INCORPORATING THE IMPACTS OF UNCERTAIN FIELDWORK TIME ON WHOLE-FARM RISK-RETURN LEVELS: A TARGET MOTAD APPROACH

Sukant K. Misra and Stan R. Spurlock

Abstract

Given an equipment complement, a specific crop mix has a probability distribution for whole-farm net returns. Increasing crop acreage while holding the set of equipment constant will reduce fixed costs per acre, but it will also increase the length of time required to complete crucial field operations such as planting and harvesting. Thus, the probability of encountering weather-related delays in fieldwork will increase. This increase in delays may cause a decline in yields and changes in the distribution of net returns. This paper develops a Target MOTAD model capable of capturing intra-year impacts on profit that arise from the timing of planting and harvesting operations as well as inter-year impacts on profits that are due to variations in economic and weather-related factors. The model relies on estimates of available fieldwork time and a crop's harvestable yield in different time periods throughout the harvest season.

Key words: crop mix, risk, yield curve, Target MOTAD, biophysical simulation

The timing of many field operations in crop production may have an impact on the crop's yield. For instance, proper timing of crop planting will increase the likelihood of obtaining higher yields, but planting too early or too late will typically result in yield reductions. Early planting is typically associated with cold soil temperatures which may lead to slow emergence, reduced stands, delayed maturity, and thus reduction in yield (Imholte and Carter). Late planting primarily decreases the length of the growing season, causing a reduction in growing degree days (Wilcox and Frankenberger), heat unit accumulation (Cathey and Meredith), and yields. An intermediate planting date essentially prevents these problems, allowing the crop to develop and grow under more advantageous environmental conditions. However, because of limited equipment, planting may be spread over several days or weeks.

In addition, the harvestable yield on many crops may be sensitive to the timing of harvest. Harvesting the crop too early or too late could result in decreased yields. Early or delayed harvesting could also lower crop quality resulting in reduced market prices. As with planting, farmers harvest their crops over several days or weeks. More harvesting equipment per acre can increase the speed of the harvest operation, but only at an increase in cost per acre. Adverse weather can delay the harvest operation, often resulting in lower yields. Excessive rainfall and wind can cause lint weight and quality losses on cotton and weight loss on grains due to stalk damage. Also, harvesting when moisture content is high will increase drying expenses for grain crops. Harvesting in very dry conditions can also cause quality problems on grain crops. Milling yield is adversely affected by harvesting rice when it has a low moisture content.

Though farmers generally attempt to plant and harvest crops in a timely manner to obtain high yields, delays in fieldwork due to unfavorable weather do occur and can cause yield reductions. The length of time required to finish planting or harvesting a crop is dependent on several factors: (1) the number of acres to be planted or harvested; (2) the type and capacity of the planting or harvesting equipment (acres per hour that can be planted or harvested under suitable conditions); and (3) the suitable hours available within the planting and harvesting periods. The producer makes decisions concerning the first two items, but the third item is random and is primarily dependent on weather and soil conditions. Thus, farmers should take account of the probability distribution of suitable fieldwork hours when they make decisions concerning farm plans and/or machinery complements. Conceptually, a crop mix-machinery complement combina-

Sukant K. Misra is a Postdoctoral Associate in the Department of Agricultural Economics, Georgia Experiment Station, University of Georgia, and Stan R. Spurlock is a Professor in the Department of Agricultural Economics, Mississippi State University. The authors express their appreciation to the three anonymous reviewers for their helpful comments on an earlier version of the manuscript. Responsibility for contents, however, rests solely with the authors.

tion that maximizes a farmer's expected utility exists.

This area of inquiry has received wide attention and significant methodological improvements in dealing with farm plans under uncertainty have been achieved. However, it is generally recognized that incorporating the impacts of random variations in suitable fieldwork time requires significant computation. Danok, McCarl, and White developed a mixed integer model to select a machinery set and a crop plan. They used a chance-constrained approach to relate available fieldwork time to a prespecified probability level. By imposing one machinery set on the model and varying the probability level, they constructed a cumulative probability distribution of net farm income for each set and evaluated the results with stochastic dominance techniques. Boisvert and Jensen incorporated both the time available for fieldwork and the yield losses associated with untimely crop production into a farm planning model. Available fieldwork time was also handled by chance constraints in a linear programming model. Incorporating stochastic supplies of limiting inputs on farm management decisions under uncertainty has also been addressed by Paris in a symmetric quadratic programming framework. He treated stochastic limiting resources in a way analogous to stochastic net revenues and yields.

