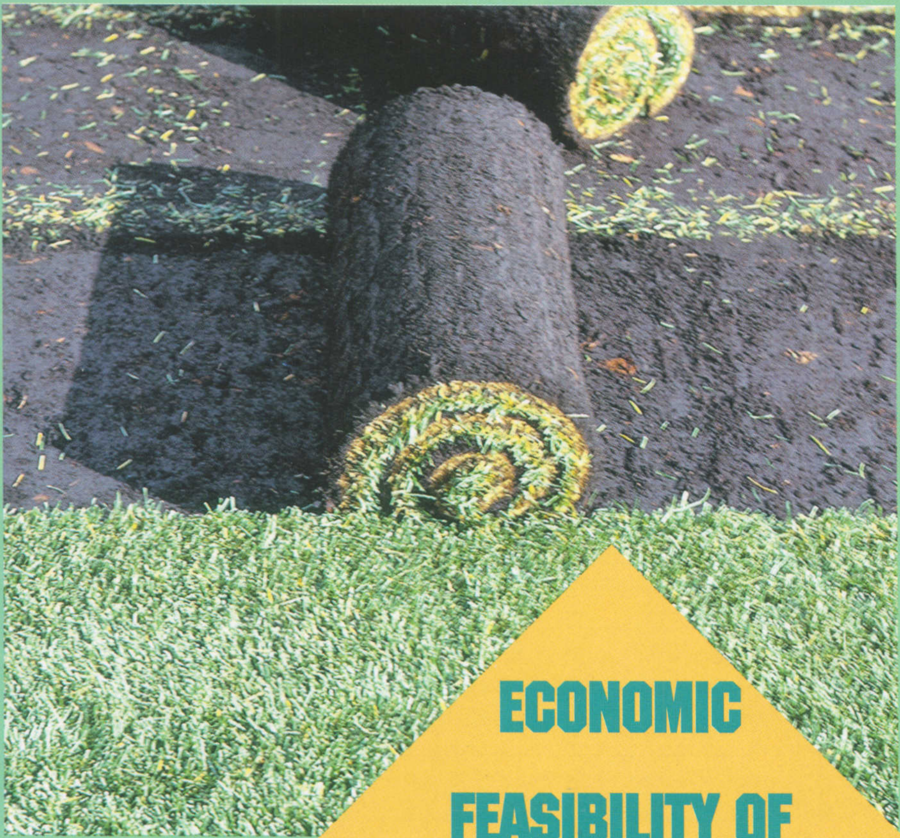

ECONOMIC FEASIBILITY OF TURFGRASS-SOD PRODUCTION

BULLETIN 625 MARCH 1995
ALABAMA AGRICULTURAL EXPERIMENT STATION
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TABLE OF CONTENTS

First printing 3M, March 1995

Economic Feasibility of Turfgrass-Sod Production

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INTRODUCTION

IN THE 1980s, THE AGRICULTURAL SECTOR underwent numerous changes, many of which were attributable to depressed prices for agricultural products and reduced asset values. Farms that were once profitable became economically unstable. Accordingly, many farmers began to evaluate alternative enterprises in order to improve their economic situation. Turfgrass-sod production emerged as one alternative use for the resources employed with traditional agricultural enterprises *(2)*.

Since the early 1980s, Alabama's turfgrass industry has changed dramatically, becoming an important component of the agricultural sector with about $50 million in farm-level receipts *(6)*. Technological improvements and the desire to gain economies of scale have led to larger turfgrass-sod operations and increased capital investments. At the same time, the market for Alabama turfgrass-sod has grown from primarily a local market to more centralized regional markets *(7)*.

Turfgrass-sod production in Alabama is still a relatively young and growing industry, increasing from about 500 acres in the late 1960s to about 25,000 acres today. Previous research on the industry has focused mainly on costs of production, capital requirements, and levels of net return *(1)* and cash flows and returns for various turfgrass species *(7)*. Little research has been undertaken to determine the economic feasibility of incorporating turfgrass-sod production into an existing farm or the competitive advantage of alternative warm-season turf species. However, with more farmers evaluating turfgrass-sod production as an alternative to traditional farm enterprises, determining the economic feasibility of such alternatives has become increasingly important.

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Purposes

A major purpose of this study was to conduct an economic analysis of the feasibility of incorporating turfgrass-sod production, which is specialized and capital intensive, into an existing farm operation which consists of traditional agricultural enterprises. Specifically, the study analyzed the economic feasibility of incorporating turfgrass-sod production into a south Alabama farm already involved in the production of cotton, soybeans, and wheat.

A second objective was to conduct a price sensitivity analysis on alternative turfgrass species to determine whether a competitive advantage exists among bermudagrass, zoysiagrass, and centipedegrass. This analysis revealed how optimal combinations of turf species change as the price of a given grass varies. It also evaluated how seasonal declines in bermudagrass prices affect optimal production combinations of grasses. A third objective was to analyze the impact of maintaining certain production levels of the higher valued grasses — centipede and zoysia.

A final objective was to determine the effect of producer debt on the optimal combinations of turfgrass-sod species. Starting capital levels analyzed in the study ranged from totally borrowed to no borrowed capital.

Procedures

To accomplish these objectives, a programming model was needed to evaluate both the production of traditional agricultural enterprises and the production of turfgrass-sod. From previous Auburn University research, two possibilities were identified. The first was a linear programming model that determines the profit maximizing combination of turf crops. The second was a mixed integer programming model that determines the optimal crop mix for a representative south Alabama farm involved in the production of cotton, wheat, and soybeans. These models were revised to accomplish the objectives of this study.

The linear programming model used in the analysis was developed *(4)* to determine the optimal combinations of turf varieties for selected production situations given specified resource constraints. The first step in developing this model was to define a model turfgrass farm that employs current production practices. Choice of turfgrass species was based on a 1990 study *(7)* that showed bermudagrass, centipedegrass, and zoysiagrass to be the most popular among Alabama turfgrass producers. Next, enterprise budgets were developed to estimate costs, revenues, and capital requirements for a 100-acre turfgrass-sod farm. Existing budgets from an earlier study *(7)* were updated for the three warm-season turfgrasses and modified to reflect the various production periods associated with each type (See Appendix A).

Budgets represented establishment and re-establishment for both early- and late-season periods for each of the three grasses. Establishment included costs for fumigation and extensive soil preparation, while re-establishment involved regeneration from strips of grass left during harvest with minor land preparation. Late season budgets differed from early season estimates in two regards: the grass was established or re-established after the middle of the production season; and less productive months during the fall, winter, and spring were accounted for in the production cycles.

From this budget information, a multiperiod linear programming model was developed to determine the profit maximizing combinations of turf crops for a seven-year period. Profit maximization was subject to several constraints related to available land and capital, as well as the length of the growing season for the grasses. For a portion of the analysis, the model also contained constraints that forced a minimum production level of zoysiagrass and centipedegrass, which are higher valued but have longer production cycles. These constraints ensured that the higher-valued varieties would be grown along with bermudagrass, which typically has a lower price and shorter production cycle.

The linear programming model was modified to reflect production conditions in south Alabama. This adjustment was made so that the results of the model could be used in conjunction with a "representative" south Alabama cotton, wheat, and soybean farm with 948 acres.

The linear programming model was used to conduct a price sensitivity analysis. This analysis revealed the effects of different turfgrass-sod prices on the optimal combinations of turf varieties. To conduct this analysis, different prices for each type of turfgrass were used while the prices of the other grasses were held constant. This approach allowed the model to analyze the effects of price variations in each turfgrass separately from the other varieties. The model also evaluated the impact of seasonality in the price of bermudagrass — represented as a 5-cent per month decline in the peak spring price of $1.00 per square yard.

The amount of starting capital available to the producer also was varied in the model. Producers considering turfgrass-sod production as an alternative farm enterprise have their own unique situations and will likely have different amounts of starting capital available for use. Varying the amount of starting capital demonstrated the effects of potential capital constraints on the optimal combinations of turf species.

The representative south Alabama farm and mixed integer programming model used in this study were created in a study *(3)* that evaluated crop mix and farm program participation decisions made under conditions of the 1990 Farm Bill. Cotton was chosen as a crop on the 948-acre farm because of its popularity, ranking first among all row crops grown in Alabama in total cash receipts. Wheat and soybeans were chosen as alternatives because both are adapted for production in Alabama and much of the state's farmland will support the double-cropping of these commodities *(3)*.

