Soybeans

STAFF PAPER

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ABSTRACT

Two biophysical crop growth models are interfaced to simulate the performance of double-cropped wheat and soybeans over 20 weather scenarios. The impact of wheat harvest timeliness on net returns is assessed for seven alternative management strategies. Risk efficient strategies are identified for six risk intervals using generalized stochastic dominance.

Keywords: simulation, risk, stochastic dominance, wheat, soybeans.

IMPACT OF WHEAT HARVEST TIMELINESS ON RISK EFFICIENCY OF DOUBLE-CROPPED SOYBEANS

Introduction

Over the past decade, the double-cropping of wheat and soybeans has become a popular enterprise for producers in the South. A double-cropped system begins with winter wheat seeded in mid-late October and harvested in early June. Soybeans are then planted to the same acreage and harvested in autumn. Typically, the additional net returns from the wheat and the improved cash-flows in June at wheat harvest have more than compensated for the usual decrease in double-cropped soybean yields which may average 10% less than full-season soybean yields.

In spite of these advantages, there is a tradeoff in that the producer accepts a potential increase in risk with a double-cropped system. Any delays in the wheat harvest will subsequently delay soybean planting and increase the probability of reduced soybean yields.

One risk-reducing decision rule which the producer has at his option is to harvest wheat earlier. This can be done by initiating the wheat harvest when the grain moisture content of the mature crop is relatively high in lieu of waiting for field drydown to "near-storage-safe" moisture levels. By reducing the field drydown period of wheat, the entire time window of field operations can be moved forward in the season, but not without a cost. A higher moisture content necessitates artificial drying costs, or, in the case of direct sales to an elevator, a graduated price discount on the wheat which increases with the moisture level.

This paper makes a preliminary assessment of the risk-return tradeoffs of initiating wheat harvest earlier in the growing season using

grain moisture content of the standing mature crop as the decision variable. Two phenological crop growth models are linked to simulate the biophysical interdependencies of double-cropped wheat and soybeans over 20 "states of nature" using Arkansas weather data. Simulated yields and double-crop net returns generated with seven alternative grain moisture contents at initiation of wheat harvest are presented. The seven strategies are then ranked using generalized stochastic dominance ordering.

Simulation Models

Model description. CERES-Wheat (Ritchie and Otter) and the Soybean Integrated Crop Management (SICM) model (Wilkerson et al.) are phenological crop growth models which simulate daily plant development and yield as a function of both management and environmental variables. User inputs to the models describing crop environmental conditions include daily climatological data (maximum and minimum temperature, solar radiation), and parameters reflecting characteristics of the soil-type to be simulated. Both models contain a soil moisture subcomponent (Ritchie) which simulates water balance in the root profile of the growing crop. Management inputs to the models include planting date, seed density and spacing, genotype and irrigation.

CERES-Wheat and SICM were tested separately under Arkansas conditions and validated using data collected in Arkansas (Trice; Prickett). Adaptations incorporated into core SICM routines resulted in a revised soybean model named ASICM (for Arkansas SICM) which includes alterations to the soil-water uptake equations and changes in the pheno-

logy to accommodate a shorter growing season (Prickett).

Model interface. CERES-Wheat and ASICM were initially designed to be used independently of each other. In order to accommodate the simulation of a double-cropped system for the present study, the two models were interfaced to enable tandem simulation of wheat followed by soybeans. Of paramount importance to the design of this interface was that the resulting combined model--WHEATSOY--reflect the interdependencies of a double-cropped system. The two algorithms contained in WHEATSOY which accomplish the most important aspects of this interdependence are (1) the linkage of the soil water balance components of the wheat and soybean models, and (2) the addition of a grain drydown component to the wheat model.

With respect to (1), after the wheat has been harvested and the wheat subcomponent of WHEATSOY has completed simulation for any cropping season, ending soil moisture status coefficients for the entire soil profile of wheat are passed into the soybean subcomponent. These passed coefficients become initial values of the soybean soil profile for that cropping season. The importance of this linkage is that significant amounts of moisture can be extracted from the soil profile by the wheat crop. This could inadvertently affect soybean emergence and/or germination in a double-cropped system if adequate amounts of water are not available to the soybeans at planting.