Discrete stochastic programming (DSP) is a method that allows any number of the objective function, restraint, and input-output coefficients to be represented by discrete probability distributions (Cocks; Rae). This method allows the construction of either linear or non-linear programming models, and can evaluate problems in which sequential decisions are made. Several applications of DSP have been made in agricultural economics (Leatham and Baker; Apland and Kaiser), but the models become extremely large in accounting for all possible outcomes.

Computer simulation of a production process has also been used to evaluate alternative farm plans or machinery complements (McClendon et al.; Sorensen and Gilheany). A specific plan is imposed on the model and stochastic yields and prices in conjunction with daily historical weather data from many years may be used to generate estimates of probability distributions of net returns. Various types of efficiency criteria may be used to determine the risk-efficient decision sets (Wetzstein et al.). The simulation model would generally have rules to follow in the event that fieldwork time requirements in certain periods are unavailable in any year. For example, targeted acreage can be left unplanted and/or yields can be penalized. Simulation models are typically not developed to find optimal solutions, and therefore may have to be run many times to cover a wide range of farm plans. The advantages of using historical weather data should not, however, be underestimated.

The objective of this paper is to present a Target MOTAD linear programming formulation that: (1) can be used to determine a set of crop plans which meets the second degree stochastic dominance criterion, (2) utilizes historical weather data to derive estimates of available fieldwork time, and (3) incorporates yield penalties for planting and harvesting in nonoptimal time periods. The model essentially simulates an endogenously determined crop mix over a period of years and transfers any losses in revenue due to insufficient fieldwork time to the objective function. Thus, whole-farm net return is treated as a discrete stochastic variable.

ALLOCATING CROP ACREAGE UNDER UNCERTAINTY

The economic outcome (profit) of a specific crop mix for a single production period can only be determined after the crops are harvested, i.e., all quantities and prices of outputs and inputs will be known after the harvest is completed. However, farmers allocate acreage among alternative crops prior to the time in which outcomes are made known. In many instances, farmers decide on a specific crop mix even before performing pre-plant field operations such as land preparation and fertilizer applications. Thus, the economic outcome of the selected crop mix is a random variable at the time that the decision is made, and is dependent on a large number of stochastic weather-related and economic conditions that occur throughout the production period.

Variability in input levels, crop yields, input and output prices, and availability of time for field operations contribute to variability in profits. The farmer should, therefore, attempt to consider all these relevant sources of risk, estimate the probability distribution of profits for alternative crop plans, and then select the plan that maximizes expected utility. Data requirements and computational difficulties make this type of risk analysis extremely difficult. Use of historical data may be of value in developing estimates of probability distributions. If a specific crop mix could be held constant over several years on a farm, each year could represent one state of nature, and the cumulative distribution function (CDF) of whole-farm profits could be constructed for the observed outcomes. Furthermore, if annual outcomes from different crop mixes could be observed over the same period of years, then a CDF for each alternative crop mix could be constructed.

A risk efficiency criterion could be applied to the observed CDFs to identify a set of risk-efficient crop mixes.

It would, however, be infeasible to observe enough multi-period outcomes for the potentially large (possibly infinite) number of alternative crop mixes. A whole-farm simulator could be used to estimate the required CDFs for a reasonable number of alternative plans, but an optimization technique that could derive the set of risk-efficient crop mixes would be preferred. Moreover, the selected optimization technique should also incorporate time constraints during critical stages of production, such as planting and harvesting periods, and include yield and/or quality impacts that are associated with alternative planting and harvesting dates. A Target MOTAD model that meets these requirements is specified in the next section.