The original mixed integer programming model was revised from a five-year to a seven-year period, thus making the farm analysis segment compatible with results from the turfgrass-sod production model. A seven-year period was chosen for the turfgrass model because most equipment used in turfgrass production has a useful life of around seven years.

Results from the linear programming model were incorporated into the mixed integer programming model to determine the economic feasibility of incorporating turfgrass-sod production into a conventional farming operation. Results obtained from the turfgrass price sensitivity analyses were incorporated separately into the mixed integer programming model. These analyses illustrated how different turfgrass prices affect the feasibility of combining sod production with conventional agricultural enterprises.

Appendix B presents a more detailed description of the assumptions, methodology, and models utilized in this analysis.

ANALYSIS

The analysis section is comprised of two broad segments: (1) optimal turfgrass-sod combinations and (2) economic feasibility of growing turf on a traditional farm. Segment 1 presents results concerning competitive position and net returns (objective functions) for the grasses from seven alternative scenarios related to grass prices, market factors, and capital availability. Specifically, the models select crop mixes that maximize seven-year net return for the 100-acre farm, considering:

1. Scenario 1 (base model) — limited capital and grass prices set at $1.00, $1.22, and $1.85 per square yard for bermuda, centipede, and zoysia, respectively;

2. Scenario 2 — base model plus seasonality in the price of bermudagrass, represented by a 5-cent per square yard per month decline from the peak price of $1.00 in the spring;

3. Scenario 3 — Scenario 2 with 10 acres each of centipede and zoysia forced into production;

4. Scenario 4 — Scenario 2 plus evaluation of sensitivity of crop combinations to the price of bermuda (i.e. at what price for bermuda will the other grasses become competitive);

5. Scenario 5 — same as Scenario 4 except that the price of centipede was analyzed for sensitivity;

6. Scenario 6 — same as Scenario 4 except that the price of zoysia was evaluated for sensitivity; and

7. Scenario 7 — same as Scenario 2 except that available capital was allowed to increase from $1 to $300,000.

Labor could be hired, if needed, in all scenarios.

In Segment 2, the scenarios from Segment 1 were re-evaluated as part of a traditional farm with 948 acres. Up to 100 acres could be allocated to one or more of the turfgrass species and/or to wheat, soybeans, or cotton. As in Segment 1, the goal was to select enterprise combinations that maximize net return over the seven-year period.

Optimal Turfgrass-Sod Combination

The base model evaluated the competitive position of the three grasses with typical market prices of $1.00, $1.22, and $1.85 per square yard used for bermuda, centipede, and zoysia, respectively. In this scenario, the simulated farm allocated all 100 acres to the production of bermuda, and net returns for the seven-year period reached $1,965,733 (Table 1).

During the first year, bermudagrass was established in March, the first month in any year that the grasses can be established or re-established (Table 2). In the model, bermuda established in the early season (March-June) required 10 growing months before harvest; when re-established in the late season (July-October), it required six

Table 1. Results of Alternative Scenarios, Linear Programming Model, 100-Acre Turfgrass Farm With Seven-Year Production Horizon, South Alabama, 1993-94[1]

Scenario	Acreage produced	Net returns
Scenario 1: Bermuda = $1; centipede = $1.22; zoysia = $1.85	100 bermuda	$ 1,965,733
Scenario 2: Constrained by seasonal decline in bermuda price of 5 cents a month	100 bermuda	1,615,917
Scenario 3: Constrained to include 10 acres each of centipede and zoysia	80 bermuda 10 centipede 10 zoysia	1,264,908
Scenario 4: Price sensitivity on bermuda		
$1.40	100 bermuda	2,678,947
.70	100 bermuda	809,629
.60	73.6 bermuda[2]	603,538
Scenario 5: Price sensitivity on centipede		
$2.72	70 bermuda 30 centipede[3]	1,653,933
Scenario 6: Price sensitivity on zoysia		
$2.65	98 bermuda 2 zoysia[4]	1,615,987
Scenario 7: Sensitivity to starting capital		
$ 1 capital	100 bermuda	1,615,917
300,000 capital	100 bermuda	1,694,765

[1]All but Scenario 1 include bermuda price sensonality.

[2]73.6 acres of bermuda are planted in March, Year 1; 26.4 acres of zoysia in April, Year 1. By March, Year 4, 100 acres are planted in zoysia.

[3]Year 1.

[4]Year 1.

TABLE 2. OPTIMAL CROP COMBINATION FOR 100-ACRE TURF FARM USING TYPICAL PRICES FOR BERMUDAGRASS, CENTIPEDEGRASS AND ZOYSIAGRASS (BASE MODEL), SOUTH ALABAMA, 1993-94

Year	Month	Activity	Acres
1	March	Establish bermuda	100
2	May	Re-establish bermuda	100
3	March	Re-establish bermuda	100
	July	Re-establish bermuda	100
4	May	Re-establish bermuda	100
5	March	Re-establish bermuda	100
	July	Re-establish bermuda	100
6	May	Re-establish bermuda	100
7	March	Re-establish bermuda	100

months. Grasses could not be established or re-established from November-February. Throughout the seven-year-period of the base scenario, bermudagrass was harvested upon reaching maturity and re-established the following month.

Scenario 2 identified the optimal combination of grasses and the level of net return when bermudagrass is subject to a seasonal decline in price. Seasonality was represented by a 5-cent per month decline from the base price of $1.00 per square yard

TABLE 3. OPTIMAL CROP COMBINATION FOR 100-ACRE TURF OPERATION WITH CONSTRAINTS FORCING THE PRODUCTION OF 10 ACRES EACH OF CENTIPEDEGRASS AND ZOYSIAGRASS, SOUTH ALABAMA, 1993-94

Year	Month	Activity	Acres
1	March	Establish Bermuda	80
	April	Establish Centipede	10
	April	Establish Zoysia	10
2	May	Re-establish Bermuda	80
3	March	Re-establish Bermuda	80
	May	Re-establish Centipede	10
	May	Re-establish Zoysia	10
	July	Re-establish Bermuda	6
	October	Establish Centipede	10
	October	Establish Zoysia	10
4	May	Re-establish Bermuda	60
5	March	Re-establish Bermuda	60
	March	Re-establish Centipede	10
	March	Re-establish Zoysia	10
	July	Re-establish Bermuda	60
6	March	Re-establish Centipede	10
	March	Re-establish Zoysia	10
	May	Re-establish Bermuda	60
	September	Establish Bermuda	20
7	March	Re-establish Bermuda	60

for early-season bermuda. The resulting optimal combination of grasses was the same as observed for Scenario 1 (Table 2). However, with the seasonal decline in the price of bermuda, net returns decreased by $349,816 to $1,615,917 for the seven-year period (Table 1).

Some producers must meet customer demands for different varieties of turfgrass, or they must meet the needs of a market niche they have identified and developed. Therefore, scenario 3 placed contraints on the model that forced the production of 10 acres each of zoysiagrass and centipedegrass. The net profit for this model was $1,264,908 for the seven-year period, a decrease of $700,825 from the base estimate (Table 1).

The representative farm simulated in the model was committed to selling 10 acres each of zoysiagrass and centipedegrass in as many of the seven years as possible. To meet the year-three obligation, 10 acres each of the two higher-valued varieties were established in April of year one (Table 3). Zoysiagrass and centipedegrass need 17 growing months before harvest, which required the representative farm to devote additional acreage to these varieties during year three and after in order to meet the annual commitments for these grasses. A continuous cycle of 10 early-season and 10 late-season acres of both zoysiagrass and centipedegrass were harvested and re-established in these latter years. As expected, all land not devoted to the forced production of centipedegrass and zoysiagrass was planted in bermudagrass — 80 acres up to July of year three, when 60 acres were re-established.

Price Sensitivity Analysis with Price Seasonality for Bermuda

After finding the optimal turfgrass-sod combinations, a price sensitivity analysis for each variety was conducted. These analyses revealed how a change in the price of one variety affected the optimal combination of turfgrass-sod varieties produced. Price sensitivity analyses were conducted without the constraints that force the production of centipedegrass and zoysiagrass. This approach determined the price level for each grass required for the other varieties to become feasible for production.