With respect to (2), the grain drydown model which was added to WHEATSOY is used to simulate the moisture content of wheat between physiological maturity and harvest maturity. Physiological maturity is reached when all simulated growth processes in the wheat model terminate

and there is no further dry matter accumulation of grain or vegetative plant components; harvest maturity designates that the moisture content of the wheat has attained a user-selected threshold level (MCHVST) which permits initiation of harvest. The grain drydown component in WHEATSOY is based on a model developed by Chen and McClendon. Starting at physiological maturity, the drydown algorithm is activated and computes the daily moisture reduction of the mature wheat crop as a function of its absolute moisture level and intermittent rainfall. The algorithm includes a "rewetting" function which may result in an increase in moisture status if there is sufficient precipitation on consecutive days which causes the grains to reabsorb moisture.

Potential interactions. Simulation of soil moisture in the root profile of the wheat crop continues until the MCHVST threshold is reached. At that point, the wheat is harvested, and both, the soil moisture status coefficients and simulation program control are passed to the soybean subcomponent. Potential interaction between the soil moisture interface and the grain drydown may result in simulated scenarios bounded by the following two extremes: (1) Excessive precipitation after physiological maturity of wheat may result in a lengthy drydown which delays wheat harvest and soybean planting, but which reduces the risk of poor soybean emergence due to moisture deficit. (2) A droughty period after physiological maturity of wheat may shorten the wheat drydown period permitting an earlier wheat harvest and soybean planting, but at greater risk of insufficient moisture for the newly planted soybeans.

Experimental Design

The simulation study was designed to evaluate the impact on double-cropping risk-returns of reducing the field drydown period by initiating wheat harvest at seven alternative grain moisture contents (MCHVST) ranging between storage-safe (13.5%) and high moisture (20%) levels. Each of the seven harvest initiation "strategies" was simulated over 20 alternative "states of nature" using WHEATSOY. Twenty years of daily historical weather data for Stuttgart, Arkansas for the years 1964-1983 inclusive were used to simulate these alternative weather scenarios.

Each scenario began with wheat (Coker 68-15) planted on October 15 and harvested when grain moisture reached the specified threshold level (MCHVST) which defined that strategy. After an arbitrary 10-day delay following wheat harvest--to allow for conventional tillage practices--soybeans (Lee 74) were planted. Throughout the remainder of the growing season, simulated soybean irrigation was scheduled whenever soil moisture fell below -.4 bars on the tensiometer.

Economic model. WHEATSOY model output for wheat and soybean yield was used to calculate net returns ($/ac) for each of the 140 strategy-years simulated. Net returns (NR) were defined as gross returns (GR) from the sale of each of the two crops minus selected costs (TC) of crop production associated with each crop, i.e.

(1) NR_w ($/ac) = $GR_w - TC_w$

(2) NR_s ($/ac) = $GR_s - TC_s$

(3) NR_{dc}($/ac) = $NR_w + NR_s$

where w, s, and dc refer to wheat, soybeans and double-cropping, respectively. The net returns value measures the dollar contribution to

overhead labor, management, land and overhead capital.

Gross returns (GR) in this analysis is the product of simulated yield and price received. For wheat, gross returns were adjusted by imposing a discount on production for moisture content in excess of 13.5%, i.e.

(4) GR_W (\$/ac) = $PRICE_W$ * [$YIELD_W$ *(1-$DISCOUNT_{mchvst}$)]

Elevators in Arkansas follow a schedule by which they discount the volume of a grain purchase by a factor (DISCOUNT) which increases with the moisture content of the grain to be purchased. The discount is zero at a moisture content of 13.5% and reaches .19 for 20% moisture wheat. Implicitly, this discount defrays the cost of artificial drying.

Prices of wheat (\$3.62/bu) and soybeans (\$6.92) used in the analysis are five year average Arkansas commodity prices indexed to 1984 levels (Crop and Livestock Reporting Service). Production costs of wheat (\$94.15/ac) and double-crop soybeans (\$100.00/ac) are based on Arkansas enterprise budgets (Smith et al, 1984a; 1984b). Total costs (TC) for both crops include a variable charge for hauling (\$.15/bu); additional costs for soybeans include an overhead charge (\$42.68/ac) for irrigation equipment and a variable charge (\$2.80/acre-inch) for actual water applied.