SPECIFICATION OF A GENERALIZED MODEL

A Target MOTAD model is constructed under the assumption that the decision-maker possesses the utility function U = c + a R + b min(R - T, 0) where R is income, T is a target income level, min is the minimum operator, and a, b 0 (Tauer). Since this utility function is increasing and concave over R (it has linear segments which are kinked at T), the decision maker is risk-averse. The expected utility form of this kinked utility function for an action having discrete outcomes can be shown to be: E(U) = c + a E(R) - b | E(ND) | where E(U) is expected utility, E(R) is expected income, and | E(ND) | is the absolute value of the expected negative deviation from the target. Thus, E(R) and | E(ND) | values from alternative actions can be used to rank those actions if c, a, and b are known. However, if these parameters are unknown, a risk-efficient frontier comprising crop mixes[1] can be sought. Target MOTAD solutions are found by maximizing E(R) subject to | E(ND) |, which, when parameterized by discrete intervals over its feasible range, produces a set of whole-farm plans at points on the risk-efficient frontier.

The proposed Target MOTAD model includes a block of time-related planting and harvesting activities and constraints for each year. The optimal solution provides the same crop mix each year, but allocation of acres among planting and harvesting period activities within a given year may be different from the allocation in other years. The selection of acres to plant or harvest in specific intra-year time periods is driven primarily by the profitability of the activities, performance rates of equipment complements, and time available to perform the activities. The model is capable of capturing intra-year impacts on profit that arise from the timing of planting and harvesting operations as well as inter-year impacts on profits that are due to variations in weather-related and economic factors.

Sufficient time within a year would allow planting and harvesting activities to be performed during their more profitable time periods in that year. Alternatively, insufficient time would force planting and harvesting activities to be performed during less profitable time periods. If a solution requires planting or harvesting in these less profitable time periods in one or more years, the loss in expected profits due to reduced timeliness is accounted for by the model. Thus, there could be a range of acreage for a particular crop in which more acres could increase expected profit without increasing risk, but eventually increases in expected profit could be had only at the expense of increased risk brought about by reduced timeliness.

A Target MOTAD model treating whole-farm profit as stochastic is specified as:

$$(1)\quad \text{Max } E(R) = \sum_{y} PROB_y(PR_y - NR_y)$$

$$(2)\quad \sum_{c} ACRES_c \leq LAND$$

$$(3)\quad -ACRES_c + \sum_{p} ACPLT_{cpy} = 0 \text{ for all c, y}$$

$$(4)\quad \sum_{c} PPR_{cpy} + ACPLT_{cpy} \leq PLTIM_{py} \text{ for all p, y}$$

$$(5)\quad -ACPLT_{cpy} + \sum_{h} ACHRV_{cphy} = 0 \text{ for all c, p, y}$$

$$(6)\quad \sum_{c}\sum_{p} HPR_{cphy}\, ACHRV_{cphy} \leq HVTIM_{hy} \text{ for all h, y}$$

$$(7)\quad \sum_{c}\sum_{p}\sum_{h} (GM_{cphy}\, ACHRV_{cphy}) - PR_y + NR_y = 0 \text{ for all y}$$

$$(8)\quad PR_y - NR_y + ND_y \geq T \text{ for all y}$$

$$(9)\quad \sum_{y} PROB_y ND_y \leq |E(ND)|$$

where

[1] All crop mixes on the Target MOTAD efficient frontier meet the second degree stochastic dominance (SSD) criterion (see Tauer for the proof).

$E(R)$	is expected net returns from the endogenously determined crop mix;
$PROB_y$	is the probability of year y occurring;
PR_y	is returns above variable costs in year y;
NR_y	is the absolute value of returns below variable costs in year y;
$ACRES_c$	is acres of crop c produced;
$LAND$	is total acreage available;
$ACPLT_{cpy}$	is acres of crop c planted during period p in year y;
PPR_{cpy}	is the performance rate (hours/acre) required to plant crop c during planting period p in year y;
$PLTIM_{py}$	is the time (hours) available to plant all crops during planting period p in year y;
$ACHRV_{cphy}$	is acres of crop c (that were planted in period p) harvested during harvesting period h in year y;
HPR_{cphy}	is the performance rate (hours/acre) required to harvest crop c planted in period p during harvesting period h in year y;
$HVTIM_{hy}$	is the time (hours) available to harvest all crops during harvesting period h in year y;
GM_{cphy}	is the per-acre gross margin (price received times yield, minus variable cost) of crop c planted in period p and harvested during period h in year y;
ND_y	is the absolute value of the negative deviation from a target income level in year y;
T	is the target income level; and
$\|E(ND)\|$	is the absolute value of the expected negative deviation from a target income level (represents the level of risk).