Price Sensitivity Analysis on Bermudagrass

The first sensitivity analysis was conducted on bermudagrass, including the effects of price seasonality (Scenario 4). The price of bermudagrass was varied in 10-cent increments from a high of $1.40 to a low of 60 cents (Table 4). Raising the price above the $1.00 base had no effect on the optimal combination of turfgrass varieties. However, net profits rose and fell as the price was increased and decreased. This was expected, since net return is directly related to the price received for the different varieties.

Minimal changes occurred in the optimal combination of turfgrass varieties when the price of bermudagrass was decreased to 70 cents (Table 5). At this price, the model farm still chose to grow bermudagrass on all 100 acres of cropland. However, instead of re-establishing all 100 acres in March of year three as in the base scenario, 6.8 acres

TABLE 4. BERMUDAGRASS PRICES AND THEIR RELATED NET RETURN, SOUTH ALABAMA, 1993-94

Price	Net return
$1.40	$2,678,947
1.30	2,413,190
1.20	2,147,432
1.10	1,881,674
1.00	1,615,916
0.90	1,350,159
0.80	1,084,401
0.70	809,629
0.60	603,538

TABLE 5. OPTIMAL TURFGRASS-SOD COMBINATION FOR 100-ACRE TURF OPERATION WITH PRICE OF BERMUDAGRASS AT 70 CENTS, SOUTH ALABAMA, 1993-94

Year	Month	Activity	Acres
1	March	Establish Bermuda	100
2	May	Re-establish Bermuda	100
	September	Re-establish Bermuda	6.8
3	March	Re-establish Bermuda	93.2
	July	Re-establish Bermuda	100
4	May	Re-establish Bermuda	100
5	March	Re-establish Bermuda	100
	July	Re-establish Bermuda	100
6	May	Re-establish Bermuda	100
7	March	Re-establish Bermuda	100

were re-established in September of the second year. The remaining 93.2 acres were then re-established in March of the third year. Otherwise, the optimal combination was the same as when bermudagrass was priced at $1.00.

The model provided different results at 70 cents because this price provided the farmer with less operating capital. At higher prices, the simulated farm sold 100 acres of bermudagrass in April of the second year, repaid all debts, and still had enough money to cover all expenses until more grass was sold in February of year three. At 70 cents, however, the farmer had enough money to repay debts but could not cover all expenses until more grass was sold. After selling grass in April and repaying the debts, the farmer had only enough money to cover expenses through July of the second year. Instead of borrowing money to cover the remaining expenses, the farmer chose to sell 6.8 acres of the bermudagrass in August to provide enough money to cover expenses until the remaining 93.2 acres were sold in February of the third year. Selling the bermudagrass in August was the reason grass is re-established in September of year two. The 93.2 acres was held until February because that is when the price of bermudagrass is highest.

When the price of bermudagrass dropped to 60 cents per square yard, there were more changes in the optimal combination of turfgrass-sod varieties. Instead of establishing all 100 acres in bermudagrass, the modeled farm chose to establish some cropland in zoysiagrass (Table 6). In March of year one, 73.6 acres were established with bermudagrass, and the remaining 26.4 acres were established with zoysiagrass in April. The 73.6 acres of bermudagrass were harvested in April, year two, and re-established in May. The following September, 65.7 acres were harvested and sold to pay off remaining debts and cover expenses for that month; the remaining 7.9 acres were harvested in October. This approach resulted in 65.7 acres of bermudagrass being re-established in October of year two, while the remaining 7.9 acres were re-established in March of year three.

The 26.4 acres of zoysiagrass established in the first year were harvested and sold in April of year three. These acres were re-established with zoysiagrass in May. In March of the fourth year, the 73.6 acres previously allocated for bermudagrass were established in zoysiagrass. From this point through the end of year seven, all the land was used for re-establishment of zoysiagrass.

TABLE 6. OPTIMAL TURFGRASS-SOD COMBINATION FOR 100-ACRE TURF OPERATION WITH PRICE OF BERMUDAGRASS AT 60 CENTS, SOUTH ALABAMA, 1993-94

Year	Month	Activity	Acres
1	March	Establish Bermuda	73.6
	April	Establish Zoysia	26.4
2	May	Re-establish Bermuda	73.6
	October	Re-establish Bermuda	65.7
3	March	Re-establish Bermuda	7.9
	May	Re-establish Zoysia	26.4
4	March	Establish Zoysia	73.6
5	March	Re-establish Zoysia	26.4
6	April	Re-establish Zoysia	73.6
7	—	—	—

Price Sensitivity Analysis on Centipedegrass

Next, a price sensitivity analysis was conducted on centipedegrass (Scenario 5). Lowering the price of centipede would have no effect on the optimal crop combination or net returns, because the model allocated all available land to bermuda at base prices. Therefore, the price of centipedegrass was raised in 10-cent increments from its base level of $1.22 per square yard until it became competitive with bermuda and thus feasible to produce.

Centipedegrass entered production only when its price reached $2.72 (Table 7). At that price, approximately 70 acres of bermudagrass and 30 acres of centipedegrass were established in year one and then continually re-established through year seven. The net return for this model was $1,635,933 for the seven-year period (Table 1).

Table 7. Optimal Turfgrass-Sod Combination for 100-Acre Turf Operation with Price of Centipedegrass at $2.72, South Alabama, 1993-94

Year	Month	Activity	Acres
1	March	Establish Bermuda	70.1
	April	Establish Centipede	29.9
2	May	Re-establish Bermuda	70.1
3	March	Re-establish Bermuda	70.1
	May	Re-establish Centipede	29.9
	July	Re-establish Bermuda	70.1
4	May	Re-establish Bermuda	70.1
5	March	Re-establish Bermuda	70.1
	March	Re-establish Centipede	29.9
	July	Re-establish Bermuda	70.1
6	May	Re-establish Bermuda	70.1
	September	Re-establish Centipede	29.9
7	March	Re-establish Bermuda	70.1

Price Sensitivity Analysis on Zoysiagrass

Finally, a price sensitivity analysis was conducted on zoysiagrass (Scenario 6). As with centipede, lowering the price of zoysia had no effect on optimal combination or net return, so its price was increased in 10-cent increments from the base of $1.85 per square yard. Upon reaching $2.65 per square yard, zoysiagrass became competitive with bermudagrass (Table 8).

Approximately 98 acres of bermudagrass and two acres of zoysiagrass were established in the first year. These acres were then continually re-established in the same pattern until September of year six. At this point, the 1.8 acres which had been in zoysiagrass production were established in bermudagrass. This change was made

Table 8. Optimal Turfgrass-Sod Combination for 100-Acre Turf Operation with Price of zoysiagrass at $2.65, South Alabama, 1993-94

Year	Month	Activity	Acres
1	March	Establish Bermuda	98.2
	March	Establish Zoysia	1.8
2	May	Re-establish Bermuda	98.2
3	March	Re-establish Bermuda	98.2
	April	Re-establish Zoysia	1.8
	July	Re-establish Bermuda	98.2
4	May	Re-establish Bermuda	98.2
5	March	Re-establish Bermuda	98.2
	March	Re-establish Zoysia	1.8
	July	Re-establish Bermuda	98.2
6	May	Re-establish Bermuda	98.2
	September	Establish Bermuda	1.8
7	March	Re-establish Bermuda	98.2

because zoysiagrass could not be re-established at that time and be ready for harvest before the end of year seven. Therefore, bermudagrass, with its shorter production cycle, was established in place of zoysiagrass. Net return for this model was $1,615,987 (Table 1).

Price Sensitivity Analysis Without Price Seasonality for Bermuda

Price sensitivity analyses provided slightly different results when bermudagrass price seasonality was not considered. When seasonality was a factor, the model began to demonstrate crop-mix changes when bermuda was priced at 70 cents per square yard. However, without price seasonality, the 70-cent level provided the same optimal solution as the base price of $1.00. At 60 cents, the model with price seasonality began to bring zoysiagrass into production. But without price seasonality, zoysiagrass was not brought into production until the price of bermudagrass reached 50 cents per square yard.

Also in the models without price seasonality, the prices of centipedegrass and zoysiagrass had to be increased to higher levels before the crops were brought into production. The prices of zoysiagrass and centipedegrass had to be raised to $2.95 and $3.02, respectively. Both these prices are 30 cents per square yard higher than in the model with bermuda price seasonality.