Results

Table 1 provides sample statistics for simulated yields, dates of planting and harvesting, and net returns generated under the seven strategies over the 20 states of nature. Consistent with the hypotheses stated above, initiating wheat harvest at higher moisture contents has

the effect of increasing soybean yields by permitting an earlier planting date.

For example, a wheat harvest at 20% moisture results in getting soybeans planted an average seven days earlier (June 7) than with a wheat harvest at 13.5% moisture (June 14). As a result, the high moisture wheat harvest strategy (20%) results in an average 5.58 bushel increase in soybean yields compared to the low moisture strategy (41.50 vs. 35.92 bu/ac, respectively), but wheat yields are discounted by over 10 bushels (43.45 vs. 53.65 bu/ac at 20% and 13.5%, respectively). Although these two extreme strategies result in minimal differences in expected net returns ($131.12 vs. $132.15/acre, respectively), Figure 1 demonstrates that an intermediate strategy (16.5%) results in the highest expected returns to the producer.

Weather risk. The sensitivity of each of the seven strategies to weather risk is indicated by the sample standard deviations, and the simulated minima and maxima in Table 1. Most noteworthy is that high moisture strategies reduce the incidence of down-side yield risk (i.e., higher minimum yields) for soybeans and, hence, result in lower variance of soybean yield and net returns. Figure 2 depicts this sensitivity graphically; Figure 3 rearranges this information into cumulative distributions. The low moisture strategies in this analysis are especially sensitive to weather scenarios (1974, 1979, 1981) in which excessive rainfall extends the wheat drydown period and delays soybean planting into late June-early July causing reduced yields and negative returns.

Risk-efficient strategies. Alternative decision makers will rank

the seven harvest strategies differently depending on their preference for, or aversion to risk. Rankings of these seven strategies using generalized stochastic dominance ordering (Meyer 1977a, 1977b) are presented in Table 2. The risk aversion intervals presented in Table 2--including approximations for first (FSD) and second degree stochastic dominance (SSD)--were arbitrarily defined for this study and approximate empirical estimates of Pratt-Arrow coefficients from the literature (Love and Robison; Wilson and Eidman).

Table 2 shows that the set of all risk averse decision makers (SSD) will maximize expected utility by choosing one of the high moisture strategies (15.5, 16.5, 17.5, or 20%). However, when decision makers whose preferences approach risk neutrality are deleted from this set, the efficient choice for those only moderately or strongly risk averse is decisively narrowed to the 20% strategy, which has low expected returns, but minimal down-side risk. By contrast, a risk-preferring producer would select the low moisture strategy.

Conclusion

This study interfaces two phenological crop growth models in order to assess the impact of delayed wheat harvest on the economic performance of a double-cropping soybean system in a risk-returns setting. The preliminary results showed that: (a) highest expected net returns are attained when wheat harvest is initiated at an intermediate (16.5%) moisture level; and, (b) down-side yield risk and variance of net returns are minimized when wheat harvest is initiated at high (20%) moisture levels enabling a more timely soybean planting.

Although the study ignores market issues (i.e., price risk) which are important in a double-cropping perspective, it demonstrates the potential for using biophysical models to assess: (a) cropping system production risk using multiple-year simulations; and, (b) within-year interactions between the cropping system environment and production-management alternatives.

Figure 1. Mean Net Returns ($/acre) and Mean Date Planted (Julian date) for Alternative MCHVST