Equation (1), the objective function, calculates whole-farm expected profit (exclusive of fixed costs) by averaging annual expected net returns across years (states of nature). The inclusion of PR_y and NR_y is necessary to allow whole-farm net returns in any year to be either positive or negative. However, note that equation (7) implies that if $PR_y > 0$ then $NR_y = 0$, and if $NR_y > 0$ then $PR_y = 0$.

Equation (2) places an upper limit on the total number of acres that may be under cultivation on the farm. Equation (3) transfers produced acres of each crop to planting activities which are differentiated by crop, planting period, and year. Equation (4) places an upper limit on the amount of time available for planting during each period in each year. Equation (5) transfers planted acres to harvested acres which are differentiated by crop, planting period, harvesting period, and year. Equation (6) places an upper limit on the amount of time available for harvesting during each period in each year.

Equation (7) calculates the profit (exclusive of fixed costs) from the crop mix in each year and transfers the amount to either a positive or a negative net returns activity. Equation (8) transfers annual net returns (if below a target income level) to a negative deviation activity. The target level could be equal to whole-farm fixed costs that the farmer would at least attempt to cover every year. Various target income levels may be specified to determine the sensitivity of the model to alternative target levels. Finally equation (9) restricts the absolute value of the probability-weighted sum of the negative deviations to be less than or equal to an exogenously determined risk level, which is parameterized within its feasible range to obtain the SSD risk-efficient frontier.

If desired, equation (2) may be modified to allow land to be unconstrained, implying that equations (4) and (6) will use the farm's equipment complement as the constraining resource. Also, other equations similar to equation (2) could be included to account for resource constraints such as heterogeneous land types, capital limitations, and upper or lower bounds on acreage of specific crops. Similarly, equations (4) and (6) may be relaxed to include different types of specialized planting and harvesting equipment.

The model determines the optimal acreage for each crop (production activities), and holds this crop mix constant for years one through N with the aid of the planting balance rows and planting activities. Within each year, the planting constraint rows determine the number of acres to plant in each period. The harvesting balance rows are used to transfer each crop's planted acreage into one or more harvesting period activities. The harvesting constraint rows determine the time periods in which acres of each crop are harvested. The profit balance row transfers the gross margins (which may be positive or negative) from the harvesting period activities to either a positive or negative net returns activity in the objective function. The target balance row transfers the negative deviation (if any) to the target constraint row.

AN EMPIRICAL APPLICATION: THE CASE OF RISK MANAGEMENT IN COTTON HARVESTING

The application of the Target MOTAD approach in incorporating the impacts of uncertain suitable fieldwork time on risk-return levels is illustrated in this section. To keep the illustration simple, the model was developed for a single crop enterprise (cotton) to evaluate three maturity management practices given uncertainty in lint prices, yields, and time available to harvest. Results derived from applying the model to Mississippi Delta conditions are presented.

Due to the high fixed costs of equipment, cotton producers strive to produce as many acres as possible with a given machinery complement to obtain lower per unit fixed costs. With a given fleet of harvest equipment, a specific number of acres can be picked on an average day, implying that more planted acres will increase the total length of the harvest period. If yield was constant every day during the harvest period, then the producer would not be concerned with weather-related harvest delays. However, after cotton bolls open, they begin to lose weight if left unpicked in the field. This weight loss causes reductions in yield and revenue if the harvest cannot be completed within the expected harvest period. Thus, unfavorable weather during the harvest period can result in a delayed harvest, lower realized yields, and reductions in profits. Harvest period weather cannot be known with certainty prior to the planting period. Therefore, the decision on how many acres to plant needs to be evaluated within a risk framework.

