and therefore no binding constraints were realized in the model.

Under the experiment for suitable field days which are 70-percent likely, the risk-neutral and first two risk-aversion levels (i.e. 60 percent and 75 percent with significance levels) again are identical to the base-case scenario. However, the results for the extreme risk aversion level of 85 percent do differ. While the net returns are higher than the equivalent base case scenario at $259,635, the ability to reduce risk has been impaired as reflected by the c.v. of 18.87 percent compared to the base-case highly risk averse situation of 18.46 percent. Nonetheless, there is a slightly higher level of minimum net returns at $173,500 compared to the base-case $172,726. There is evidence of an effective overall risk management strategy. While the April 26 and June 21 soybean production planting is still relied upon, an additional May 10 soybean planting is now necessary. The focus on MG III soybean production is retained. Furthermore, the reliance on wheat production has lessened from 146 acres to 48 acres with a one week later planting at October 4. While the incorporation of corn planted March 29 under the medium maturity class cultivar has been eliminated from the equivalent base case results under these conditions, greater acreage is allocated to April 19 planting with a change from the late maturity class of the base-case scenario to strictly using the early maturing class variety during this planting time. Nonetheless, while soybean yield remains virtually unchanged compared to the base-case highly risk averse situation, there is a four-bushel reduction in mean wheat yield to a level of 53 bushels per acre and about a four-bushel reduction in corn yield to 114 bushels per acre.

Results for the experiment of 80-percent likelihood of days suitable for fieldwork were notably different from the base-case (Table 2). While the half corn, half soybean enterprise mix remained consistent, the planting period was extended. Soybean planting took place over a three-week rather than a two-week period, later extending to the inclusion of a May 10 planting. The entire planting was in MG IV soybean. Furthermore, corn planting included the earlier planting of March 29 and April 12, extending the planting period to four weeks. The late maturity class was included in corn production decisions throughout as it was for the base-case scenario under risk neutrality. While there was a slight reduction in mean net returns to a level of $293,287 or 99.62 percent of the base-case risk-neutral scenario, the variability of net returns was reduced. Specifically, the c.v. of net returns was 23.27 percent compared to 23.59 percent and the minimum level of net returns was increased by over $10,000 to $155,494. Consequently, concern for uncertainty of days suitable for fieldwork and the implementation of machinery operations associated with the production plan leads to a potential for a natural management of risk associated with fluctuations in income as well.

As aversion to income risk increases under the 80-percent likelihood of days suitable for fieldwork, the initial soybean production decisions remained the same as the base case with only the acreages involved altering. Soybeans are planted later and a greater percentage of MG III is used. Similar to the base-case scenario when going from risk neutrality to slight risk aversion, a later planting of corn is used to reduce income risk. Again, a substantial reliance upon the May 24 planted corn is prevalent but is added to the three-week planting period of April 5 through April 19. The late maturity class is still used throughout for corn production but, by definition of a decrease in the resource allotment for time allowed for fieldwork performance, leads to the need for spreading out planting and harvesting. The mean net returns are about $250 less than the equivalent base-case scenario and the c.v. is not as favorable (20.76 percent versus 20.67 percent). However, the minimum net returns are about $1600 greater. These trends continue for the income risk significance level of 75 percent. While there are changes in acreage allocations to the different production decisions, the types of soybean production decisions remain consistent with that of the base case scenario equivalent. However, the corn production decisions require a greater number of planting periods than the base-case scenario with an additional week added before both the original April 12 and May 24 planting of corn. Also, parallel results are found on comparisons to the base-case as income risk aversion increases with respect to economic impacts. Specifically, as with the case of the 60-percent income risk significance level, the more re-

Table 2. Restricted Case (80% Likelihood of Days Suitable for Fieldwork) Net Returns and Production Strategy Results by Risk Attitude

Section I. Net Returns above Specified Costs

	Risk Significance Level[a]			
Component	50%	60%	75%	85%
Mean ($)	293287.46	288518.89	287073.34	263505.92
Std. Dev. ($)	68240.23	59887.94	58700.09	50368.62
C.V. (%)	23.27	20.76	20.45	19.11
Min ($)	155493.63	176828.82	188977.88	173549.75
Max ($)	424455.10	413578.91	410800.93	360454.12
Percent of Profit Max (%)	99.62	98.00	97.51	89.51