Variation of Starting Capital

Starting capital available to the producer also was varied in the analysis to determine its effect on the optimal solution for the model (Scenario 7). Bermuda price seasonality was considered, but there was no forced production of zoysia or centipede. Starting capital was increased in $50,000 increments from its original value of $1 (all borrowing) up to $300,000 (all equity).

Increasing capital had no effect on the optimal combination of turfgrass-sod varieties. The model farm continued to allocate all available cropland to bermudagrass production when the producer's starting capital was increased to $300,000. However, increasing available capital from $1 to $300,000 did increase net return from $1,615,917 to $1,694,765. With a greater level of starting capital, the producer borrows less and thus has smaller interest expenses and increased profitability (Table 9).

TABLE 9. CAPITAL VARIATION AND THE EFFECT ON NET RETURNS, 100-ACRE TURFGRASS OPERATION, SOUTH ALABAMA, 1993-94

Starting capital	Net returns
$ 1	$1,615,917
50,000	1,630,395
100,000	1,644,873
150,000	1,658,690
200,000	1,671,189
250,000	1,682,977
300,000	1,694,765

Economic Feasibility of Turf on a Traditional Farm

Results of scenarios 1-7 were incorporated into the mixed integer programming model, which simulates a 948-acre, more conventional farming operation in south Alabama. This approach placed turfgrass-sod production into competition with cotton, wheat, and soybeans for the resources available on the farm. Thus, the economic feasibility of incorporating turfgrass-sod production into a more traditional farm could be evaluated. The producer in this model had the option of devoting up to 100 of the 948 acres to turfgrass-sod production.

Results of the base scenario — in which bermuda, centipede, and zoysia were priced at $1.00, $1.22, and $1.85, respectively — were first incorporated into the more comprehensive farm model. Since this scenario provided the highest net return in turfgrass production, it was expected to provide a situation in which turfgrass would be the most competitive with cotton and the other crops. Under conditions of the base scenario, the representative farm produced turfgrass-sod on all 100 of the acres set aside for that purpose (Table 10).

In years one and two of the farm simulation, all acreage not planted in turfgrass was allocated to cotton production outside the commodity program. This 848-acre allocation was made to allow the representative farm to build cotton base. Cotton acreage eligible for enrollment in the Farm Bill commodity program is calculated as a moving average of acres planted for the three years prior to enrollment. In exchange for limiting cotton acreage to a portion of this base, producers are eligible for deficiency payments. To expand cotton base acreage, farmers can plant cotton outside the farm program for one or more years.

In year three, program cotton was produced on 565 acres, which was the size of the cotton base that year. Another 283 acres were allotted to the production of double-cropped wheat and soybeans outside the program. The representative farmer continued to produce program cotton up to its base limit in years 4-7, with the remainder of

TABLE 10. CROP COMBINATIONS SELECTED BY MIXED INTEGER MODEL, 948-ACRE FARM IN SOUTH ALABAMA, 1993-94[1]

Year	Turf	AFC	APC	SB	WAPW	WTSB
1	100	848	0	0	0	0
2	100	848	0	0	0	0
3	100	0	565	0	0	283
4	100	0	754	0	0	94
5	100	0	722	0	0	126
6	100	0	680	0	0	168
7	100	0	719	0	0	129

[1]AFC = cotton outside the governmental program; APC = program cotton; SB = soybeans; WAPW = program wheat double cropped with soybeans; and WTSB = non-program wheat double cropped with soybeans.

the available cropland used for double-cropped wheat and soybeans outside the program.

Forced production of centipedegrass and zoysiagrass (Scenario 3) provided less profitable results than the base model. Therefore, it was possible that the mixed integer model would choose not to produce turfgrass under Scenario 3 conditions. However, the results from this model were exactly the same as the results reported in Table 10, with 100 acres being allocated to turfgrass production.

Other scenarios with lower net returns (obtained from conducting price sensitivity analyses on the turfgrasses) also were incorporated into the mixed integer programming model. Results were the same as those shown in Table 10. Even with the price of bermudagrass lowered to 40 cents per square yard, turfgrass competed well with traditional agricultural commodities for resources.

SUMMARY

The primary objective of this study was to determine the economic feasibility of turfgrass-sod production. Other objectives were to determine: the price sensitivity of alternative turfgrass species; the effect of price on competitive advantage of each variety; the feasibility of incorporating turfgrass-sod production into an existing farm; and the effect of limited starting capital on the optimal combination of turfgrasses.

To accomplish these objectives, two models were developed. One was a linear programming model concerned with determining the profit maximizing combination of alternative turfgrass-sod warm-season varieties typically grown in south Alabama. The other was a mixed integer programming model dealing with crop mix decisions on a representative south Alabama cotton, wheat, and soybean farm.

The linear programming model was used to provide information concerning optimal combination of turfgrasses, price sensitivity of each variety, and the effect of limited starting capital on the optimal combination. These results were incorporated into the mixed integer programming model to determine the economic feasibility of producing turfgrass-sod on a more conventional farm and to evaluate the effects of different turfgrass prices on that feasibility.

The linear programming model allocated the entire 100 acres of available cropland to bermudagrass production when no constraints were included to force the production of other turfgrass species. When constraints were included to force production of other turfgrass species, all land not needed to satisfy these constraints was allocated to bermudagrass production.

Price sensitivity analyses revealed very few changes in the optimal combination of turfgrass-sod varieties. Including the effect of price seasonality, the price of bermudagrass had to be lowered 40 cents per square yard below its base price before other turfgrasses were brought into production. Base prices of centipedegrass and zoysiagrass had to be increased $1.50 and 80 cents, respectively, with prices of other varieties held constant, before these grasses were brought into production.

The same outcome was found when results from the linear programming model were incorporated into the mixed integer model. In each scenario, the entire 100 acres available for turfgrass-sod production on the 948-acre south Alabama farm were used for that purpose. Thus, turfgrass-sod competed effectively with traditional agricultural enterprises for resources.

CONCLUSIONS

This study indicates that bermudagrass is the most profitable of the three turfgrass species analyzed, regardless of the effects of price seasonality and the level of starting capital. Price variations in the different varieties have little effect on the profit maximizing combination of grasses. These findings are not likely to change unless current market conditions, production practices, and prices change drastically. Of course, demand conditions in particular markets may affect these conclusions; for example, consumer demand for the premium-valued grasses.

Furthermore, results of this study suggest that it is economically feasible to incorporate turfgrass-sod production into an existing, more conventional, farming operation. This relationship holds true even when the prices received for the different turfgrass-sod species are well below their averages.

Given current prices, markets seem sufficient to absorb additional production, but farmers considering turfgrass as an alternative enterprise must understand the differences between turfgrass markets and traditional crop markets. While traditional crops generally have readily available markets, turfgrass outlets are not always available. They must be nurtured and developed. Turf producers may need to provide transportation, handling, sprigging, and other services to attract buyers. Traditional crop farmers who wish to produce turf might develop relationships with larger, established turf farms and produce grass for them on a contract basis. Thus, they can benefit from the market contacts and expertise of these operations and salespeople. Ideally, farmers growing turf on a contract basis would understand their costs so as to effectively bargain for favorable prices on contract.

A shortcoming of the analysis is that markets are assumed to be present for the available turf at maturity and harvest. As noted, bermudagrass prices have shown a tendency to be seasonally sensitive to market supplies. Thus, producers may have to hold mature grass in inventory longer than that defined in this study. However, the analysis somewhat addresses this issue through use of conservatively long production cycles. To the extent that this issue is not addressed in the analysis, defined net returns will be reduced. Previous research indicates that turf operations exhibit substantial scale economies *(2)*. Thus, larger turf farms will have greater ability to cope with downward price pressures and still maintain a profit.

Production cycles for the three grasses are extremely important in influencing economic feasibility. Bermudagrass benefits from its relatively short production cycle and the resulting impact on cash flow. More than one crop of bermudagrass can be produced in the same amount of time it takes to grow one crop of either centipedegrass or zoysiagrass. Therefore, the total profits per unit of land for a fixed time period are greater for bermudagrass production, given current markets and related prices.

New, more intensive production practices or introduction of new technologies to shorten production cycles could affect feasibility. For example, use of netting to permit earlier harvest, especially for centipede and somewhat for zoysia, could cut several months off of the production cycle and limit problems related to slower root development and integrity of the squares or rolls in harvest and installation. These alternative technologies and practices would require additional economic analysis.