Harvest decisions are defined in this paper to be options that directly affect realized lint yields, and include: (1) selecting the harvest initiation date, (2) deciding on the number of acres to produce given a known set of equipment, and (3) allocating acreage to different management practices so that selected portions of the crop mature at different times. A harvest plan merely specifies the choices that the producer makes. This paper concentrates on planted acreage and allocation of different maturity management practices.

Model Development

The objective function of the cotton harvesting model maximized expected returns above variable costs over a ten-year period (1978-1987) for a Mississippi Delta cotton farm having one two-row picker with an appropriate equipment complement. Only first-pick data were incorporated, in the belief that important acreage decisions should not be based on second-pick considerations. Each year had its own block of activities and constraints, allowing the model to treat each year as a discrete state of nature. Each year's activities were divided into planting/production, harvesting, and selling categories for three types of maturity management practices (early, standard, and late).

Planted acreage for a particular maturity management practice (held constant over the 10-year period) was the primary decision variable. Pre-harvest variable costs (including a land charge) per acre were deducted from the profit row for each acre produced. Each acre produced was transferred to the harvest activities, which were specified as 13 consecutive five-day periods (September 10 to November 13), with each period being constrained by hours suitable for harvest. Harvest variable costs per acre were deducted for each acre harvested.

Each five-day harvest period had estimates of cotton lint and cottonseed yield (pounds per acre) that were derived from simulated "yield curves" for each maturity management practice (to be discussed later). To restrict harvest in any year from beginning before 75 percent of the bolls were open, the model was constrained to initiate harvest in the period prior to the period in which yield reached its maximum. Lint and cottonseed yields from harvested acres were transferred to selling activities which generated the revenue for each year. Post-harvest variable costs (hauling and ginning) per pound of lint were deducted from the lint price.

The expected returns above variable costs (RAVC) were calculated assuming that each year had an equal probability of occurrence. Positive RAVC were transferred to the objective function with a coefficient of 0.10 and negative RAVC were transferred with a coefficient of -0.10. The annual RAVC were also used to calculate the negative deviations from a target income level, which was defined to represent annual fixed costs (machinery ownership, overhead, and management). A negative deviation from the target income level in any year was transferred to the negative deviation row with a technical coefficient of 0.10. This row was used to constrain the sum of the weighted negative deviations to be less than or equal to E(ND), the measure of risk. The value of E(ND) was parameterized to generate a risk-efficient frontier.

Data Requirements

The model requires data for a "yield curve" for each of the three maturity management practices for each year. The potential agronomic yield depends on the number of fruiting sites on the plant, the percentage of the fruiting sites that develop into open bolls, and the weight of each open boll. The yield in relation to time is conceptualized as a curve that increases at an increasing rate as bolls begin to open, increases at a decreasing rate when open bolls start losing weight while other bolls are still opening, starts declining before all bolls are open, and continues to decline after all bolls are open.

The GOSSYM/COMAX cotton growth simulator (Baker et al.) was used to generate the upward portion of the yield curves. Solid (40 inch rows), dryland cotton on a fine sandy loam soil was selected for the simulations. Planting dates, varieties, and nitrogen fertilizer rates were varied to obtain early, standard, and late maturity conditions. For the early maturity management practices, an early cultivar such as Deltapine 20 or DES 119 was specified to emerge on May 1 each year. Nitrogen was applied at 60 lbs/acre 10 days prior to emergence and at 90 lbs/acre 50 days after emergence. For the standard management practices, a mid-season cultivar (Deltapine 50, Stoneville 506, Stoneville 453, or Stoneville 112) was selected to emerge May 5 each year. Nitrogen was applied at 40 lbs/acre 10 days prior to emergence and at 110 lbs/acre 50 days after emergence. For the late management practices, a full-season cultivar such as Stoneville 825 or Deltapine 90 was set to emerge May 5 each year. Nitrogen was applied at 60 lbs/acre 10 days prior to emergency and at 75 lbs/acre 50 days after emergence.