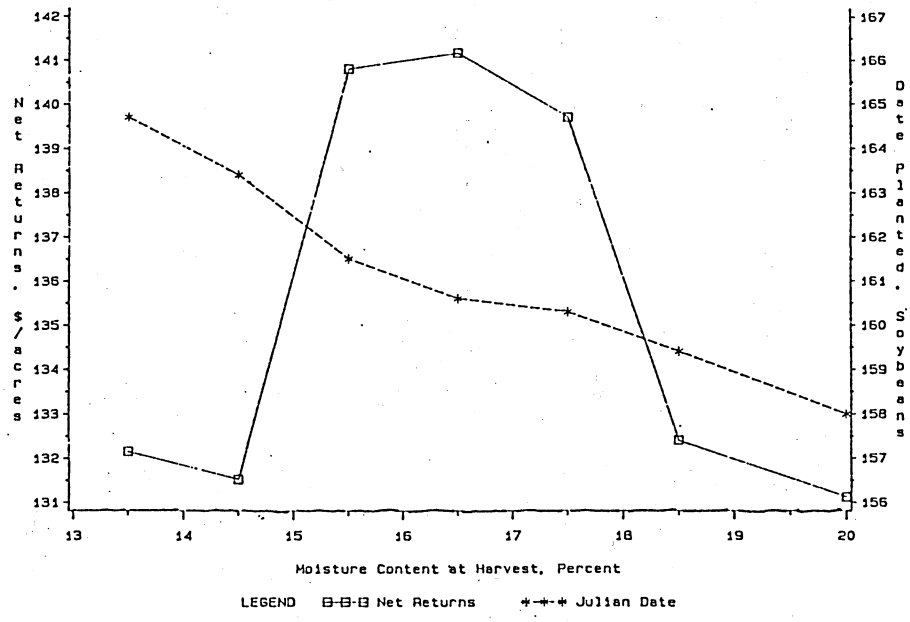

Figure 2 Simulated Net Returns for Three MCHVST Over a Twenty-year Period, $/acre