REFERENCES

(1) Adrian, John L., J. A. Yates, and Ray Dickens. "Commercial Turfgrass-Sod Production in Alabama." Alabama Agricultural Experiment Station Bulletin #529, August 1981.

(2) Adrian, John L., Robert White, and Ray Dickens. "Turfgrass-Sod Production as An Alternative Use for Farm Resources." Journal of the American Society of Farm Managers and Rural Appraisers. 56(1992):41-46.

(3) Cain, Danny L. "Acreage and Farm Program Participation Decisions Made on Alabama Cotton Farms Under Provisions of The 1990 Farm Bill." Unpublished Master's Thesis, Auburn University, August 1992.

(4) Hamrick, John. Unpublished Manuscript. Auburn University, Alabama. 1993.

(5) Loyd, William Michael. "Turfgrass-Sod Production: Economic Feasibility." Unpublished Master's Thesis, Auburn University, March 1994.

(6) White, Robert W. "Economic and Agronomic Aspects of Commercial Turfgrass-Sod Production in Alabama." Unpublished Master's Thesis, Auburn University, 1990.

(7) White, Robert W., John L. Adrian, and Ray Dickens. "Alabama's Turfgrass-Sod Industry." Alabama Agricultural Experiment Station Bulletin #610, 1991.

APPENDIX A

Estimated costs per acre per production period for establishing or re-establishing 100 acres of alternative turfgrass varieties on a South Alabama farm, 1993-94

Appendix Table 1. Early-season Establishment of Bermudagrass

Item	Cost per acre
Variable Costs	
Herbicides	$ 48.78
Insecticides/Fungicides	15.56
Fertilizer and lime	171.00
Fuel and lubrication	126.40
Repairs	193.47
Hired labor	160.00
Irrigation	77.76
Land preparation	900.00
Other	117.22
Interest on variable capital	162.92
Total variable costs	1,973.11
Fixed costs	
Insurance	41.86
Taxes	4.66
Depreciation	128.94
Miscellaneous	16.88
Interest on fixed capital	444.92
Total fixed costs	637.26
Total costs	2,610.37

Appendix Table 2. Early-season Establishment of Centipedegrass

Item	Cost per acre
Variable Costs	
Herbicides	$ 85.40
Insecticides/fungicides	27.24
Fertilizer and lime	275.00
Fuel and lubrication	221.20
Repairs	338.52
Hired labor	230.00
Irrigation	181.44
Land preparation	900.00
Other	205.13
Interest on variable capital	221.75
Total variable costs	2,685.68
Fixed costs	
Insurance	74.75
Taxes	8.32
Depreciation	230.25
Miscellaneous	30.25
Interest on fixed capital	794.50
Total fixed costs	1,138.07
Total costs	3,823.75

Appendix Table 3. Early-season Establishment of Zoysiagrass

Item	Cost per acre
Variable Costs	
Herbicides	$ 85.40
Insecticides/fungicides	27.24
Fertilizer and lime	289.00
Fuel and lubrication	221.20
Repairs	338.52
Hired labor	230.00
Irrigation	181.44
Land preparation	900.00
Other	205.13
Interest on variable capital	223.01
Total variable costs	2,700.94
Fixed costs	
Insurance	74.75
Taxes	8.32
Depreciation	230.25
Miscellaneous	30.25
Interest on Fixed Capital	794.50
Total fixed costs	1,138.07
Total costs	3,839.01

Appendix Table 4. Late-season Establishment of Bermudagrass

Item	Cost per acre
Variable Costs	
Herbicides	$ 64.05
Insecticides/fungicides	20.43
Fertilizer and lime	171.00
Fuel and lubrication	165.90
Repairs	253.89
Hired labor	160.00
Irrigation	77.76
Land preparation	900.00
Other	154.60
Interest on variable capital	177.09
Total variable costs	2,144.72
Fixed costs	
Insurance	41.86
Taxes	4.66
Depreciation	128.94
Miscellaneous	16.94
Interest on fixed capital	444.92
Total fixed costs	637.32
Total costs	2,782.04

Appendix Table 5. Late-season Establishment of Centipedegrass

Item	Cost per acre
Variable cost	
Herbicides	$ 100.65
Insecticides/fungicides	32.11
Fertilizer and lime	275.00
Fuel and lubrication	260.70
Repairs	338.97
Hired labor	230.00
Irrigation	213.84
Land preparation	900.00
Other	241.76
Interest on variable capital	233.37
Total variable costs	2,826.40
Fixed costs	
Insurance	74.75
Taxes	8.33
Depreciation	230.25
Miscellaneous	30.25
Interest on fixed capital	794.50
Total fixed costs	1,138.08
Total costs	3,964.48

Appendix Table 6. Late-season Establishment of Zoysiagrass

Item	Cost per acre
Variable Cost	
Herbicides	$ 100.65
Insecticides/fungicides	32.11
Fertilizer and lime	289.00
Fuel and lubrication	260.70
Repairs	398.97
Hired labor	230.00
Irrigation	213.84
Land preparation	900.00
Other	241.76
Interest on variable capital	234.63
Total variable costs	2,841.66
Fixed costs	
Insurance	74.75
Taxes	8.33
Depreciation	230.25
Miscellaneous	30.25
Interest on fixed capital	794.51
Total fixed costs	1,138.08
Total costs	3,979.74

Appendix Table 7. Early-season Re-establishment of Bermudagrass

Item	Cost per acre
Variable cost	
Herbicides	$ 12.20
Insecticides/fungicides	3.89
Fertilizer and lime	93.00
Fuel and lubrication	31.60
Repairs	48.36
Hired labor	100.00
Irrigation	25.92
Land preparation	0.00
Other	29.30
Interest on variable capital	30.98
Total variable costs	375.25
Fixed costs	
Insurance	11.96
Taxes	1.33
Depreciation	36.84
Miscellaneous	4.84
Interest on fixed capital	127.12
Total fixed costs	182.09
Total costs	557.34

Appendix Table 8. Early-season Re-establishment of Centipedegrass

Item	Cost per acre
Variable cost	
Herbicides	$ 76.25
Insecticides/fungicides	24.30
Fertilizer and lime	209.00
Fuel and lubrication	197.50
Repairs	302.25
Hired labor	200.00
Irrigation	162.00
Land preparation	0.00
Other	183.15
Interest on variable capital	121.90
Total variable costs	1,476.35
Fixed costs	
Insurance	53.60
Taxes	6.00
Depreciation	165.78
Miscellaneous	21.78
Interest on fixed capital	572.04
Total fixed costs	819.42
Total costs	2,295.77

Appendix Table 9. Early-season Re-establishment of Zoysiagrass

Item	Cost per acre
Variable cost	
Herbicides	$ 76.25
Insecticides/fungicides	24.30
Fertilizer and lime	223.00
Fuel and lubrication	197.50
Repairs	302.25
Hired labor	200.00
Irrigation	162.00
Land preparation	0.00
Other	183.15
Interest on variable capital	123.16
Total variable costs	1,491.61
Fixed costs	
Insurance	53.82
Taxes	6.00
Depreciation	165.78
Miscellaneous	21.78
Int. on fixed capital	572.04
Total fixed costs	819.42
Total costs	2,311.03

Appendix Table 10. Late-season Re-establishment of Bermudagrass

Item	Cost per acre
Variable cost	
Herbicides	$ 36.60
Insecticides/fungicides	11.68
Fertilizer and lime	93.00
Fuel and lubrication	94.80
Repairs	145.08
Hired labor	120.00
Irrigation	77.76
Land preparation	0.00
Other	87.91
Interest on variable capital	60.01
Total variable costs	726.84
Fixed costs	
Insurance	29.90
Taxes	3.33
Depreciation	92.10
Miscellaneous	12.10
Interest on Fixed Capital	317.80
Total fixed costs	455.23
Total costs	1,182.07

APPENDIX TABLE 11. LATE-SEASON RE-ESTABLISHMENT OF CENTIPEDEGRASS

Item	Cost per acre
Variable cost	
Herbicides	$ 100.65
Insecticides/fungicides	32.11
Fertilizer and lime	275.00
Fuel and lubrication	260.70
Repairs	398.97
Hired labor	230.00
Irrigation	213.84
Land preparation	0.00
Other	241.76
Interest on variable capital	157.77
Total variable costs	1,910.88
Fixed costs	
Insurance	74.75
Taxes	8.33
Depreciation	230.25
Miscellaneous	30.25
Interest on fixed capital	794.51
Total fixed costs	1,138.08
Total costs	3,048.88