Growing conditions (in the computer simulation model) during a year were dependent on daily weather data recorded at the Delta Branch Experiment Station, which is located in Washington County, Mississippi. Variations in weather caused the potential agronomic yield to increase or decrease from one year to the next. Also, variations in weather caused both the rate and time of year at which bolls opened to vary across years. On average, there was a 10-day spread between the peak yields of the three maturity practices.

GOSSYM/COMAX is not designed to account for the weight loss of open bolls. Therefore, the downward portion of the yield curves had to be developed independently of the growth simulator. Data collected by Parvin on farms throughout the Delta area during 1986 and 1987 were used to estimate per acre pounds of lint lost per day after 100 percent of the bolls had opened. The further into the harvest season, the greater the rate of weight loss. The lint loss equations for the first eight harvest periods and the last five harvest periods were as follows:

(a) lint loss per day = .0046 + .0051 * yield
(September 10 - October 19 time period)

(b) lint loss per day = .1003 + .0091 * yield
(October 20 - November 13 time period)

These equations were applied to the peak agronomic yields predicted by the growth simulator to generate the downward portion of the yield curves.

Peak yields estimated by the growth simulator averaged about 1,000 pounds of lint per acre. These yields are higher than Washington county average yields, but were satisfactorily correlated with the county averages over the ten-year period. In seven out of 10 years, peak yields of early maturity practices were higher than those of standard practices. Peak yields of standard practices were higher than those of late practices in eight out of 10 years.

To account for picker inefficiencies, realized lint yield was assumed to be 91 percent of agronomic yield. Cottonseed yields were calculated from the realized lint yields by assuming a ratio of 1.5641 pounds of cottonseed per pound of lint. This is equivalent to lint weight being 39 percent of seed cotton weight.

Cost of production budgets were developed for each of the three types of maturity management practices to obtain estimates of variable costs for the 1987 growing season. Pre-harvest operating expenses were estimated to be $218.13/acre, $225.43/acre, and $227.41/acre for the early, standard, and late management practices, respectively. A land rental charge of $85/acre was included as a pre-harvest variable cost. Harvest variable cost, based on a performance rate of 0.75 hours/acre for a two-row picker, was estimated to be $29.55/acre.

Statewide season average cotton lint and cottonseed prices were collected from the Mississippi Agricultural Statistics Service. Both the lint and seed prices were deflated to 1987 dollars by using the consumer price index (1987 as the base year). A hauling and ginning cost of $0.10/pound of lint was deducted from the lint price to account for post-harvest variable costs.

Total fixed cost (machinery ownership, overhead, and management costs) was used to represent the target income level for a 250-300 acre operation. Machinery ownership cost (depreciation plus interest on investment) was estimated to be $27,000 for an equipment complement having one two-row picker. Overhead and management costs were assumed to be approximately five and 15 percent, respectively, of variable costs plus machinery ownership costs. The addition of overhead ($4,500) and management ($12,500) to machinery fixed costs resulted in a total fixed cost of $44,000.

The GOSSYM/COMAX simulator was also used to generate the data for days suitable for harvest in each year. The simulator was modified to calculate the moisture content in the top 15 centimeters of the middle of the row. A day in which soil moisture was above 80 percent of field capacity or rainfall was greater than 0.15 inches was assumed to have been unsuitable for harvesting. The number of suitable days in each five-day harvest period was multiplied by the number of working hours per day (average sunlight hours per day less four hours to account for morning dew, machinery repair and maintenance, work breaks, and travel to and from the field) to derive an estimate of hours available for harvest in each period.

RESULTS

Five models were developed to generate risk-efficient frontiers. The level of risk was represented by the expected negative deviation from a target income level. First, each of the three maturity management practices (early, standard, and late) were modeled separately. To determine impacts of combining different management practices, two additional models were developed: early and standard practices together, and all three practices simultaneously. The results from the models are presented in this section.

Results of six different risk levels for each of the models of individual practices are presented inTable 1. As evidenced by E(R) and E(ND) values, the early maturity practices dominated the standard and late maturity practices. As expected, higher mean incomes (also higher risk levels) resulted from more acres being planted. Early maturity practices resulted in more planted acreage per two-row picker than did the standard and late practices due to the longer harvest season available when harvest is initiated earlier. None of the models had returns above variable costs that exceeded the target income of $44,000 in all 10 years.