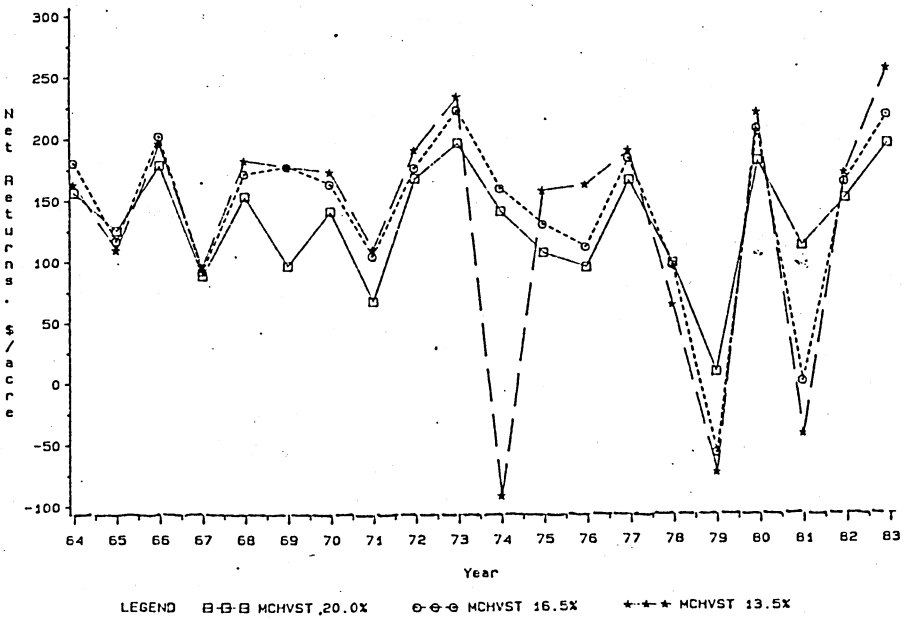

Figure 3. Cumulative Distribution of Net Returns for Three MCHVST Strategies

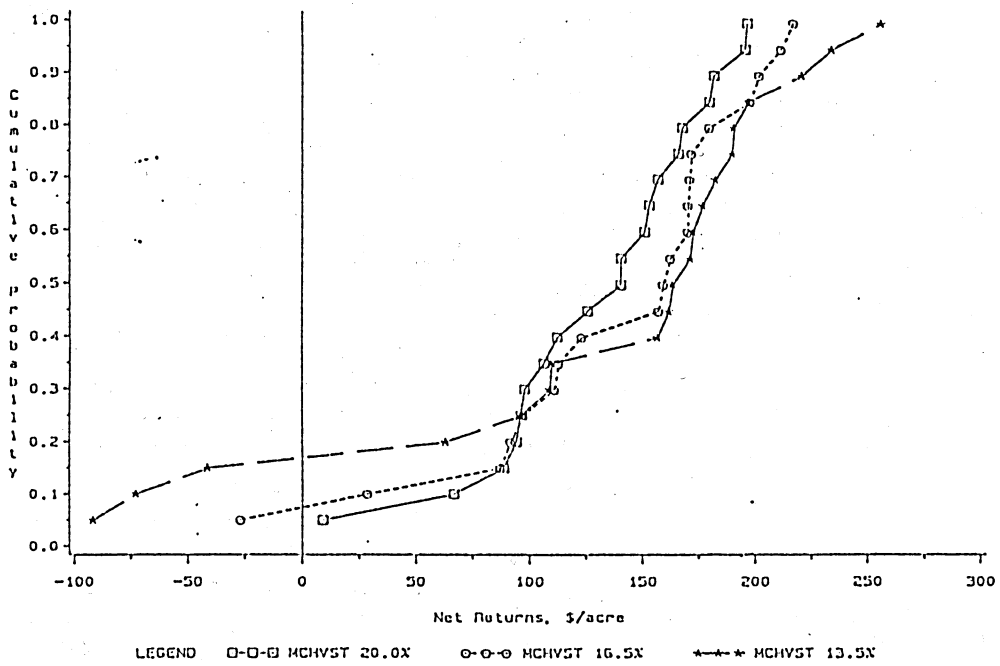

Table 1. Summary sample statistics for simulated wheat and soybeans at seven alternative wheat moisture levels at harvest initiation.

MCHVST	20%	18.5%	17.5%	16.5%	15.5%	14.5%	13.5%
Wheat:							
$\bar{x}$ (Bu/ac)	43.45	46.68	48.81	50.44	51.50	52.58	53.65
Mat	0520	0520	0520	0520	0520	0520	0520
Har	0528	0529	0530	0531	0531	0602	0604
Soybeans:							
$\bar{x}$ (bu/ac)	41.50	40.02	39.88	39.29	38.61	36.50	35.92
s	8.02	9.98	9.44	10.59	11.10	14.42	14.67
cv	0.19	0.25	0.24	0.27	0.29	0.39	0.41
Max	50.54	54.17	54.16	54.16	54.00	54.00	53.83
Min	21.74	14.44	14.44	9.65	9.65	0.00	0.00
Plt	0607	0608	0609	0610	0610	0612	0614
Mat	1030	1101	1101	1102	1103	1103	1104
Net Returns:							
$\bar{x}$ ($/a)	131.12	132.40	139.71	141.16	140.80	131.52	132.15
s	47.41	63.64	62.07	70.58	74.26	94.36	98.17
cv	0.36	0.48	0.44	0.50	0.53	0.72	0.74
Max	195.99	209.02	216.68	222.74	233.86	237.90	255.42
Min	9.15	-34.41	-26.73	-56.24	-52.40	-95.27	-91.51

Notation: $\bar{x}$ = sample mean; s = standard deviation; cv = coefficient of variation; Mat = mean maturity date; Har = mean harvest date; Plt = mean planting date. Max and Min are the maximum and minimum values simulated over the twenty year period. All 4-digit dates are (month-month-day-day).

Table 2. Ranking of seven moisture content at harvest initiation strategies for alternative risk efficiency criteria[1]

Efficiency Criterion	Risk Interval[2]	Efficient Set[3]
FSD	-.0010, .0010	All Strategies
SSD	.0000, .0010	20, 17.5, 16.5, 15.5
Risk Preferring	-.0008, -.0001	13.5
Risk Neutral	-.0001, .0001	20, 17.5, 16.5, 15.5 14.5, 13.5
Slightly Risk Averse	.0001, .0004	20
Strongly Risk Averse	.0004, .0010	20

[1]All rankings were calculated for a 700 acre farming operation, which is the average area of wheat and soybean farms in Arkansas County, Arkansas.
[2]Lower and upper bound of Pratt Arrow coefficient of absolute risk aversion.
[3]Preferred set of strategies (MCHVST).

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