APPENDIX TABLE 12. LATE-SEASON RE-ESTABLISHMENT OF ZOYSIAGRASS

Item	Cost per acre
Variable cost	
Herbicides	$ 100.65
Insecticides/fungicides	32.11
Fertilizer and lime	289.00
Fuel and lubrication	260.70
Repairs	398.97
Hired labor	230.00
Irrigation	213.84
Land preparation	0.00
Other	241.76
Interest on variable capital	159.03
Total variable costs	1,926.06
Fixed costs	
Insurance	74.75
Taxes	8.33
Depreciation	230.25
Miscellaneous	30.25
Interest on fixed capital	794.51
Total fixed costs	1,138.08
Total costs	3,064.14

APPENDIX B

Assumptions, Methodology, and Models Used in Turfgrass Feasibility Analysis

An objective of this study was to determine the economic feasibility of incorporating a turfgrass-sod production enterprise into an existing farm operation. To accomplish this objective, two different programming models were used. One model was a linear programming model dealing with the optimal combination of turf crops for selected production situations given specified resource constraints. The other model is a mixed integer programming model dealing with crop mix decisions on a representative south Alabama cotton, wheat, and soybean farm with 948 acres of available land. The linear programming model was used to determine which combination of turfgrass varieties would be integrated into the mixed integer programming model for the representative south Alabama farm. The following discussion provides details relative to the models used and assumptions included to conduct this study.

Linear Programming Model

The linear programming model used in this study is a revision of a model used in a study to determine the optimal combinations of turf varieties for selected production situations given specified resource constraints *(4)*. This model represents a 100-acre turfgrass-sod production enterprise located in central Alabama. The first step in developing the linear programming model was to construct a model turfgrass farm which exhibits the practices common to turf operations currently in production in Alabama. To develop the model farm, the turfgrass species suitable for growth in Alabama had to be identified. Bermudagrass, centipedegrass, and zoysiagrass were found to be most popular in Alabama and were thus used in the models.

Next, enterprise budgets were developed to estimate costs of producing turfgrass sod. The existing budgets from a 1990 study *(7)* were updated for each of the three turfgrass species. These budgets were modified to fit the various production periods associated with each specie and to reflect differences between establishment and re-establishment alternatives. From this budget information, the multi-period linear programming model was developed. The estimated cost for early- and late-season establishment and re-establishment of bermudagrass, centipedegrass, and zoysiagrass are shown in Appendix A.

The estimated costs shown in appendix tables 1-12 have a fairly consistent ratio of fixed to total cost. For early-season bermudagrass establishment, fixed cost makes up approximately 24% of total cost. For early-season centipedegrass and zoysiagrass establishment, the fixed costs comprise approximately 29% of the total cost. There is little change in the cost ratios when late-season establishment is considered, with the fixed to total cost ratio changing by less than 1% for all of the turfgrass-sod varieties.

When considering re-establishment, there is an increase in the fixed to total cost ratio for each of the three varieties. Bermudagrass has a fixed to total cost ratio of 33% for early-season re-establishment and a ratio of 37% for late-season re-establishment. Early-season re-establishment of centipedegrass has a fixed to total cost ratio of 36%, while early-season re-establishment of zoysiagrass has a ratio of 35%. The fixed to total cost ratios for both centipedegrass and zoysiagrass increase to 37% when late-season re-establishment is considered. The main reason for the increase in the fixed to total cost ratio from establishment to re-establishment of the three varieties is that land preparation, a variable cost, is minimal in the re-establishment process, while it is one of the major expenses in establishing turfgrass.

The major variable expense for both early- and late-season establishment of any of the turfgrass varieties is land preparation. The largest fixed cost for early- or late-season establishment is interest charged on fixed capital, with this item being nearly twice as high for centipedegrass and zoysiagrass as it is for bermudagrass per crop. For the re-establishment of the different varieties, there is usually a small outlay for land preparation. The largest fixed cost for both early- and late-season re-establishment is interest charged on fixed capital, just as it was for establishment of the turfgrass varieties.

The objective of this model was to maximize profit over a seven-year period. This goal of profit maximization was subject to several constraints. Only 100 acres of land were available for turfgrass in each of the seven years. In the initial analysis, the amount of starting capital also was limited to $1 in the model. This requirement forced money to be borrowed in order for turfgrass to be grown and made the model more realistic because few producers have the large amount of capital needed to grow turfgrass-sod unless they obtain it by borrowing. An early model also contained constraints which forced a minimum level of centipede and zoysia to be grown. This action ensured that the higher-valued varieties with longer production periods would be grown along with the lower-valued variety with a shorter production cycle. Specifically, the model forced 10 acres of both zoysiagrass and centipedegrass to be sold in years three through seven. These grasses were not forced to be sold in years one and two because the grasses were still in production. Other constraints included labor and length of the growing season. However, the model did allow additional labor to be hired when needed.

The main difference between producing turfgrass-sod in central Alabama and southern Alabama is the length of the growing season in each area. The growing season for turfgrass-sod production is generally around two months longer in southern Alabama than in central Alabama. Because of this, the main revisions to the linear programming model dealt with lengthening the growing season for each of the turfgrass varieties. After the revisions were completed, the linear programming model for south Alabama had a growing season of eight months, compared to six months for central Alabama. This change resulted in a shorter production period for each of the turfgrass-sod varieties. This, in turn, allowed each variety of turfgrass to be established or re-established more frequently in south Alabama than was possible on a central Alabama farm. Appendix Table 13 shows the number of growing months required by each turfgrass variety for both early- and late-season establishment and re-establishment.

APPENDIX TABLE 13. GROWING MONTHS SPECIFIED FOR TURFGRASS VARIETIES, SOUTH ALABAMA, 1993-94

Grass and season	Growing months required
Bermudagrass establishment	
Early season	10
Late season	10
Bermudagrass re-establishment	
Early season	4
Late season	6
Centipedegrass re-establishment	
Early season	17
Late season	17
Zoysiagrass establishment	
Early season	17
Late season	17
Zoysiagrass re-establishment	
Early season	14
Late season	17

Appendix Table 14 presents a comparison between south and central Alabama for the production period of the different turfgrass-sod varieties. This table illustrates the effect that lengthening the growing season by two months has on the production period for each of the turfgrass-sod varieties.

The linear programming model used was comprised of several different sections. Each of these sections was revised to reflect the eight-month growing period in south Alabama. After these revisions were complete, results from the model were available to be incorporated into the mixed integer programming model.

One section of the linear programming model dealt with cash flow. This section allowed money to borrowed, repaid, and saved. It also allowed interest to be earned on savings and interest to be charged on borrowed capital. Another section of the model allowed establishment and re-establishment of the various turfgrass species. Other sections of the model permitted sod to be sold or placed in inventory and labor to be hired, when necessary

Appendix Table 15 illustrates the cash flow section of the model for June of year two in MPSX format. The first digit after each variable name represents the month, and the second digit represents the year. For example, the BOR6-2 variable stands for borrowing in June of year two. The IE column takes interest earned on savings and transfers it into that income. The TDBT column transfers debt from one period to the next and allows for interest to be charged on the debt. The value of .0067 for the BRXT

Appendix Table 14. Comparison of Production Periods for Turfgrass Species, South and Central Alabama, 1993-94

Grass and season	Area of Alabama	
	South	Central
	Months	*Months*
Bermudagrass establishment		
Early season	14	16
Late season	14	22
Bermudagrass re-establishment		
Early season	4	4
Late season	10	12
Centipedegrass establishment		
Early season	25	29
Late season	25	35
Centipedegrass re-establishment		
Early season	18	26
Late season	25	35
Zoysiagrass establishment		
Early season	25	29
Late season	25	35
Zoysiagrass re-establishment		
Early season	18	26
Late season	25	35

APPENDIX TABLE 15. CASH FLOW SECTION FOR JUNE OF YEAR TWO IN MPSX FORMAT, LINEAR PROGRAMMING MODEL

IE6-2	INTF6-2		1.00000	NTRAN-2	-	1.00000
TDBT6-2	DEBT6-2	-	1.00000	BRXT6-2		.00670
TDBT6-2	DEBT6-2		1.00000			
IXP6-2	BRXT6-2	-	1.00000	CASH7-2		1.00000
IXP6-2	XTRAN-2		1.00000			
BOR6-2	CASH6-2	-	1.00000	DEBT6-2		1.00010
SAV6-2	CASH6-2		1.00000	SAVT6-2		1.00000
SAVB6-2	MONT6-2	-	1.00000	SAVT6-2	-	1.00000
MONN6-2	MONT6-2		1.00000	CASH7-2	-	1.00000
MONL6-2	MONT6-2		1.00000	SAVT7-2		1.00400
MONL6-2	INTF7-2	-	0.00400			
REPAY6-2	CASH6-2		1.00000	DEBT7-2	-	1.00000

variable is the interest rate charged against borrowed capital for that month. It is derived by dividing 8%, the annual interest rate used in the model, by 12 months. IXP is the interest expense column. It charges the interest expense against cash and increases the total expenses. The BOR column is the borrowing activity. It increases both the amount of cash available and the amount of debt owed.