Results for six different risk levels for the two models of mixed practices are presented in Table 2. The two mixed practices models dominated the three individual practices models. As evidenced by E(R) and E(ND) values, the combination of all three maturity practices slightly dominated the combination of just the early and standard practices. However, the range of total planted acreage was identical in both models. As the level of risk was reduced for the two-practice model (solutions 19-24), acreage allocated to early maturity practices decreased until the lowest risk level was achieved, with standard practice acreage declining at the lowest risk level. The same trend existed for the three-practice model (solutions 25-30). The acreage allocated to the late practice model was fairly stable as risk was reduced.

The models were not designed to allow picking after November 13 or the use of custom harvesting.

Table 1. Target MOTAD Results for Individual Maturity Practices Simulated Over a 10-Year Period for a Mississippi Delta Cotton Farm, from 1978 to 1987

Solution number	E(R)[a]	E(ND)[b]	Acres Planted EMP[c]	SMP[d]	LMP[e]	No. of Years Target was Met
	dollars		acres			years
1	103,359	8,710	340	-	-	6
2	103,315	7,960	327	-	-	7
3	103,166	7,210	314	-	-	7
4	102,997	6,460	300	-	-	7
5	101,822	5,710	287	-	-	7
6	97,955	4,986	263	-	-	8
7	84,101	6,758	-	279	-	8
8	83,955	6,200	-	261	-	8
9	82,900	5,640	-	243	-	8
10	80,943	5,080	-	225	-	8
11	76,946	4,520	-	207	-	8
12	72,809	3,974	-	188	-	9
13	49,272	18,036	-	-	208	6
14	48,811	17,210	-	-	199	6
15	48,301	16,370	-	-	190	6
16	47,772	15,530	-	-	181	6
17	47,064	14,690	-	-	170	5
18	45,285	13,880	-	-	144	5

[a] E(R) - mean returns above variable costs.
[b] E(ND) - mean negative deviations froma target of $44,000.
[c] EMP - early maturity practices.
[d] SMP - standard maturity practices.
[e] LMP - late maturity practices.

Table 2. Target MOTAD Results for Mixed Maturity Practices Simulated Over a 10-Year Period for a Mississippi Delta Cotton Farm, from 1978 to 1987

Solution number	E(R)[a]	E(ND)[b]	Acres Planted EMP[c]	SMP[d]	LMP[e]	Total	No. of Years Target was Met
	------- dollars -------		--------------- acres ---------------				years
19	109,531	4,661	155	195	-	350	8
20	109,106	4,345	154	174	-	328	8
21	108,333	4,020	141	174	-	315	8
22	107,518	3,695	129	174	-	303	8
23	106,414	3,370	107	192	-	299	8
24	101,869	3,065	118	145	-	263	9
25	111,468	4,400	155	105	90	350	8
26	110,934	4,110	143	105	92	340	8
27	110,311	3,820	132	106	92	330	8
28	109,517	3,530	121	110	87	318	8
29	108,674	3,240	112	105	87	304	8
30	100,182	2,970	128	50	85	263	9

[a] E(R) - mean returns above variable costs.
[b] E(ND) - mean negative deviations froma target of $44,000.
[c] EMP - early maturity practices.
[d] SMP - standard maturity practices.
[e] LMP - late maturity practices.

If cotton growers could profitably harvest in late November or December then expected returns would increase and risk levels would decrease. Similar outcomes could be expected if cotton growers could profitably use custom harvesting. However, when the harvest is delayed due to adverse weather, custom harvesting may not be available.

SUMMARY AND CONCLUSIONS

Measuring the risk from delays in fieldwork is important in a farmer's planning procedure. Stochastic limiting resources are difficult to incorporate into optimization models, but are somewhat easier to include in simulation models. First, a generalized Target MOTAD model that incorporates the impacts of uncertain suitable fieldwork time on whole-farm risk-return levels was developed and presented. The model accounts for the yield penalties associated with weather-related delays during the planting and harvesting seasons. The application of the Target MOTAD approach in incorporating the impacts of uncertain suitable fieldwork time on risk-return levels was then illustrated for cotton production in the Mississippi Delta. This application was developed to evaluate three maturity management practices given uncertainty in lint prices, yields, and time available to harvest.