Section II. Production Strategies Results in Acres

			Risk Significance Level[a]			
Crop	Planting Date	Maturity Class	50%	60%	75%	85%
Soybean	April 26	MG3	0.00	438.86	438.86	436.09
Soybean	April 26	MG4	460.80	21.94	0.00	0.00
Soybean	May 3	MG3	0.00	76.80	0.00	0.00
Soybean	May 3	MG4	76.80	0.00	0.00	0.00
Soybean	May 10	MG3	0.00	43.03	82.72	77.63
Soybean	May 10	MG4	137.50	0.00	0.00	0.00
Soybean	June 21	MG3	0.00	0.00	0.00	161.28
Soybean	June 21	MG4	0.00	94.37	153.42	0.00
Corn	March 29	LATE	3.00	0.00	0.00	88.96
Corn	April 5	LATE	96.00	49.77	96.00	0.00
Corn	April 12	LATE	192.00	192.00	192.00	6.76
Corn	April 19	EARLY	0.00	0.00	0.00	221.16
Corn	April 19	LATE	384.00	78.77	0.00	0.00
Corn	May 10	EARLY	0.00	0.00	0.00	94.96
Corn	May 17	LATE	0.00	0.00	32.54	0.00
Corn	May 24	EARLY	0.00	0.00	0.00	32.08
Corn	May 24	LATE	0.00	354.46	354.46	320.04
Soybean Mean Yield (bu/ac)			45.93	45.17	44.91	44.84
Wheat Mean Yield (bu/ac)			0.00	0.00	0.00	0.00
Corn Mean Yield (bu/ac)			125.63	124.92	124.78	112.42

[a] See footnote a of Table 1.

stricted suitable field day experiment leads to a decline in mean net returns and lower c.v. of net returns while the minimum net returns level increases.

This trend in descriptive summary statistics for net returns results does not hold true at the 85 percent income significance risk level. Although c.v. of net returns is again lower than the base-case equivalent and the level of minimum net returns is again higher than the base-case equivalent, the mean level of net returns is higher at $263,506 versus $255,776. Additionally, the production decision to plant MG III soybean on May 10 enters the optimal solution over and above the base-case scenario. Interestingly, while the base-case scenario relied upon five planting dates for corn, the 80 percent likelihood of days suitable for fieldwork experiment under high income risk aversion only uses four planting dates for corn but spreads out harvest for the May 24 planting of corn by utilizing both early and late maturity classes. Eliminated from the base-case optimal solution for the more restricted fieldwork experiment is the early March 29 planting of corn and its corresponding medium maturity class. Also, unlike in its base-case counterpart, wheat is not present in the more restricted fieldwork high-risk aversion experiment. Consequently, for the conditions examined within this study, as both income risk aversion and aversion to fieldwork uncertainty heighten, the production decision selected began to differ more dramatically than with the consideration of income risk aversion alone.

Summary and Conclusion

While risk management has long been considered to be an important component of the agricultural producer's decision-making environment, the current economic and financial environment creates a special need to focus upon this aspect in whole farm planning. Risk management is a complicated undertaking with several basic categories of risk sources to be considered, including production, marketing or price, and institutional and financial risk. In turn, there are many sources of risk within each of these categories including, for example, the fluctuation of yields and the risk of days unsuitable for fieldwork as a result of weather. Furthermore, a host of risk management strategies is present within each of these categories. For example, in addition to the use of enterprise mix and diversification in reducing production risks, there is the potential for risk reduction through alternative planting dates, maturity class varieties, and plant population. For this study, a hypothetical Kentucky grain producer in the Ohio Valley Region of Kentucky was modeled using biophysical simulation and mathematical programming. Specifically, the economic model incorporated a mean-variance framework and a chance-constrained, Charnes and Cooper method for examining different likelihoods of days suitable for fieldwork.

Results indicate that income risk can be reduced through crop diversification, varied planting dates, and alteration across different maturity classes. Specifically, the negative correlation between wheat and many soybean and corn production strategies' yields is exploited in risk reduction under extreme risk aversion. Additionally, earlier planting of earlier maturity group soybeans can be used to reduce the risk associated with fluctuations in yield as a means of avoiding drought conditions during pod fill that can occur in summer. Furthermore, the later planting date of corn can also be used to reduce risk and diversify across maturity classes of corn varieties in the event of high-risk aversion.

Production risks associated with days unsuitable for fieldwork may be reduced through the reliance upon alternative planting dates to spread out time required for planting during this critical period. Furthermore, using different maturity classes can enable the farmer to spread out time requirements for harvest and reduce the requirements for machinery operations during this critical period. Additionally, because the distribution of days suitable for fieldwork is not normal, many weekly field time constraints may not become binding until high levels of desire for likelihood of suitable field days is considered. Therefore, production decisions and corresponding production practices may not change under initial concerns over machinery operation implementation associated with uncertain field days.

Consequently, while there is overlap in the reduction of income risk and production risk of days unsuitable for fieldwork, the two are not totally congruent. By definition, planning for the risk of days unsuitable for fieldwork is more restrictive and will not yield identical solutions to a less restrictive case. Coupling high risk aversion of both income and suitable field days risk leads to different production decisions than when considering just uncertain days for fieldwork. Considering both actually leads to fewer planting dates and maturity class cultivars for corn production under the conditions modeled within this study. Ultimately, it is important to consider both forms of risk despite the overlap in production practice risk reduction potential because of their interaction and the subsequent effect of this interaction on the specific production practices used.

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