The SAV column is the saving activity for that period and increases the cash available. The SAVB column is the saving activity for the entire model. It monitors the total amount of money in savings and transfers money into the MONN and MONL columns. The MONN column makes money available for the next period. The MONL column takes money not used by MONN and puts it into savings for the next period, allowing it to accumulate interest. The value of .004 for the INTF variable is the monthly interest rate for money in savings. It is derived by dividing 4.8%, the annual interest rate for savings used in the model, by 12 months. The REPAY column is used for repayment of debts. It decreases both the amount of debt owed and amount of cash available for operation.

Another section of the model allows for the establishment and re-establishment of the various turfgrass species. Appendix Table 16 shows a section of the linear programming model dealing with the establishment of bermudagrass in March of year two.

The CASHi-j variables represent the expenses associated with the establishment of bermudagrass in month i of year j. CASH3-2 has a higher value because of the large cost of land preparation, which has to be done in the first month. The XTRAN variables represent the total expenses associated with the establishment of bermudagrass for that year.

The LANDi-j rows require that each acre of bermudagrass established in March of year two occupy at least one acre of land in that month and year. The LABi-j rows force each acre of bermudagrass established in March of year two to use the specified amount of labor in that month and year. The LAB3-2 and LAB4-3 rows have a value

Appendix Table 16. Bermudagrass Establishment Section for March of Year Two in MPSX Format, Linear Programming Model

EBERM3-2	CASH3-2	991.31000	CASH4-2	91.31000
EBERM3-2	CASH5-2	91.31000	CASH6-2	91.31000
EBERM3-2	CASH7-2	91.31000	CASH8-2	91.31000
EBERM3-2	CASH9-2	91.31000	CASH0-2	91.31000
EBERM3-2	CASH3-3	91.31000	CASH4-3	91.31000
EBERM3-2	XTRAN-2	1630.48000	XTRAN-3	182.62000
EBERM3-2	LAND3-2	1.00000	LAND4-2	1.00000
EBERM3-2	LAND5-2	1.00000	LAND6-2	1.00000
EBERM3-2	LAND7-2	1.00000	LAND8-2	1.00000
EBERM3-2	LAND9-2	1.00000	LAND10-2	1.00000
EBERM3-2	LAND11-2	1.00000	LAND12-2	1.00000
EBERM3-2	LAND1-3	1.00000	LAND2-3	1.00000
EBERM3-2	LAND3-3	1.00000	LAND4-3	1.00000
EBERM3-2	LAB3-2	8.00000	LAB4-2	2.00000
EBERM3-2	LAB5-2	2.00000	LAB6-2	2.00000
EBERM3-2	LAB7-2	2.00000	LAB8-2	2.00000
EBERM3-2	LAB9-2	2.00000	LAB10-2	2.00000
EBERM3-2	LAB3-3	2.00000	LAB4-3	8.00000
EBERM3-2	SLB4-3	-4000.00000		

of 8.0 because it generally requires about eight man hours per acre both to establish and harvest bermudagrass. The other LAB rows have a value of 2.0 because that is how many man hours per acre it usually requires to maintain the bermudagrass.

The SLB row allows the harvested bermudagrass to be transferred to the section of the model where it can be sold. It has a value of 4,000 because that is how many square yards of sod assumed to be harvested from one acre of turfgrass. Thus, 17.4% of the area is available for grass strips to re-establish the turf and to reflect waste or non-marketable grass.

Other sections of the model allow the sod to be sold or placed into inventory and allow labor to be hired, when necessary. Appendix Table 17 illustrates sections of the model dealing with the sale and inventory of grasses, and the hiring of labor in March of year three. The EINVB column is the activity for putting bermudagrass in inventory. The .00025 value for the LAND3-3 row requires .00025 of an acre of land to be occupied when one square yard of sod is held in inventory. The SLBi-j rows allow bermudagrass to be brought into inventory and transfer it from one month to the next.

The SBERM column is the activity for selling bermudagrass. It increases NTRAN and CASH by the value of one yard of sod. In this case, one square yard of bermudagrass is worth 95 cents. It also credits RSBER with one square yard of sod. The RSBER row allows for the re-establishment of bermudagrass after it is harvested and sold. For every square yard of bermudagrass that is sold, .00025 acres of land can be re-established with bermudagrass.

APPENDIX TABLE 17. INVENTORY, SALE, AND HIRE LABOR SECTIONS FOR MARCH OF YEAR THREE IN MPSX FORMAT, LINEAR PROGRAMMING MODEL

EINVB3-3	LAND3-3		.00025	SLB2-3		1.00000
EINVB3-3	SLB3-3	-	1.00000			
SBERM3-3	CASH3-3	-	.95000	NTRAN-3	-	0.95000
SBERM3-3	RSBER4-3	-	.00025	SLB3-3		1.00000
HLAB3-3	CASH3-3		800.00000	XTRAN-3		800.00000
HLAB3-3	LAB3-3	-	160.00000			

The HLAB column is the activity that allows labor to be hired when it is needed. It increases labor available in that period by 160 hours and charges CASH and XTRAN $800. The cost of labor in the model is $5 per hour. The $800 results from multiplying 160 hours of labor by the rate of $5 per hour.

After the linear programming model had been revised to reflect south Alabama conditions, it could be used to evaluate the sensitivity of grass production to alternative prices of the grasses. This analysis was conducted to determine the effect that different turfgrass-sod prices have on the optimal combination of turfgrass-sod varieties. The goal of this approach was to determine the price a given turfgrass-sod variety must reach before the other varieties were brought into production. To conduct this analysis, different prices for each turfgrass variety were used while the prices of the other varieties were held constant.

The first price variations were done on bermudagrass. The original price used for bermudagrass in the linear programming model was $1.00 per square yard. From $1.00, the price of bermudagrass was varied in 10-cent increments up to $1.40 and down to 60 cents. At the same time, the prices of centipedegrass and zoysiagrass were held constant at the base levels of $1.22 and $1.85 per square yard, respectively. Because the price of bermudagrass tends to decrease throughout the marketing period, the price received for bermudagrass was decreased by 5 cents per square yard per month.

Price variations were then analyzed for centipedegrass and zoysiagrass. The price of centipedegrass was varied in 10-cent increments from its original price of $1.22 up to $2.72. The price of zoysiagrass also was varied in 10-cent increments, from its original price of $1.85 up to $2.65. Unlike bermudagrass, however, the prices of centipedegrass and zoysiagrass do not generally decrease throughout the marketing season. Thus, the price of zoysiagrass and centipedegrass are held at the base levels.

The price sensitivity analyses also were conducted on the three varieties without bermudagrass being subject to price seasonality. This approach revealed how the optimal combination of turfgrass-sod varieties changes when there is no seasonal decrease in the price of bermudagrass.

After the price sensitivity analysis was completed, the amount of starting capital available to the producer was varied in the linear programming model. This variation was done to determine the effect of different amounts of starting capital on the

APPENDIX TABLE 18. DATA FOR REPRESENTATIVE SOUTH ALABAMA FARM, 1993

Land availability (acres)	
Total cropland	948
Initial cotton base	492
Initial wheat base	38
Yields	
Cotton (lb./a.)	678
Wheat (bu./a.)	36
Double-cropped soybeans (bu./a.)	22
Full-season soybeans (bu./a.)	24
Variable costs per acre	
Cotton	$ 333.02
Full-season soybeans	82.54
Double-cropped soybeans	149.76
Market price per unit	
Cotton	$ .62
Wheat	2.50
Soybeans	5.50
Target price per unit	
Cotton	$ .729
Wheat	4.00
Deficiency payment per unit	
Cotton	$ .109
Wheat	1.50

optimal combination of turfgrass-sod varieties. To conduct this analysis, the amount of starting capital available in the model was varied in $50,000 increments from its original value of $1 up to $300,000.