The models showed that planting more acres per two-row picker tended to increase expected returns but also increased the level of risk. Even though earliness was shown to have significant benefits, a combination of maturity management practices performed better than a single practice. This implies that cotton growers should attempt to incorporate at least the early and standard maturity management practices in their crop plans. Also, the risk-return tradeoff should be considered when allocating acreage to specific maturity practices.

The formulation does, however, require a significant amount of data and the results derived from these models are, of course, dependent on the data used. Agronomic data relating yield to planting dates as well as harvest dates is required. This type of data needs to be collected from experimental plots and incorporated into crop growth simulation models. Given sufficient and appropriate data, the model presented here can be used to evaluate different farm resource situations, newly developed production systems, and farmer responses to alternative policy scenarios under risk. The model may become quite large given that its size is dependent on the number of years simulated, the number of planting/harvesting periods within each year, and the number of alternative crops. However, this formulation seems to be of considerable interest for both methodological simplicity and computational ease.

REFERENCES

Apland, J. D., and H. Kaiser. *Discrete Stochastic Sequential Programming:A Primer*. University of Minnesota Staff Paper Series, March 1984.

Baker, D. N., J. R. Lambert, and J. M. McKinion. *GOSSYM: A Simulator of Cotton Crop Growth and Yield.* S. C. Agricultural Experiment Station, Clemson University, Technical Bulletin No. 1089, Nov. 1986.

Boisvert, R. N. and H. R. Jenson. *A Method for Farm Planning Under Uncertain Weather Conditions with Application to Corn-Soybean Farming in Southern Minnesota.* Minnesota Agr. Exp. Sta. Tech. Bull. No. 292, 1973.

Cathey, G. W. and W. R. Meredith, Jr. "Cotton Response to Planting Date and Mepiquat Chloride." *Agron. J.*, 80 (1988):463-466.

Cocks, K. D. "Discrete Stochastic Programming." *Manage. Sci.*, 15(1968):72-79.

Danok, A. B., B. McCarl, and T. K. White. "Machinery Selection Modeling: Incorporation of Weather Variability." *Am. J. Agr. Econ.*, 62(1980):700-708.

Imholte, A. A. and P. R. Carter. "Planting Date and Tillage Effects on Corn Following Corn." *Agron. J.*, 79(1987):746-751.

Leatham, D. J. and T. G. Baker. "Farmers' Choice of Fixed and Adjustable Interest Rate Loans." *Am. J. Agr. Econ.*, 70(1988):803-812.

Mississippi Agricultural Statistics Service. *Mississippi Agricultural Statistics.* Jackson MS, 1978-1987.

Paris, Quirino. "Revenue and Cost Uncertainty, Generalized Mean-Variance, and Linear Complementarity Problem." *Am. J. Agr. Econ.*, 61(1979):268-275.

Parvin, D. W., Jr., and J. W. Smith. "The Economics of Cotton Harvesting in the Midsouth, With Emphasis on Early Season Insect Control." Miss. Ag. and For. Exp. Sta.,Staff Paper Series No. 74, Dec. 1985.

Rae, A. N. " Stochastic Programming, Utility, and Sequential Decision Problems in Farm Management." *Am. J. Agr. Econ.*, 53(1971):449-460.

Sorensen, E. E. and J. F. Gilheany. "A Simulation Model for Harvest Operations under Stochastic Conditions." *Manage. Sci.*, 16(1970):549-565.

Tauer, L. W. "Target MOTAD." *Am. J. Agr. Econ.*, 65(1983):606-610.

Wetzstein, M. E., P. I. Szmedra, R. W. McClendon, and D. M. Edwards. "Efficiency Criteria and Risk Aversion: An Empirical Evaluation." *So. J. Agr. Econ.*, 20. 1(1988):171-178.

Wilcox, J. R. and E. M. Frankenberger. "Indeterminate and Determinate soybean Responses to Planting Date." *Agron. J.*, 79(1987):1074-1078.