The mixed integer programming model used in this study was originally created in a study of crop mix and farm program participation decisions made under conditions of the 1990 Farm Bill *(3)*. Data collected from the Alabama Cooperative Extension Service and the Gulf Coast Farm Analysis Association were used to design a representative south Alabama farm. The main cash crop grown on the farm was cotton. Wheat and soybeans also were included since both are adapted for production in Alabama. The representative farm had 948 acres of available crop land, with an initial cotton base of 492 acres and an original wheat base of 38 acres. Using this and the other data, the mixed integer programming model was developed from the representative farm. Appendix Table 18 provides a description of the representative south Alabama farm.

Labor in the mixed integer programming model is divided into six periods. The representative south Alabama farm is assumed to have an initial endowment of unpaid family labor equal to two full-time equivalents. In addition, the model could hire additional labor if it is needed. The hired labor is assumed to be hourly and could be hired in any period in which it is needed. This approach allowed labor to be hired only

APPENDIX TABLE 19. LABOR REQUIREMENTS FOR CROP ENTERPRISES IN MAN-HOURS PER ACRE, ALABAMA, 1993

Time period	Enterprise		
	Cotton	Soybeans	Wheat-Soybeans
	Hr./a.	*Hr./a.*	*Hr./a.*
Feb. 11-March 31	.2	.6	.4
April 1-April 30	.6	.7	0
May 1-June 30	1.5	1.1	1.3
July 1-Aug. 31	1.2	0	0
Sept. 1-Nov. 30	.4	1.0	2.1

in the needed periods and not contracted for a full year. The cost of hiring additional labor is $5.00 per hour. Appendix Table 19 gives the per acre estimated labor requirements for the crops considered in the model.

The main revision to the mixed integer programming model was converting it from a five-year to a seven-year period. This change is made so that it would be comparable with the results of the linear programming model, which is based on a seven-year period. A seven-year period is used in the turfgrass linear programming model because most equipment used in turfgrass-sod production has a useful life of approximately seven years. After this revision, the results from the linear programming model were incorporated.

The first step in integrating the results of the linear programming model into the mixed integer programming model was to combine the optimal combination of turfgrass varieties into a single activity, labeled TURF. To do this, all the expenses for each year were totaled. These expenses included variable and fixed costs. The labor expense for each year also were included in this total. Next, the total returns for each year were calculated. The total costs were then subtracted from the total returns for each year, giving net income per year. This value is then divided by 100, because the model is producing 100 acres of turfgrass. This adjustment results in net income per acre for each year. These values are entered into the mixed integer programming model for the INTRAN variables.

Appendix Table 20 is a sample matrix for the second year from the mixed integer programming model. It was in this section that the model chose which combination of crops to grow on the south Alabama farm. For turfgrass-sod to be considered economically feasible, the mixed integer programming model had to choose to grow turfgrass when compared to the other crops available.

The TURF column represents the turfgrass-sod production activity for year two of the model. The TR1-i rows force the model to produce the same amount of turf in each year of the model. This requirement prevents other crops from being grown on land that had turf established on it the previous year. The INTRAN row is the income transfer row. It is negative in the TURF column because it represents net income for each year. It is positive in the other columns because it represents variable cost per acre for these activities.

The TCRPL row is the total cropland constraint for each year. It forces total cropland used in each year to be equal to or less than 948 acres. The LAB rows are the labor constraints for each period of each year. They are constrained to be equal to or less than the total man-hours available in each period. If more labor is needed than is available, the model allows it to be hired at $5.00 an hour. The SODLD row constrains the amount of cropland that can be planted to turfgrass in each year. It forces land established in turf to be 100 acres or less in each year.

The PLAC column is the planted program cotton acreage activity for each year. The TFCOT row is a nonprogram cotton transfer for each year. The TPCOT row transfers the amount of program cotton produced each year into another activity where a deficiency payment can be calculated.

The XLAC column represents planted program cotton acreage on cotton optional flex acres in each year. The OFLMC row limits the maximum amount of program planted acres of cotton to the amount of available optional flex acres originating from program cotton. The OFLM row limits the total amount of optional flex acres from both program cotton and program wheat.

The AFC column is the nonprogram cotton acreage activity for each year. The ANCL row calculates the total number of cotton acres planted and "considered planted" for each year. The FAL row keeps nonprogram cotton from entering the solution unless the nonparticipation activity is chosen. If nonparticipation is chosen, the large negative transfer from the FAL row becomes a nonconstraining resource used by the nonprogram cotton acreage activity.

The XFC column represents nonprogram cotton planted on normal flexed acreage in each year. The XF2 column is the nonprogram cotton planted on wheat optional flex acreage activity for each year. The NFLM row is the normal flex acreage constraint for each year.

The SB, XB, and XB2 columns all deal with soybeans. The SB column is the soybean acreage activity for each year, the XB column is the soybean acreage planted on normal flex acreage activity in each year, and the XB2 column is the soybean acreage planted on optional flex acreage in each year. TSB is a soybean transfer row for each year.

The WTSBPA column represents planted program wheat-soybean acreage for each year. The XTSBPA column represents planted program wheat-soybean acreage on wheat optional flex acres for each year. The TWT row is a wheat transfer for each year and the WTPWT row is a program wheat transfer for each year. The OFLMD row limits the maximum amount of program planted acres of wheat to the amount of available optional flex acres originating from program wheat.

The WTSB, XTSB, and XTS2 columns deal with nonprogram wheat-soybean acreage. The WTSB column represents nonprogram wheat-soybean acreage for each

TABLE 20. EXAMPLE MATRIX FOR MIXED INTEGER MODEL

Rows	TURF-2	PLAC-2	XLAC-2	AFC-2	XFC-2	XF2-2	SB-2	XB-2	XB2-2	WTSBPA-2	XTSBPA-2	WTSB-2	XTSB-2	XTS2-2	RIIS[1]
TRI-1	1														=0
TRI-2	-1														=0
INTRAN-1	-1845.06	284.05	284.05	284.05	284.05	284.05	82.54	82.54	82.54	149.76	149.76	149.76	149.76	149.7	=0
TCRPL-2	1			1			1					1			L948
LAB2-1		.6	.6	.6	.6	.6									L520
LAB2-2		.2	.2	.2	.2	.2	.6	.6	.6	.4	.4	.4	.4.4		L520
LAB2-3		.6	.6	.6	.6	.6	.7	.7	.7						L520
LAB2-4		1.5	1.5	1.5	1.5	1.5	1.1	1.1	1.1	1.3	1.3	1.3	1.3	1.3	L520
LAB2-5		1.2	1.2	1.2	1.2	1.2									L520
LAB2-6		1.7	1.7	1.7	1.7	1.7	1.5	1.5	1.5	2.1	2.1	2.1	2.1	2.1	L520
SODLD-2	1														L100
TFCOT-2		-580	-580	-580	-580	-580									L0
TFCOT-2		-580	-580												L0
OLFMC-2			1												L0
ANCL-2				-1											=0
FAL-1				1											L0
NFLM-2					1			1					1		L0
OLFM-2			1			1			1		1		1		L0
TSB-2							-21	-21	-21	-19	-19	-19	-19	-19	L0
WPLIM-2										-1					G0
TWT-2										-42	-42	-42	-42	-42	L0
WTPWT-2										-42	-42				L0
OFLMD-2											1				L0
WFAL-1												1			L0
ANWL-2												-1			=0

[1]L stands for less than or equal to, and G stands for greater than or equal to.

year, the XTSB column represents nonprogram wheat-soybean acreage planted on normal flex acreage in each year, and the XTS2 column represents nonprogram wheat-soybean acreage planted on cotton optional flex acreage in each year.

After the results from the linear programming model were incorporated, the results obtained from conducting the price sensitivity analysis for turfgrass were incorporated into the mixed integer programming model. These results were integrated in the same manner as the original results. This approach revealed how the economic feasibility of producing turfgrass on a more traditional farm is affected by different prices for turfgrass-sod.